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Global Trends of the Researches on COVID-19: A Bibliometric Analysis via VOSviewer

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COVID-19 Araştırmalarının Küresel Eğilimleri: VOSviewer ile Bibliyometrik Analiz

Abstract
Objective: This study aims to make a retrospective analysis of the publications on coronavirus infection emerging in Wuhan, China on December 8, 2019, spreading to the world and being announced as a pandemic. **Method:** Web of Science database was scanned using the keywords "Coronavirus, COVID-19, 2019 novel coronavirus disease, 2019 novel coronavirus infection, 2019-nCoV disease, 2019-nCoV infection, coronavirus disease 2019, coronavirus disease-19" on the studies published between January 1 and April 30, 2020. Identification and analysis of the data were based on criteria such as countries, publications, authors, journals, institutions, cited references, and some relationships between these variables. Descriptive features of publications were analyzed in Microsoft Excel. Analysis and visualization of some selected criteria were carried out through the VOSviewer and the ArcGIS. **Results**: Web of Science database was scanned using the keywords "Coronavirus, COVID-19, 2019 novel coronavirus disease, 2019 novel coronavirus infection, 2019-nCoV disease, 2019-nCoV infection, coronavirus disease 2019, coronavirus disease-19" on the studies published between January 1 and April 30, 2020. Identification and analysis of the data were based on criteria such as countries, publications, authors, journals, institutions, cited references, and some relationships between these variables. Descriptive features of publications were analyzed in Microsoft Excel. Analysis and visualization of some selected criteria were carried out through the VOSviewer and the ArcGIS. **Conclusion:** Through the bibliographic matching method used to form clusters of publications, the main focus and major topics in these publications were highlighted. This study once again emphasized that the researches on COVID-19 are a really important key to ending this pandemic.

Key words: COVID-19, Coronavirus, SARS-COV-2, bibliometric analysis

Özet
Amaç: Bu çalışmada, 8 Aralık 2019 tarihinde Çin'in Wuhan kentinde ortaya çıkan, dünyaya yayılan ve pandemi olarak ilan edilen koronavirüs enfeksiyonu ile ilgili yayınların geriye dönük bir analizini yapmayı amaçlamaktadır. **Yöntem:** "Coronavirus, COVID-19, 2019 novel coronavirus disease, 2019 novel coronavirus infection, 2019-nCoV disease, 2019-nCoV infection, coronavirus disease 2019, coronavirus disease-19" anahtar kelimeleri kullanılarak Web of Science veri tabanında 1 Ocak ve 30 Nisan 2020 tarihleri arasında yayınlanan çalışmalar taranmıştır. Verilerin tanımlanması ve analizi ülkeler, yayınlar, yazarlar, dergiler, kurumlar, alıntı yapılan referanslar ve bu değişkenler arasındaki bazı ilişkiler gibi kriterlere göre yapılmıştır. Yayınlara dair tanımlayıcı özellikler Microsoft Excel kullanılarak analiz edilmiştir. Seçilen bazı kriterlerin analizi ve görselleştirilmesi VOSviewer ve ArcGIS aracılığıyla gerçekleştirilmiştir. **Bulgular:** Çalışmaya, belirlenen tarihler arasında yayınlanan 1782 makale dahil edilmiştir. Çalışma, dünya çapında güçlü bir yazar iş birliği olduğunu ve pandemi ile mücadeleye katkıda bulunan çok sayıda finansman kuruluşunun olduğunu göstermiştir. **Sonuç:** Yayın kümelerini oluşturmak için kullanılan bibliyografik eşleştirme yöntemi aracılığıyla, bu yayınlarda yer alan temel odak ve ana konular vurgulanmıştır. Bu çalışma COVID-19 ile ilgili araştırmaların pandemiyi sona erdirmede önemli bir anahtar olduğunu vurgulamıştır.

Anahtar Kelimeler: COVID-19, Coronavirus, SARS-COV-2, bibliometric analysis

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INTRODUCTION

Humanity has encountered many viruses that threatened it at different times throughout history. In those times, scientists conducted researches on viruses and tried to determine the physical and mental effects of them. Also, efforts to develop vaccines to fight against the viruses have been among the leading studies in each period. Coronavirus (2019-nCoV) is a virus detected in Wuhan, China, and spread rapidly all over the world (Tang et al., 2020). WHO (2020a) described COVID-19 as an infectious disease caused by a newly discovered coronavirus. It is also stated that many people will have this disease of mild to moderate severity, but those who are elderly or have chronic diseases will be more affected. More than 3 million coronavirus cases were detected in more than 180 countries as of April 30, 2020, and 217769 people died due to it (WHO, 2020b).

WHO made a statement on January 30, 2020, that COVID-19 broke out as the sixth major public health emergency worldwide (Lai et al., 2020). Many precautionary statements have been made and restrictions have been imposed worldwide against the COVID-19 outbreak that continues to spread uncontrollably. All of these have led researchers worldwide to study on COVID-19 to take steps with scientific results. Publications such as laboratory studies, case studies, studies investigating social effects, etc., have increased rapidly. Healthcare workers, decision-makers, and researchers must work together to prevent the spread of this human-threatening and rapidly spreading the virus (Cascella et al., 2020). As a result of many members working together, the number of publications has reached thousands as of April 30, 2020.

