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Telemedicine Literature during COVID-19: A Scientometric Analysis

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Abstract

Background: During the COVID-19 pandemic, telemedicine is applied for various purposes, such as reducing the time of diagnosis and initiating treatment, quarantining and stabilizing patients, enabling the system to closely monitor the citizens at home, and supporting health professionals.

Objectives: The present study used Scientometrics analysis to comprehensively analyze the body of research conducted on telemedicine regarding COVID-19.

Methods: By using a searching formula, 900 documents were retrieved from the Web of Science. Co-authorship networks were drawn by CiteSpace and Gephi software that are free and powerful illustrating networks. The selected co-authorship indicators were Degree Centrality, Betweenness Centrality, and Closeness Centrality.

Results: Andrea M. Russo had by far a high degree of centrality, compared to other authors. Regarding the countries, Belgium and Portugal had a larger node, indicating that they had a higher degree of centrality. Neurosciences had a large node, showing the higher degree of centrality of this subject area. Psychology and Clinical Neurology were also the nodes with a higher degree of centrality. The degree of centrality was high for the University of Zurich, University of Barcelona, and King College London, and the connections of these nodes were more and even stronger, compared to other nodes.

Conclusion: This study, which was based on 900 scientific credentials in the field of telemedicine during COVID-19, indicated the level of cooperation among authors, countries, and organizations in 2020. Moreover, by presenting different indicators in these networks' researchers, countries, and key organizations were introduced for each indicator.

Keywords: COVID-19, Scientometrics, Telehealth, Telemedicine

1. Background

In order for governmental associations to provide appropriate medical services, information regarding features, such as population, education, and health-related issues, are crucial to be known. However, there are impediments, including economic, geographical, and demographic issues, which make it hard to achieve tangible results. For instance, those living in rural areas are deprived of receiving services available to urban citizens. In addition, employing disqualified medical staff results in some enigmatic challenges in this domain. Adaptation of computer-related technology for medical services has enhanced this area, which primarily leads to "Health Telematics" or "Telemedicine" (1).

According to World Health Organization, Telemedicine is defined as "the delivery of healthcare services, where distance is a critical factor, by the healthcare professionals using information and communication technologies for the exchange of valid information for the diagnosis, treatment, and prevention of diseases and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities"(2). Telemedicine has been shown to be a valuable asset in underserved communities where people are deprived of clinical care, especially in remote areas (3).

After being informed, WHO distinguished a sudden outbreak of a respiratory disease with various symptoms, including fever, cough, and dyspnea in early January 2020. The disease was later called COVID-19 (4). Afterward, social distancing was regarded as one of the vital behaviors for reducing and mitigating the exponential expansion of this epidemic. Here is where telemedicine provides health and support, especially in public health, prevention, and clinical practices (4, 5).

In such situations, telemedicine is applied for certain purposes, like reducing the time of diagnosis and initiating treatment, quarantining as well as stabilizing patients, enabling the system for close monitoring of the citizens at home, coordinating medical resources used in distant locations, and supporting health professionals so that they are kept safe as key assets that must be taken care of seriously. In addition, it can be used to train citizens and ordinary people to avoid the risk of contagion (6-8). Despite the fact that it was the first time a rapid

pandemic has been witnessed, governments of many countries, like China and Singapore, managed to establish telemedicine centers and a telemedicine consultation system and run a GPS system to track patients under quarantine. In addition to these two countries, Japan, the United States, and some European countries are on the verge of implementing such utilities of telemedicine.

It has been a long time since medical researchers have made use of computer techniques on large scale to analyze datasets of publications and citations to structure the map of scientific fields (5, 6). In addition, this is also used to disseminate scientific ideas and distinguish features of publication styles to check whether an idea has reached a crucial phase transition or not (7, 8). Due to the rapid growth of technologies like data mining, information analysis, and graphic drawing, researchers are enabled to make scientific metrology and analyze the data precisely. Furthermore, bibliometrics and scientometrics are rich enough to be applied to both medical and social sciences (9). Therefore, it is distinctively possible to have a holistic view of each discipline through the knowledge map. Moreover, it can create trends and distinguish research hotspots in the intended fields (10), including pharmacy (11), psychiatry (12), education research (13), and telemedicine (14, 15) in general and during the current crisis, COVID-19 in particular (16, 17).