Each research done on the issues especially of subjects that threaten human life, such as COVID-19, is important for understanding problems, guiding to new studies, and finding solutions. Comprehensive researches that compile the study results make it easier to achieve the desired results. One of the methods that compiles the scientific results and the information of published articles with secondary analysis, and tries to determine the current situation and trends, is bibliometric analysis (Jing et al., 2015; Daim et al., 2013). In this study, it is aimed to analyze the studies on COVID-19 in line with the criteria determined by the bibliometric analysis method. Bibliometric analysis is used to determine the distribution of the studies by country, author, journal, institution, and the research areas in the subject also to provide insight on studies' descriptive features. It is believed that it will benefit the literature to reveal the general structure of the COVID-19 study area and thereby guide further studies on this subject.

METHOD

Bibliometric analysis was conducted to assess the COVID-19 publications. Bibliometric analysis is commonly used for assessing the publications of a certain research area qualitatively and quantitatively. Bibliometric analysis can be used to assess the publications by impact factor, *h*-index, citation frequency, page, and reference count, etc. These data obtained from the publications with bibliometric analysis guide field experts and researchers. In order to assess the publications about COVID-19, intensive database research was completed. Web of Science (WoS) database was chosen as the main source of publication scanning. User-friendly interface, easy access provided by the educational institution, a wide variety of data output options, and covering high-level articles from respected journals were the reasons for selecting this database. WoS contains over 21.100 peer-reviewed scholarly journals published worldwide in over 250 sciences, social sciences, and arts & humanities disciplines and covers Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, Emerging Sources Citation Index indices (WoS Core Collection, 2020). In order to conduct the analysis, criteria for data collection were determined. The summary of the data collection criteria is presented in Table 1.

Table 1. Criteria for data collection

Database	Web of Science Core Collection
Keywords	"Coronavirus" "COVID-19" "2019 novel coronavirus disease" "2019 novel coronavirus infection" "2019-nCoV disease" "2019-nCoV infection"

	"coronavirus disease 2019" "coronavirus disease-19"
Publication date	01.01.2020-30.04.2020
Language	English
Document Type*	Original research, editorial material, early access, letter or review
Access Type	Open access

*Correction, commentary, and response papers were excluded.

The data were extracted from the WoS database according to the data collection criteria. After setting the suitable output formats, data were imported into Microsoft Excel and the VOSviewer. Microsoft Excel was used to code, organize and analyze the data including the publication number, author, journal, document type, keywords, funding agencies, cited reference count, citation count, page count, and the research area. This process was completed by two authors independently, and differences spotted in the dataset were discussed until consensus. The VOSviewer is a java-based program for creating maps based on bibliographic data and for visualizing and exploring the maps (van Eck & Waltman, 2018). In the present study, the VOSviewer was used for analyzing and visualizing bibliographic coupling of publications, co-authorship between countries, co-citation, and co-occurrence of keywords. ArcGIS software was used to create a world heat map of publications. The WoS database was also used for seeking further information on publications such as *h*-index and journal's impact factors.

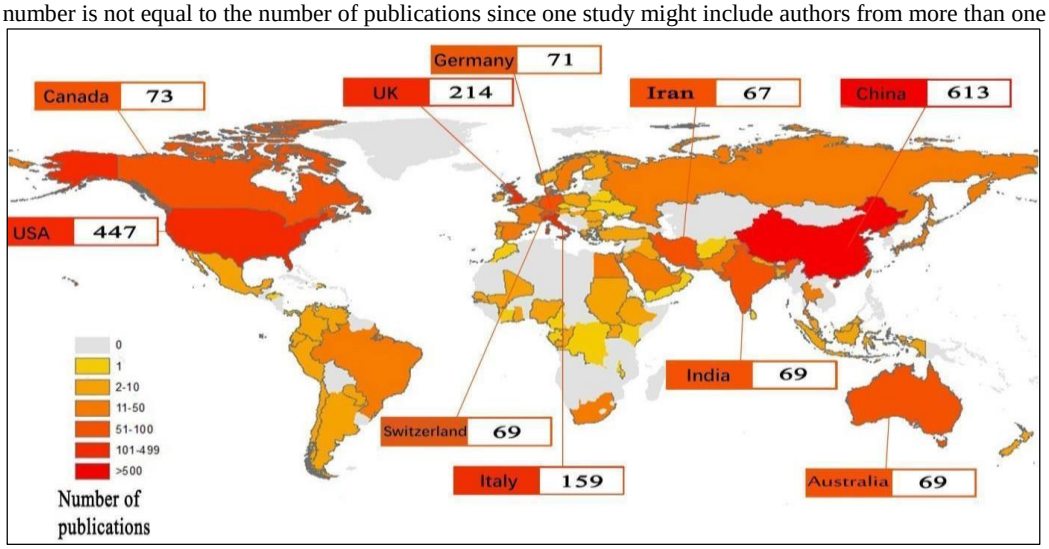
RESULTS

There are great numbers of scientific researches about COVID-19. These researches are the basis of identification, prevention, and control of the virus. In this context, the present study provides an analysis of the publications after the epidemic outbreak. As a result of the database research, it was found that a total of 1.782 publications by 7.637 authors were published in 626 journals. These papers were published by 2.463 different institutions, funded by 887 different agencies, and were published in 91 different countries.

Firstly, the distribution of publications by countries was assessed and it was found that with 613 publications, China has contributed the majority of the research in the field. China was determined as the most productive country followed by the USA (447 papers) and by the UK (214 papers). The heat map of publications that was created using ArcGIS can be seen in Figure 1.

Figure 1. Distribution of publications by countries[1]

[1]The total number is not equal to the number of publications since one study might include authors from more than one country.



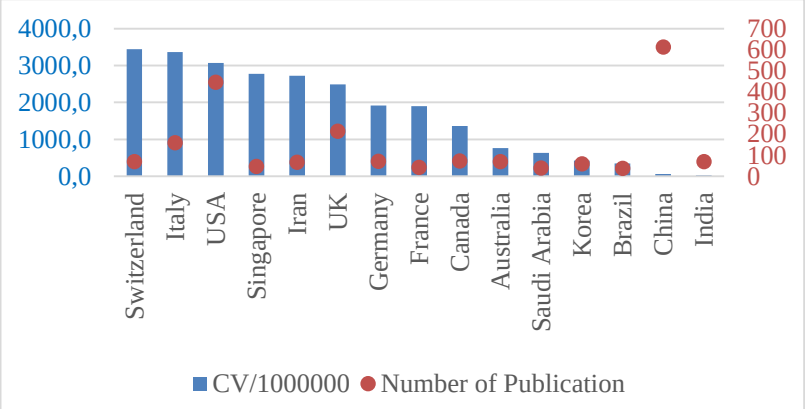
Descriptive characteristics of publications including citation count, average citation per publication, and *h*-index were also analyzed (see Table 2). The top three countries with the highest number of average citations per publication are China ($\bar{x}$=8,3), Germany ($\bar{x}$=6,2), and Australia ($\bar{x}$=5,3). The top three countries with the highest *h*-index are China (30), the USA ($\bar{x}$=18), and the UK ($\bar{x}$=15).

Table 2. Descriptive characteristics of publications by countries

No	Country	Citation (n)	Average Citation per Publication ($\bar{x}$)	*h*-index
1	China	5.087	8,3	30
2	USA	1.435	3,2	18
3	UK	675	3,2	15
4	Italy	242	1,5	7
5	Canada	239	3,3	8
6	Germany	441	6,2	10
7	Australia	363	5,3	6
8	India	35	0,5	3
9	Switzerland	122	1,8	6
10	Islamic Republic of Iran	45	0,7	3

The number of publications and the number of cases per million by countries were analyzed (see Figure 2). In terms of the number of cases per million, Switzerland was the country with the highest rate (3.444,5) and India was the country with the lowest rate (24,4). The number of the cases and publications are not collinear. The fact that China was ranked as the first country in the publication count can be explained by the fact that it is the country where the case was first emerged.

Figure 2. Overlay of the 15 countries with the most articles in total on the number of COVID-19 cases per million as of 30 April 2020.



Characteristics of publications including page, citation, and reference count are given in Table 3. It was determined that each publication received about 4 citations in WoS. The number of pages of the studies varies from 1 and 44 with an average of about 5 pages. It was also found that the average number of references was about 21.

Table 3. Characteristics of publications

Criteria	Min	Max	Average per Publication ($\bar{x}$)
Number of Pages	1	44	5,4
Number of WoS Citations	0	537	3,9
Number of References	0	326	20,6

Among all publications, 726 of them were original research, 595 of them were editorial material and 168 publications were review articles (Table 4).

Table 4. Distribution of publications by document type

Document Type	Publication (n)*
Original research	726
Editorial material	595
Early access	528
Letter	293
Review	168

* The reason why the number of publications presented in Table 5 is seen as 2310 instead of 1.782 is due to the fact that some studies have early access formats.

The productivity of the authors can be expressed by analyzing the number of their publications (see

Table 5). Viroj Wiwanitkit was found to be the most productive author with 15 publications among 7.637 authors. It was also found that Gabriel M. Leung (39,4), Kwok-Yung Yuen (39,3), and Christian Drosten (32,11) have the highest average citations per publication. In terms of the *h*-index of selected papers; Shibo Jiang and Christian Drosten were the authors with the highest rank. The research areas of the most productive authors were also analyzed and it was found that the majority (n=8) of the publications were on General Internal Medicine.

Table 5. Top 5 most productive authors on COVID-19 study

No	Authors	Country	Publication (n)	Average Citation per Publication ($\bar{x}$)	*h*-index[1]	*h*-index[2]	Research Area
1	Wiwanitkit, Viroj	China	15	0,5	1	16	General Internal Medicine; Infectious Diseases
2	Jiang, Shibo	China	11	6,9	6	7	Immunology
3	Memish, ZA	Saudi Arabia	10	9,5	4	76	General Internal Medicine
4	Leung, GM	China	9	39,4	5	60	General Internal Medicine
5	Drosten, Christian	Germany	9	32,1	6	69	Infectious Diseases; Microbiology

[1]of selected publications; [2] of all publications of the author

The most cited publications are given in Table 6. Detailed analysis of these publications shows that one of the main reasons why they were highly cited was the fact that they include case reports from Wuhan [1-8]. It has been determined that the studies carried out on the first case in the relevant country (in this case the USA and Germany) are also among the highly cited publications [9-10]. These ten publications were mainly conducted to determine the epidemiological, clinical, laboratory, radiological, and microbiological characteristics [1-9] and the evolutionary history of the virus [8], clinical outcomes of the patients [1], the source of the pneumonia clusters [2], and to draw the timeline of exposure and determine the symptoms in more detail [10]. These papers were published mostly in *Lancet* and *New England Journal of Medicine* followed by the *Journal of the American Medical Association* and *Nature*.