2. Objectives

Due to the COVID-19 pandemic and the increase in articles on telemedicine domains (18) the present study used Scientometrics analysis to analyze the research performed comprehensively and systematically in telemedicine regarding COVID-19. Information of this kind is essential for scientists, researchers, institutions, and even stakeholders to evaluate research areas where more infrastructural or scholarly contributions are required.

3. Methods

3.1. Participants

This study was carried out with the scientometrics approach and using co-authorship network analysis. In total, 2304 publications related to scientific areas of Telemedicine in COVID-19 were extracted from the Web of Science on 9 Dec 2020. The following searching formula was used: TS=((telemedicine OR telehealth OR "Mobile Health" OR mHealt OR eHealth) AND ("COVID-19" OR "2019 Novel Coronavirus Disease" OR "2019 Novel Coronavirus Infection" OR "2019-nCoV Disease OR 2019-nCoV Infection" OR "COVID-19 Pandemic" OR "COVID-19 Pandemics" OR "COVID-19 Virus Disease" OR "COVID-19 Virus Infection" OR "COVID19" OR "Coronavirus Disease 2019" OR "Coronavirus Disease-19" OR "SARS Coronavirus 2 Infection" OR "SARS-CoV-2 Infection"))

3.2. Data Collection and Analysis

Our investigation in Web of Science reached 900 documents which were saved in txt and isi formats. Co-authorship networks were drawn by website software CiteSpace (version 5.1.R8 SE) and Gephi (version 0.9.2) which are free powerful illustrating networks. Firstly, the applied and appropriate thresholds along with the number of nodes were imported into the CiteSpace software. The intended threshold (3.3.15) limits the number of network nodes considering received citations which leads to omitting weak relations. The considered threshold for this study was 2, 3, and 15 (19).

Afterward, the output of this software was imported into Gephi to draw the networks. To this end, the undirected network items were selected and Fruchterman, Force Altas2, and Noverlape algorithms were chosen to draw the intended networks. The selected co-authorship indicators were as follows: "Degree Centrality" i.e. the easiest form of centrality in which the value of each node is obtained by counting the number of its neighbors. The higher the level of centrality, the more relations and networks it reveals.

"Betweenness Centrality" designates the value of nodes as well as information transfer within the network point of view. If there exists Betweenness Centrality, this shows being in the middle of other nodes by which other communication paths proceed. "Closeness Centrality" compares the position and real distance of nodes with that of others within one network (20). In the present study, all the above-mentioned indicators were calculated for authors, countries, subject areas, and institutions. Telemedicine in Coronavirus's scientometrics information was identified by retrieving and analyzing data with features of Web of Science and Microsoft Excel (version 2010).

4. Results

Since COVID-19 has been identified at the beginning of 2020, it has become a new unknown virus quickly spreading throughout the world. As a result, extensive research began on this disease in various scientific fields around the world in 2020. The total number of findings in the field of Telemedicine during COVID-19 was reported to be 900 in the Web of Science database until December 19. These documents are reported based on the type of document in Figure 1.

Furthermore, the scientometric information of researchers is specified in this field in Figure 2. In this figure, the top 10 authors in this field are identified based on the number of their scientific productions in this field.