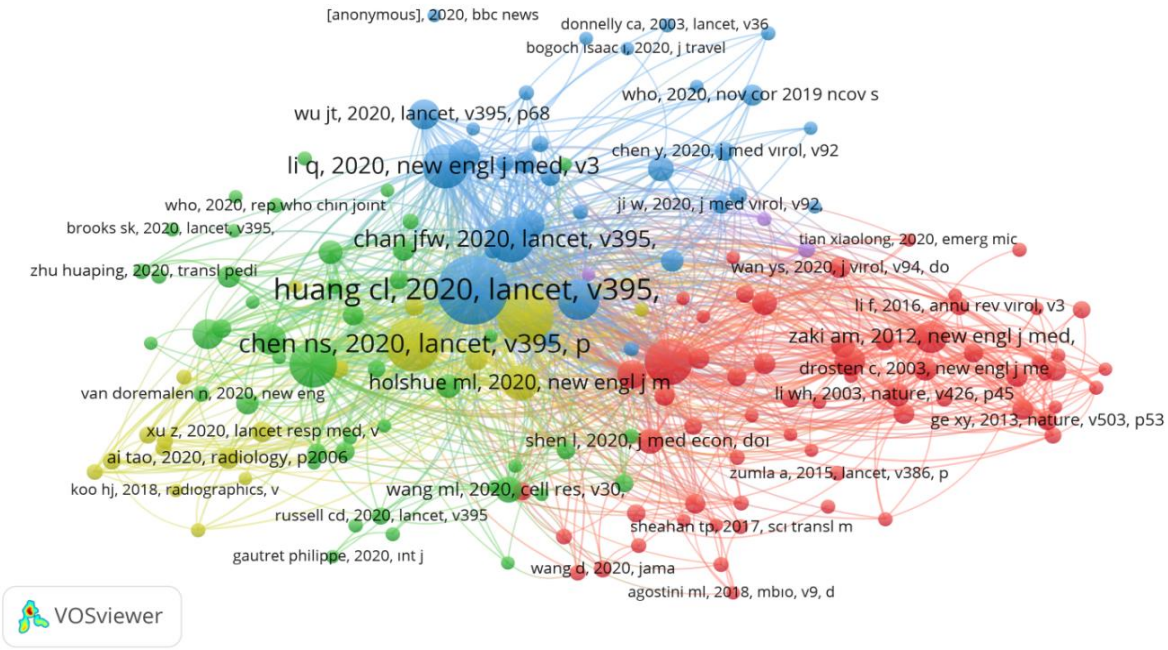
Table 6. The most cited publications on COVID-19 study

[No]	Title	Authors	Journal	WoS Citation Count (n)
1	Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China	Huang et al.	Lancet	537
2	A Novel Coronavirus from Patients with Pneumonia in China, 2019	Zhu et al.	New England Journal of Medicine	331
3	Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study	Chen et al.	Lancet	310
4	Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China	Wang et al.	Journal of the American Medical Association (JAMA)	252
5	A pneumonia outbreak associated with a new coronavirus of probable bat origin	Zhou et al.	Nature	240

The analysis of co-citations of reference is commonly used in bibliometrics (Andrés, 2009). The relationships among cited references were identified through the cited references co-citation analysis using the VOSviewer. For this analysis, the minimum number of citations of a cited reference was set as 15 and 161 cited references met the threshold. The total strength of the co-citation links of each of the 161 selected cited references were analyzed. A link depicts a connection or a relation between two items. In this context, links indicate the number of links of an item with other items while the total link strength indicates the total strength of the links of an item with other items (van Eck & Waltman, 2018). As a result, a total of 5 clusters, 7191 links, and 25056 of total link strength were found (Figure 3). Different colors of circles that are shown in Figure 3 indicate different clusters. The size of the circle reflects the citation frequency of the reference. The line between two circles represents that both papers were cited in one publication. The length of the line represents the closeness of the two papers, the link is closer when the length of the line is shorter (Van Eck & Waltman, 2014). Highly cited publications were listed in Table 6. Further information including the co-citation links and their strength can be seen in Figure 3. The top five highly cited references with large total link strength are the following:

- Huang et al., 2020, *lancet*, v395, p497 with a total link strength of 2718
- Zhu et al., 2020, n*ew engl j med*, v382, p727 with a total link strength of 1875
- Chen et al., 2020, *lancet*, v395, p507 with a total link strength of 1913
- Zhou et al., 2020, *nature*, v579, p270 with a total link strength of 1671
- Wang et al., 2020, *jama*, v323, p1061 with a total link strength of 1321

Figure 3. Map of co-citations of references



Representative publications from clusters are given in Table 7. With 29 publications the main focus of cluster 1 is virus identification. And the major topics covered are genomic characterization, epidemiological characteristics, and first cases in Wuhan. In cluster 2, there are 25 publications with the main focus of intervention options covering virus inhibitors, risk factors, and potential treatment options.

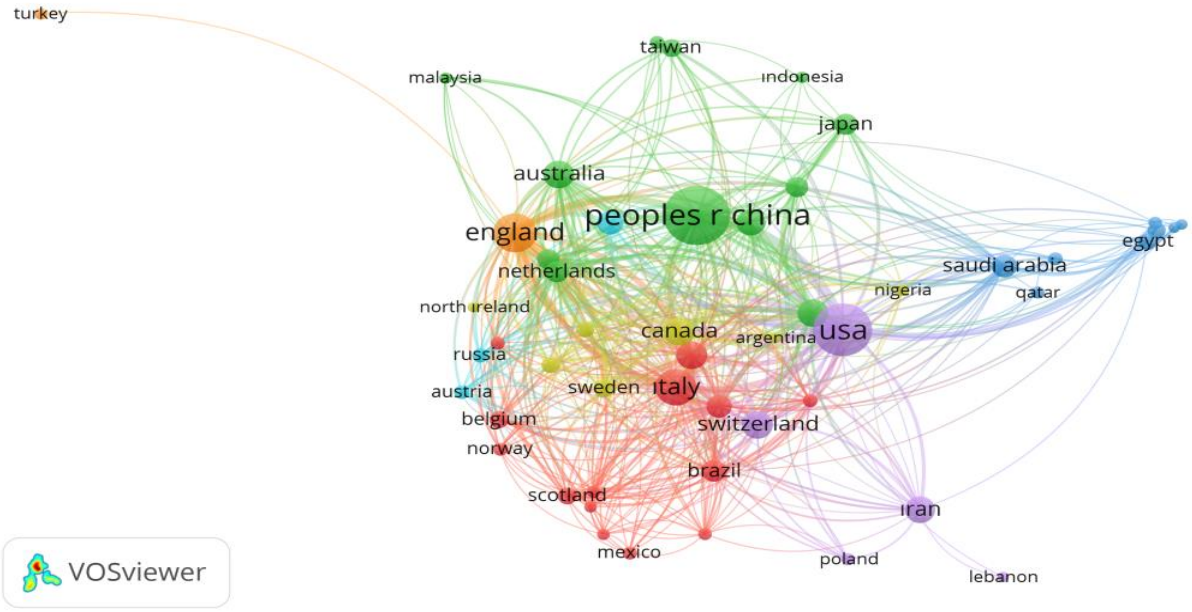
Cluster 3 includes 21 publications that are mainly about the estimation of the spread and covers now-casting and forecasting the spread, mathematical modeling, transmission pattern, and healthcare workers.

Table 7. Overview of the 6 COVID-19 clusters

Cluster	Cluster focus	Major topics covered	Publication (n)	Publications			
				Title	Authors (2020)	Citation (n)	Total link strength
1	Identification	Genomic characterization, epidemiological characteristics, first cases in Wuhan	29	Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China	Huang et al.	514	184
				A Novel Coronavirus from Patients with Pneumonia in China, 2019	Zhu et al.	324	66
				Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study	Chen et al.	298	149
2	Intervention	Virus inhibitors, risk factors, potential treatment options	25	Remdesivir and chloroquine effectively inhibit the recently emerged novel coronavirus (2019-nCoV) in vitro	Wang et al.	90	56
				Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study	Zhou et al.	64	122
				Cryo-EM structure of the 2019-nCoV spike in the prefusion conformation	Wrapp et al.	49	165
3	Estimation	Now-casting and forecasting the spread, mathematical modeling, transmission pattern, healthcare workers	21	Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study	Wu et al.	98	56
				A novel coronavirus outbreak of global health concern	Wang et al.	90	143
				The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health - The latest 2019 novel coronavirus outbreak in Wuhan, China	Hui et al.	66	2
4	Visualization	Radiological findings, transmission	20	A familial cluster of pneumonia associated with the 2019 novel coronavirı indicating person-to-person transmission: a study of a family cluster	Chan et al.	214	35
				Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia	Li et al.	205	84
				First Case of 2019 Novel Coronavirus in the United States	Holshue et al.	132	66
5	Characterization	Clinical characteristics, transmission, pathological findings	18	Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China	Wang et al.	252	216
				Transmission of 2019-nCoV Infection from an Asymptomatic Contact in Germany	Rothe et al.	99	35
				Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records	Chen et al.	60	142
6	Recognition	RT-PCR, clinical characteristics, classification	9	Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR	Corman et al.	57	44
				Clinical findings in a group of patients infected with the 2019 novel coronavirus (SARS-Cov-2) outside of Wuhan, China: retrospective case series	Xu et al.	42	194
				The species Severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2	Gorbalenya et al.	21	218

Co-authorship country analysis was conducted by using the VOSviewer to depict the collaboration of countries (see Figure 4). Each circle represents an author's country and the font size represents the collaboration frequency with other countries. Each line represents the network between the countries. The darkness of the line represents the collaboration intensity between them. Countries with the same color share a similar research area (van Eck & Waltman, 2018). For co-authorship country analysis the minimum number of documents of a country was set as 5 and 51 countries met the threshold. A total of 7 clusters, 528 links, and 627.00 total link strength were found. Authors from the USA have the highest frequency of collaboration with authors from other countries, and their collaboration with China is the strongest. China and the UK also have high collaboration relationships with other countries. Articles written by the authors from Italy, Germany and France (Cluster 1); China, Australia and India (Cluster 2) and the USA, Switzerland and Iran (Cluster 5) had a similar research area. Other countries' collaboration relationships are shown in detail on the map.

Figure 4. Map of co-authorship countries



Papers were published in 626 different journals. However, it was found that there are some prominent journals in terms of publications on COVID-19 (see Table 8). When ranked according to the number of publications it was determined that *Lancet*, *BMJ British Medical Journal*, and *Journal of Medical Virology* cover 37.38% of the articles. *New England Journal of Medicine* (52,89) was the top-ranked journal in terms of the average citation per publication. In terms of the *h*-index of papers published in selected journals, *Lancet* (14), *Journal of Medical Virology* (10) and *New England Journal of Medicine* (10) were the top-ranked journals. Indicators such as the impact factor and quartile in a category are commonly used for journal ranking based on citation calculation. Among the prominent journals, 6 of them were ranked in Q1.