Moreover, the analysis of the co-authorship

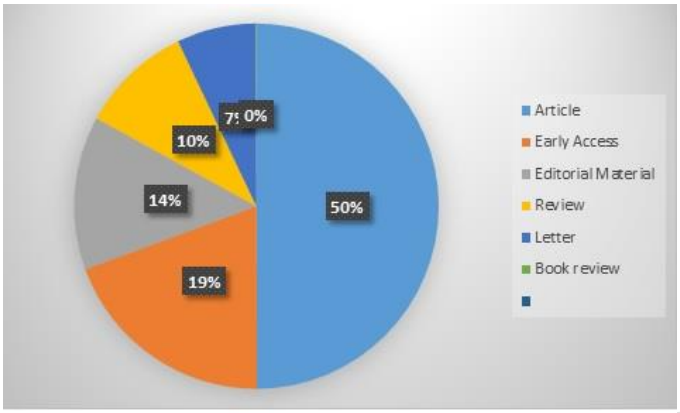

Figure 1. Scientometric information of source type in telemedicine during covid-19 research in 2020

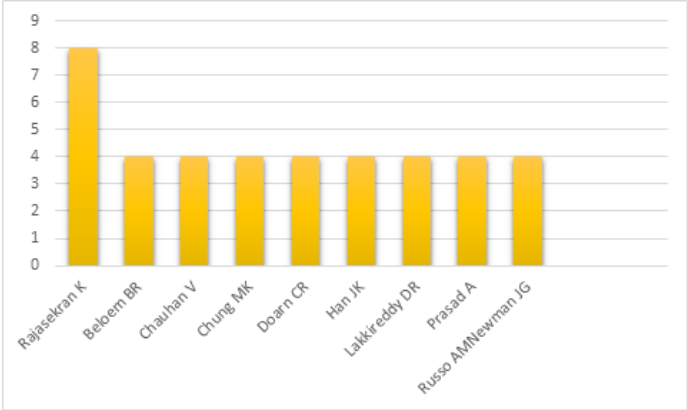

Figure 2. Scientometric information of authors in Telemedicine during COVID-19 research in 2020

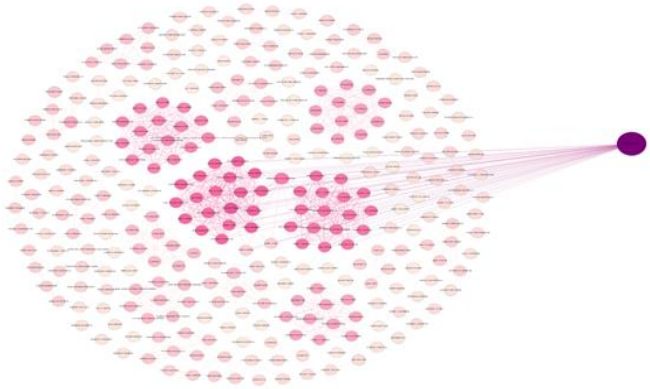

Figure 3. Co-authorship network of authors in Telemedicine during Coronavirus pandemic according to degree centrality 2020

network in this field revealed new information about the rate of cooperation of authors and also those who have collaborated in this field with other ones. There were 310 nodes and 930 connections in the co-authorship network of Telemedicine in COVID-19. Figure 3 shows the authors of this field based on the degree of centrality.

Figure 3 shows that the larger the node, the higher its degree of centrality. However, it should be noted that the value of each node depends on the number of its neighbors and mainly on the number of its connections with the neighboring nodes. Moreover, there is no shadow of a doubt that a higher number of connections leads to a higher degree of centrality. In Figure 3, Andrea M. Russo has a high degree of centrality with a large difference, compared to other authors, and as can be seen, this author has a larger node and makes more connections with other ones that exist in the two large networks of Figure 3.

The degree of centrality is specified in this table and as it is shown in Figure 2, the centrality degree of Andrea M. Russo is more than the other four authors

Table 1. Indicators for the top authors in Telemedicine Research during COVID-19 in 2020

Authors	Doc Frequency	Centrality Degree	Closeness Centrality	Betweenness Centrality	Average Degree
Andrea m. Russo	4	0.014748	1	350.8889	
Dhanunjaya R. Lakkireddy	4	0.001247	0.629032	29.66667	
Francesco Porpiglia	3	0.001009	1	24	0.061
Kristin E. Sandau	3	0.00071	0.696429	16.88889	
Aman Prasad	4	0.000189	0.75	4.5	

who have a higher degree of centrality in this field. In terms of the degree of betweenness, Andrea M. Russo has a higher degree again which means that the nodes of this author are located more than the other nodes, thereby functioning as a mediator among the connections of other nodes, causing the information flow among other nodes. If these nodes are omitted, the flow of information among other nodes will be cut off or even the web may be in danger.

By detecting the degree of closeness of the nodes, Andrea M. Russo and Francesco Porpiglia are reported to have higher degrees, which indicates the lower number of mediator authors during data transferring. It is noteworthy to mention that they receive information faster than the other authors.

According to Figure 4, the USA, Italy, and England are the top producing countries regarding Telemedicine in COVID-19 by 473, 97, and 77 cases, respectively. In Figure 5, the number of nodes and connections are 51 and 153, respectively. Belgium and Portugal have larger nodes which indicates that they have a higher degree of centrality. It also shows that these nodes have more connections with the other ones. Although countries, such as the USA, Australia, and India have 473, 55, and 41 cases of production, their degree of centrality is zero. As is shown in the illustration, they do not have any connection with other nodes. In Table 2, the indicators of the top five countries are specified in the degree of co-authorship.

The degrees of betweenness, closeness, and centrality are reported to be higher for Belgium and Portugal, and as the illustration shows they are reported to be among various nodes, requiring fewer mediators to receive information.

The scientometrics information of scientific areas that are active in Telemedicine in COVID-19 along with the number of documents in each area is presented in Figure 6. Figure 7 shows the analysis of the co-authorship network in different subject areas. There are 55 nodes and 165 connections in this network.

In Figure 7, Neurosciences has a large node that is in dark blue. This shows the higher degree of centrality of this subject area. Psychology and Clinical Neurology are also the nodes with a higher degree of centrality which means that these nodes have more connections with the other ones. Table 3 also shows the indicators of five subject areas in the co-authorship network.

The degrees of betweenness and centrality are high for both Neurosciences and Psychology. These subject areas are located among many nodes and they have fewer mediators for receiving information, while there are other subject areas in terms of the degree of closeness. That is to say, there are fewer subject areas rolling as a mediator when transferring information. Moreover, they receive information faster than other authors.

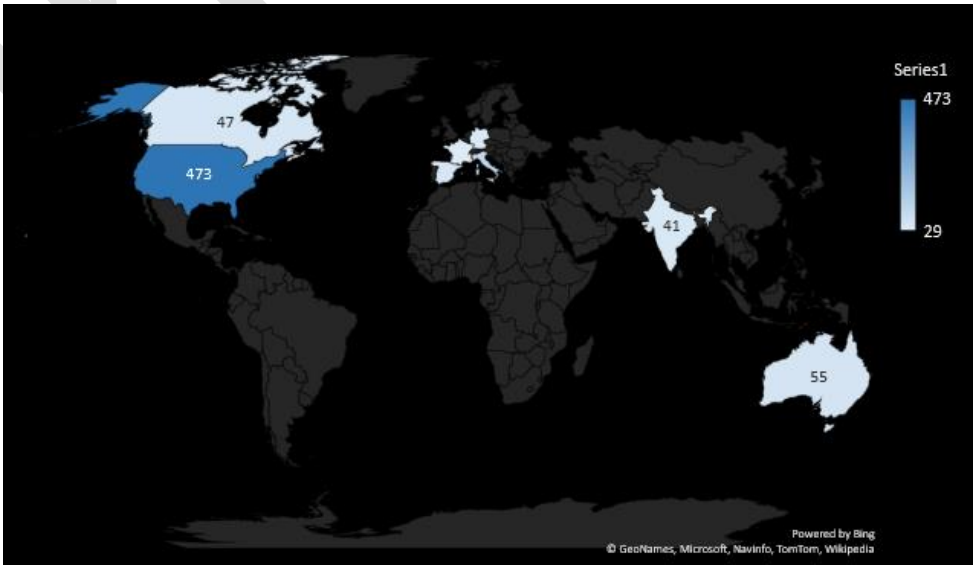

Figure 4. Scientometric information of countries in Telemedicine during COVID-19 Research in 2020