Table 8. The prominent journals on COVID-19 study

Rank	Journal	Publication	Average	*h*-index[1]	Impact	Quartile

		(n)	Citation per Publication ($\bar{x}$)		Factor[2]	in Category
1	Lancet	86	20,9	14	59.102	Q1
2	BMJ British Medical Journal	82	1,2	4	27.604	Q1
3	Journal of Medical Virology	66	6,0	10	2.049	Q3
4	Cureus	38	0,3	2	N/A[3]	N/A
5	Eurosurveillance	32	5,5	6	7.421	Q1
6	Emerging Microbes Infections	22	4,7	4	6.212	Q1
7	Journal of Korean Medical Science	21	3,3	5	1.716	Q2
8	Nature	19	17,5	3	43.07	Q1
9	New England Journal of Medicine	19	52,9	10	70.67	Q1
10	JMIR Public Health and Surveillance	18	0,0	0	5.175	N/A

[1]of selected publications; [2]the most current data available; [3]information not available

Co-citation is defined as the frequency of two items such as authors, documents, or journals cited by an article (Small, 1973). To determine the network of cited journals, the co-citation of cited sources was analyzed. The minimum number of citations of a source was set as 50 and 92 sources met the threshold. A total of 3 clusters, 3845 links, and 7510,7 total link strength were generated by the VOSviewer (Figure 5). The top five highly cited sources with large total link strength are the following:

Lancet with 1999 citations and a total link strength of 1578,3

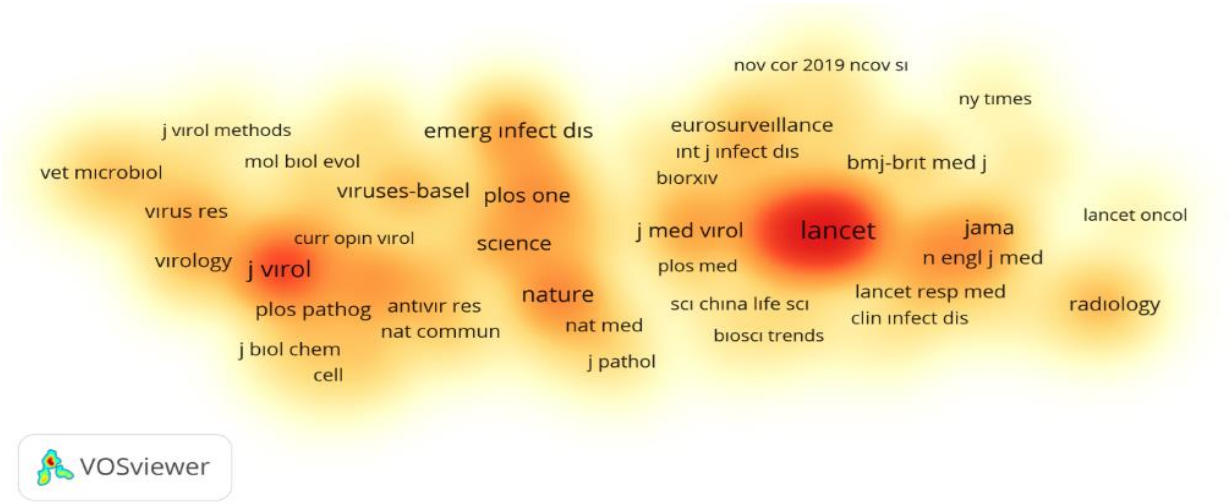
The New England Journal of Medicine with 1358 citations and a total link strength of 1167,90

Journal of Virology with 1180 citations and a total link strength of 958,5

Nature with 695 citations and a total link strength of 640,3

Emerging Infectious Disease with 491 citations and a total link strength of 443,2

Figure 5. Map of co-citation of cited sources



Top 10 highly contributing institutions were also identified and their number of publications, average citation per publication, and the *h*-index were computed (see Table 9). The institutions listed in Table 9 contributed to the quarter of the studies (25,4%) covered in this review. The University of London (n=71), which has the highest number of publications, was ranked first followed by Huazhong University of Science Technology (n=58). Chinese Academy of Sciences (27,2) and Wuhan University (26,5) were top-ranked institutions in terms of average citations per publication. It can be noted from Table 9 that the majority of the most productive institutions (7) were from China. It was also found that a total of 2463 institutions contributed to the study field.

Table 9. The most productive institutions on COVID-19 study

Rank	Institution	Country	Publication (n)	Average Citation per Publication ($\bar{x}$)	*h*-index[1]
1	University of London	United Kingdom	71	3,8	7
2	Huazhong University of Science Technology	China	58	14,7	9
3	Chinese Academy of Sciences	China	47	27,2	9
4	University of Hong Kong	China	46	18,9	11
5	Chinese Academy of Medical Sciences Peking Union Medical College	China	43	18,7	8
6	Wuhan University	China	40	26,5	10
7	Fudan University	China	38	8,5	9
8	Harvard University	United States	38	1,2	4
9	Zhejiang University	China	37	3,5	6
10	University of California System	United States	34	1,9	4

[1]of selected publications

The funding agencies of the publications were included in the scope of the review and the top ten of 887 different funding agencies are listed in Table 10. It was found that almost a quarter (23,1%) of the publications were funded by the National Natural Science Foundation of China. China, the USA, and Japan were determined to be the countries hosting the funding agencies. It was also found that the National Key Research and Development Program of China was the highest-ranked funding agency in terms of average citations per publication.