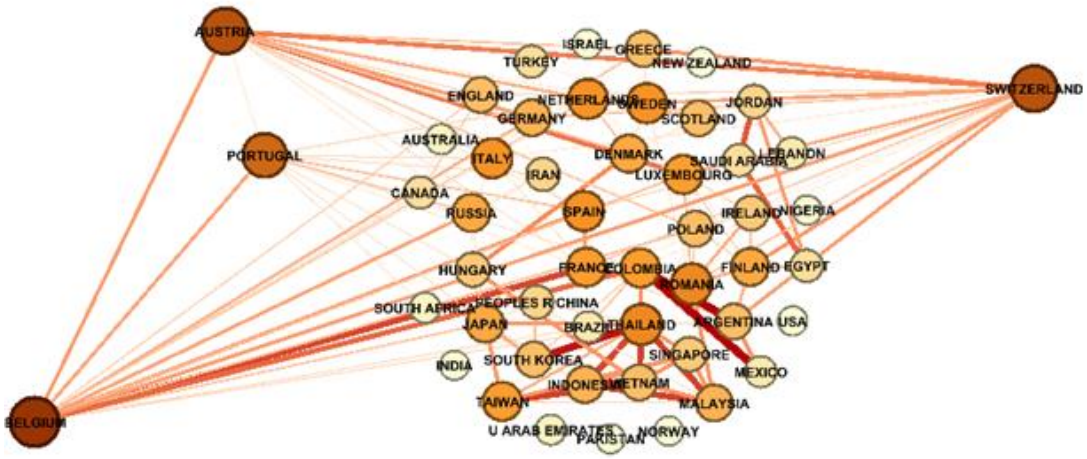

Figure 5. Co-authorship network of countries in Telemedicine in Coronavirus area according to Degree Centrality 2020

Table 2. Indicators for the top countries in Telemedicine during COVID-19 in 2020

Country	Doc Frequency	Centrality Degree	Closeness Centrality	Betweenness Centrality
Belgium	12	0.326227	0.581081	199.8142
Portugal	8	0.159902	0.530864	97.94027
Switzerland	21	0.157122	0.518072	96.23738
Scotland	9	0.139983	0.43	85.73985
Romania	3	0.131767	0.511905	80.70703

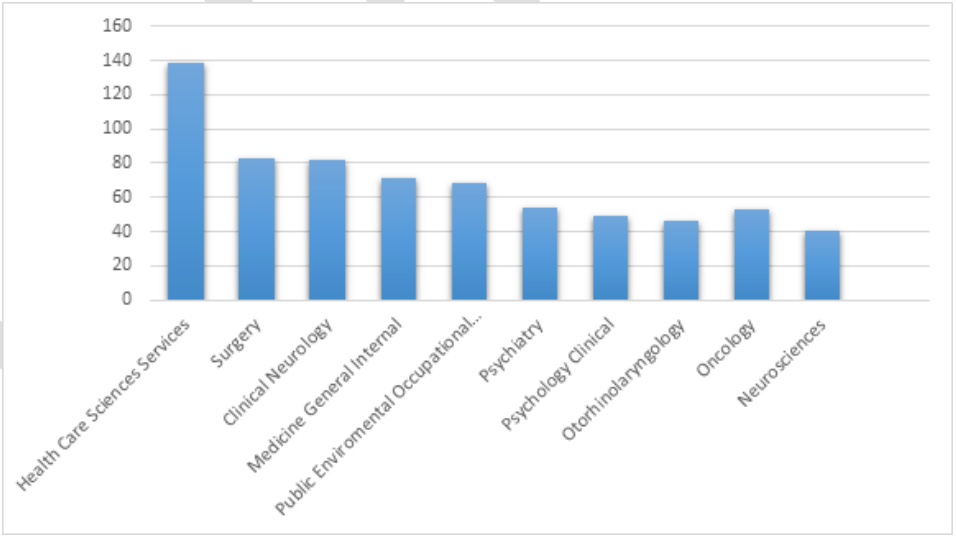

Figure 6. Scientometric information of the subject area in Telemedicine during COVID-19 pandemic Research in 2020

As it is shown in Figure 8, Harvard University and the University of California have the highest rates of production in terms of Telemedicine regarding COVID-19. In the rest, the analyses of the co-authorship network are carried out. There are 198 nodes and 594 connections in this network.

In Figure 9, the degree of centrality is high for the University of Zurich, University of Barcelona, and King College London, and as it is seen the connection of these nodes is more and even stronger with other nodes. In tables 5 and 6, the status of these indicators, among other organizations, are reported.

As is shown in Table 4, the degree of centrality and betweenness for the University of Zurich and the University of Barcelona is higher than the other universities, whereas the degree of closeness in subject areas is different as in Weill Cornell Medicine which is the first with a closeness degree of one.

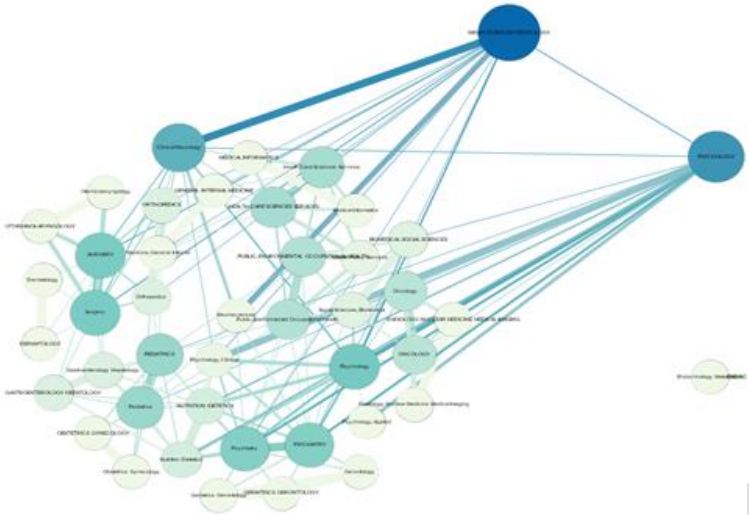

Figure 7. Co-authorship network of the subject area in Telemedicine during Coronavirus pandemic according to degree centrality 2020

Table 3. Indicators for the top subject areas in Telemedicine during COVID-19 in 2020

Subject Area	Doc Frequency	Centrality Degree	Betweenness Centrality	Subject Area	Doc Frequency	Closeness Centrality
Neurosciences Neurology	100	0.234196	167.5675	Immunology	12	1
Psychology	76	0.18093	129.4556	Urology Nephrology	28	1
Clinical Neurology	81	0.147539	105.5643	Endocrinology Metabolism	24	1
Physiology	22	0.12046	86.18889	Ophthalmology	22	1
Surgery	83	0.116702	83.5	Urology Nephrology	28	1