Table 10. Leading funding agencies for COVID-19 publications

Rank	Funding Agency	Country	Publications (n)	Average Citation per Publication ($\bar{x}$)	*h*-index[1]
1	National Natural Science Foundation of China	China	147	8,1	15
2	United States Department of Health Human Services	United States	67	4,1	10
3	National Institutes of Health NIH USA	United States	65	4,1	9
4	National Key Research and Development Program of China	China	41	33,9	8
5	NIH National Institute of Allergy Infectious Diseases	United States	17	6,4	6
6	China Postdoctoral Science Foundation	China	15	1,1	2
7	Ministry of Education Culture Sports Science and Technology Japan	Japan	13	5,0	5
8	Japan Society for the Promotion of Science	Japan	12	5,3	5
9	Canadian Institutes of Health Research	Canada	12	3,3	4
10	Grants in Aid for Scientific Research	Japan	11	6,4	5

[1]of selected publications

WoS stores the information regarding the research area for each publication and provides insights to researchers on the related fields. In the present study, it was found that among 99 different research areas, the majority of the publications were on General Internal Medicine (23,2%) followed respectively by Infectious Diseases (7,5%), Virology (7,5%), and Public Environmental Occupational Health (6,9%). In terms of average citation per publication and *h*-index General Internal Medicine was the research hotspot of COVID-19 (see Table 11).

Table 11. Top 5 research areas in COVID-19 publications

No	Research Area	Publication (n)	Average Citation per Publication ($\bar{x}$)	*h*-index[1]
1	General Internal Medicine	413	9,2	23
2	Infectious Diseases	133	4,5	12
3	Virology	133	4,4	12
4	Public Environmental Occupational Health	123	1,5	7
5	Microbiology	85	2,9	8

[1]of selected publications

The keywords help to identify the important topics of a research in any discipline. Co-occurrence analysis of the keywords is an effective tool to discover the popular topics of the publications in a selected field (Xing et al., 2018). Therefore, co-occurrence analysis of the keywords was conducted using VOSviewer. The minimum number of the occurrences of the keywords was set as 5 and 110 keywords met the threshold. A total of 12 clusters, 920 links, and 2582 total link strength were generated (see Figure 7). The total link strength of the keywords indicates the number of the publications in which two keywords occur together (Guo et al., 2019). The top 3 most frequently used keywords are the following (see Table 12):

- COVID-19 410 times with a total link strength of 752
- Coronavirus 234 times with a total link strength of 566
- SARS-COV-2 159 times with a total link strength of 434

Table 12. Results of keywords co-occurrence analysis

No	Keyword	Occurrences (n)	Links	Total Link Strength
1	COVID-19	410	119	752
2	Coronavirus	234	90	566
3	SARS-COV-2	159	75	434
4	2019-ncov	79	65	243
5	Pandemic	62	45	197
6	Pneumonia	55	48	174
7	Outbreak	39	44	158
8	Public health	37	35	136
9	Epidemiology	35	47	108
10	Novel Coronavirus	34	41	104

DISCUSSION

Science progresses based on past developments and each new study based on the use of previous studies results in a new development. All research activities contribute to the solution to the focused problems and eventually to science directly or indirectly. That is why every effort invested in each study is very valuable. Studies that review the publications and their results in a given field collectively contribute greatly to the progression of the field. For this reason, in this study, the publications about coronavirus, which is new to and perceived as a risk for the world, and is the interest of many researchers from many countries, are reviewed and summarized using bibliometric analysis.

In this study, analyzing the publications about coronavirus in the WoS database, more publications than expected were encountered. In the period determined as January 1- April 30, 2020, 1782 publications were obtained. These publications with the contribution of 7637 authors have been published in 626 different journals. Editorial materials, early accesses, letters, and reviews were among these publications where the original research was the majority document type. This can be explained by the high number of studies with a case study design that aimed to identify the virus clinically, epidemiologically, and genomically in the early phase of the pandemic. The fact that there are more than 500 cited publications in this short time might be sufficient to explain the increasing number of the publications.

As a result of reviewing the publications by countries, it was found that China alone has 34% of all publications. The reason that the number of publications in other countries is lower than that of China may be due to the origin of the virus (Chahrour et al., 2020; Thomas & Yu, 2010). This also shows that Chinese scientists fight the virus while also conducting these publications in order to share the knowledge and with scientists all around the world and inform them about the conditions.

Productive institutions and funding agencies in a

given field should be discussed while conducting a review of publications. Although productive institutions are predominant in China, the University of London was top-ranked with the highest number of articles (71). Our list of leading funding agencies for COVID-19 publications included institutions from China, the USA, Canada, and Japan. National Natural Science Foundation of China was the top-ranked funding agency in terms of the highest number of publications (147). The distribution of the number of funded publications by country was 203 from China and 149, 36, and 12 from China, the USA, Japan, and Canada respectively. Making and publishing scientific studies require extra effort, time and money (Hoogenboom & Manske, 2012). The fact that China, the USA, and Canada were found to be in the top 10 in the productive countries list may be explained by the availability of supporting funds. Therefore, it is recommended for funders to increase their focus on this field (Nasab & Rahim, 2020). A sufficient number of healthcare and research facilities and workforce will ease the way for scientific publications (and vice versa). Therefore, the number of publications might also be related to the country's health system, the research culture or the number of research institutions (Chahrour et al., 2020).

It was also found that Chinese authors have been cited 5087 times and followed by authors from the USA with 1435 citations from their 25 publications and authors from the UK with 675 citations covering 12% of the publications reviewed. The relationship between the number of publications and the number of cases per million was analyzed for the countries with the most publications. China, which has the most publication ranked 9th in the number of cases per million. It was found that China is relatively successful both in the fight against the virus and in the number of publications compared to other countries. Other countries, such as Switzerland, Italy, and the USA, which ranked first in the number of cases per million, could not perform as well in the number of publications. Variables such as institutional support, availability of education, and whether the author is in the field and involved in the case studies may affect productivity. The present study found that 16 authors had more than 7 publications in the field.