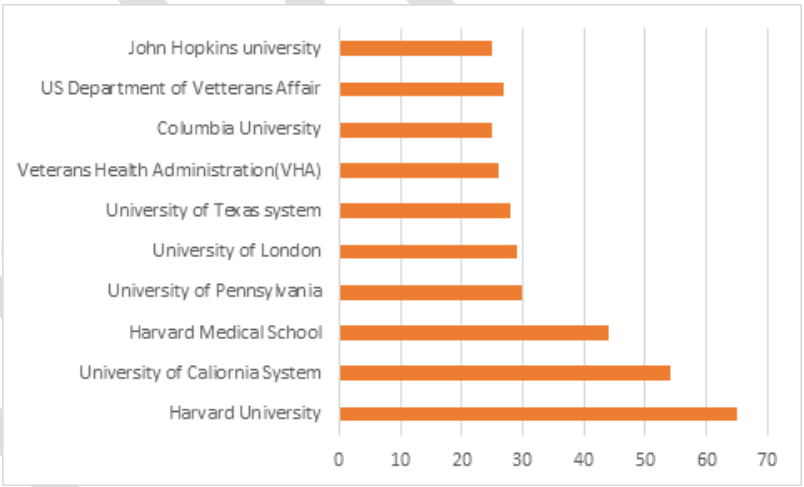

Figure 8. Scientometric information of institutions in Telemedicine during COVID-19 Research in 2020

5. Discussion

Since COVID-19 is a pandemic and unknown viral disease spreading all over the world in a short time, many studies and investigations have been conducted regarding all aspects of the disease, including prevention, caring, and treatment in all scientific areas (21, 22). In the present study, a scientometrics study was performed on co-authored networks of Telemedicine productions regarding COVID-19 in 2020, during which 900 documents were retrieved. This volume of scientific production in 1 year indicated that this issue has been of great importance to researchers around the world (17, 18).

In the present study, various indicators in the co-authored network of Telemedicine in COVID-19 were examined. One of the scales for calculating the density of a network is the network density which shows the discreteness and continuity of the network. A discrete network is a network in which the connection between links in a graph is low or the number of lines or links corresponds to or is less than

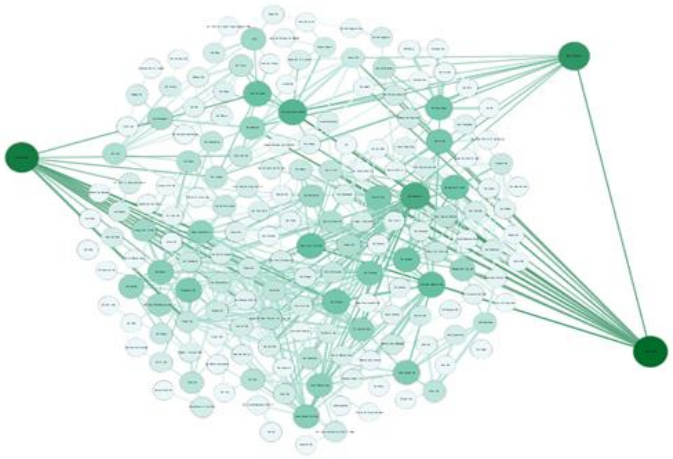

Figure 9. Co-authorship network of institutions in Telemedicine during Coronavirus pandemic according to degree centrality 2020

Table 4. The indicators for the top institutions in Telemedicine Researches during COVID-19 in 2020

Institution	Doc Frequency	Centrality Degree	Betweenness Centrality	Institution	Doc Frequency	Closeness Centrality
University Zurich	3	0.214325	2068.878	Weill Cornell Med Coll	5	1
University Barcelona	5	0.194327	1875.84	Postgrad Inst Med Educ Res	4	1
Kings Coll London	8	0.162249	1566.188	All India Inst Med Sci	6	1
University Minnesota	6	0.133504	1288.718	Case Western Reserve Univ	10	1
University Complutense Madrid	3	0.121998	1177.649	Govt Med Coll Hosp	3	1

the number of vertices or nodes, while a continuous network is a network in which the number of lines or links in a graph is greater than the number of vertices or nodes.

The analysis of the networks of authors, countries, subject areas, and organizations showed that all of these networks were dense due to the fact that the number of nodes was fewer than the number of connections in all of these networks. The average degree of the authors network showed that on average, each node is related to another node or no node which indicated the lack of tendency for cooperation among them. However, collaboration among authors is most often fundamental and important, and with the development of interdisciplinary sciences worldwide, the likelihood of conducting individual research has become very low. This is because researchers cannot incorporate all the required knowledge, skills, and time for active participation in theoretical and practical areas in more than one field (23). Therefore, this issue shows the need to strengthen scientific cooperation by appropriate planning and making policies for this field with regard to the Epidemic and application of Telemedicine in the field of Health.

To the best of our knowledge, no study has been conducted on this research community so far, but various studies on co-authorship in other fields confirm that if there is scientific cooperation in one field, it can encourage researchers to share their ideas in scientific collaborations, thereby influencing the quality of their joint work. Moreover, they can make use of specialized skills and teamwork leading to an increase in the quality and quantity of scientific research outputs (24-26).

A survey of co-authored networks among countries also shows that four countries, including Portugal, Belgium, Austria, and Switzerland in collaboration with other European countries conducted extensive research in the field of Telemedicine during the COVID-19 period. In fact, European countries have been able to form a strong network of scientific cooperation. Moreover, other countries, such as the United States, Australia, and India, which have a wide range of products in this area, compared to other countries, are unwilling to cooperate scientifically with other countries.

The results of this study are in line with those of other research performed in this field. In similar studies, the scientific productions of countries, such as the United States, Australia, China, and India have been reported very early, but they have not been successful in scientific collaborations. However, European countries, such as the United Kingdom,

Belgium, and Portugal have been able to create a strong co-authorship and communication with other countries (15, 27-29).

It should also be noted that despite the expansion of research activities in the field of Telemedicine, first-hand and second-hand resources in this field mostly belong to rich and high-profile countries. Even the implementation of Telemedicine has taken place in rich countries during COVID-19. This issue has been mentioned in many studies (15, 30) suggesting the importance of the issue. In addition, policymakers and researchers should identify the cause of this issue, given that this field is successful in all aspects of health and treatment.

Although the study of the products of organizations shows that American universities are leading the production in this field, in the analysis of the co-authorship network of organizations, no key effect of these universities was observed. It was observed that these organizations are less inclined to cooperate scientifically with other universities, especially European ones. The findings of this study were also consistent with those of other studies (15, 29), which showed that three European universities have prominent roles in collaboration among researchers from different countries. The high level of cooperation among these organizations increases the chances of more scientific cooperation and the visibility of their scientific production, thereby making it possible to achieve very effective scientific outputs from these research activities.

As can be seen, in the co-authorship network of the subject area, neurosciences is an important and key area in the relationship between the main areas of Telemedicine in COVID-19, whose degree of centrality shows that this area has strong connections with other areas such as Surgery, Psychiatry, and Public Health. In a study conducted on the scientometrics of the field of Telemedicine, it was found that Computer Science and Artificial Intelligence are very effective in this field; however, the field of Telemedicine establishes stronger connections with Surgery, Mental Health, Medical and Public Health (15).

The combination of these networks shows that although the co-authored networks are all connected and the connections in these networks are more than the number of nodes, the number of these connections is not enough and as can be seen, in most of these networks there are not strong connections. This is in contrast with the idea that researchers who have more publications are more inclined to have teammates, which indicates that authorship increases their scientific output.

Unfortunately, the obtained data shows that the most productive authors, organizations, and countries in co-authorship networks in the field of telemedicine in COVID-19 are not key nodes in these networks. Therefore, it seems that research in this field should be directed by forming specialized research groups and supporting group works, and considering the importance of co-authorship in scientific productions to increase the tendency of researchers to work in groups.

6. Conclusion

Scientometric analysis of articles can be used for clustering, studying its dynamics, and discovering emerging trends, identifying the institutions, universities, and prolific authors as well as the most cited sources. Moreover, scientometrics can help us to find authorship networks and discover new thematic clusters. Results of this study showed the scientific cooperation among authors by presenting scientific maps in the field of Telemedicine addressing COVID-19. The findings indicated the level of cooperation among authors, countries, and organizations in 2020, by presenting different indicators in these networks where researchers, countries, and key organizations were introduced for each indicator. This study can be a valuable guide for researchers and policymakers to identify the direction of research and key networks in this field for future scientific collaborations.

Footnotes

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