As a result of the country co-authorship analysis, it was found that the authors from various countries collaborated, and China was found to be located in the center of the collaboration map. Even though the first cases and publications have emerged from China might explain this, the intensive collaboration of the countries in the fight against the virus still draws attention. These collaborations can help to the progress of developments even though they are not a solution to the problem (Wolski & Gomolinska, 2020). Also, international data-sharing collaborations against problems have become trends in global research (Nature Medicine, 2020). Accordingly, it was found that the USA and the UK cooperate strongly with China.

The main focus of this research on COVID-19 includes the virus identification, epidemic process, prevention and control strategies and measures. A similar result on the main focus of the research was found in another review that analyzes papers that were published in March (Lou et al., 2020). Based on the bibliographic coupling analysis, publications were grouped into 6 clusters and common points of these publications have been determined. While Huang et al. (2020), Zhu et al. (2020), and Chen, N et al. (2020a) and many more authors mainly focused on the clinical, epidemiological and genomic characteristics of the virus; Xiang et al. (2020), Kang et al. (2020), and Duan & Zhu (2020) mainly focused on the mental health of public and healthcare workers. Apart from healthcare sciences, different disciplines have also contributed to this field. As a result of this review we can indicate that COVID-19 did not only affect clinical researches but also business management (Wang et al., 2020; Yue et al., 2020), economics (Ataguba, 2020; Ivanov, 2020), education (Moorhouse, 2020; Ortiz, 2020; Zhang et al., 2020), computer science (Fong et al., 2020; Jiang et al., 2020), engineering (Mao et al., 2020; Qu et al., 2020), mathematics (Buonomo, 2020; Chen, Y. et al., 2020b). Therefore, these clusters show that scientists with different backgrounds and experiences have contributed to the field with their own perspectives and methods.

The study titled “Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China” and published in *Lancet* was the most cited publication with 537 total citations. The study titled “A Novel Coronavirus from Patients with Pneumonia in China, 2019”, and published in *New England Journal of Medicine* was the second most cited publication with 331 total citations. And the study titled “Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: A descriptive study, 2020”, and published in *Lancet* was the third most cited publication with 310 total citations. The common point of these studies is that it involves the examination of patients diagnosed with COVID-19 in Wuhan both clinically and epidemiologically. These studies are at the forefront of the list of the most cited publications in other reviews (Nasab & Rahim, 2020; Ram, 2020). We have also found that two of the most cited publications are published in *Lancet*, therefore, we analyzed the prominent journals on COVID-19 study. As a result, we found

that with 86 publications, *Lancet* was the journal with the highest number of publications on COVID-19. *Lancet* was followed by the *BMJ British Medical Journal* with 82 publications and *Journal of Medical Virology* with 66 publications. As a result of further analysis, journals focusing on the field of virology were found to be in the top ranks in COVID-19 studies (Ram, 2020; Zhou & Chen, 2020). This is in line with our finding that the main focus of this research includes the virus identification, prevention and control strategies and measures. In journal analysis, another aspect that we focus on was determining the most-cited journals and the total link strength of the covered publications. The result of this analysis indicates that *Lancet* ranks first with 1999 citations and a total link strength of 1578.34. *Lancet* was followed by *The New England Journal of Medicine* with 1358 citations and total link strength of 1167.90. These mentioned journals were already pioneering in their subject areas. Highlighting these journals as a result of journal analyzes is thought to be guiding researchers who may focus on this subject in the future.

In the present study, the research areas and the keyword co-occurrences were also analyzed. The results did not come as a surprise. We have found that general medicine, infectious diseases, and virology were the most studied research areas. There are reviews that also found similar results (Lou et al., 2020; Nasab & Rahim, 2020). These areas contribute greatly to the prevention and control of the outbreak (Lou et al., 2020). The result of the keywords co-occurrence analysis was also as expected. The "COVID-19" was the most repeated keyword followed by "coronavirus" and "SARS-COV-2". Map of the keywords co-occurrences indicated that there are 8 clusters with COVID-19, coronavirus, and SARS-COV-2 located at the center. The largest keyword clusters included "COVID-19", "coronavirus disease 2019" and "epidemic".

CONCLUSIONS

This study aimed to present an overview of the publications in the field of COVID-19 and it showed that thousands of authors from different countries are focusing on COVID-19 which is a widely and rapidly spreading virus. Fortunately, the researches on the field are also advancing at a fast pace. Due to the nature of the science, one can say that the first research and case studies on a given subject are one of the most valuable publications for other authors to make progress. According to the bibliometric analysis, we can highlight that case studies from Wuhan or the first case studies in the country concerned aiming to diagnose the patient and to monitor the symptoms got the most of the scientific attention in this field. The size and the power of the author collaborations around the world were also noteworthy. It is believed that the results will provide valuable information for researchers, research institutions, and funding agencies. Authors are planning to monitor the future publications to conduct more extensive analysis based on other databases.

We acknowledge that there are several limitations to our study. Firstly, we used rigorous inclusion criteria to identify studies relevant to the aim of this review. Although the database search was comprehensive, it is still possible that some papers were missed. Secondly, at the beginning of the study, the aim was to analyze the publications from different databases to provide methodological triangulation for preventing document selection bias. However, it was later decided to use a single database because the formats of the data taken from different databases are different from each other and therefore cannot be analyzed together. Thirdly, many analyzes had to be repeated until the results were confirmed to be accurate. For instance, VOSviewer outputs were determined to be incorrect due to author names similarities or inaccuracies, and manual corrections were made until correct results were obtained. Finally, for review and further analysis we mainly used abstracts and titles, rather than full texts. However, the full paper was examined in the case of cluster formation and the disagreement between the authors during coding which requires further reading.

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