Mapping the Scientific Structure of Iranian Brucellosis Researches Using the Co-authorship and Co-occurrence Network Analysis

Meisam Dastani[1] iD **, Jalal Mardaneh[2]*** iD **, Jalil Moshari[3]** iD

1. Infectious Diseases Research Center, Gonabad University of Medical Sciences, Gonabad, Iran
2. Department of Microbiology, School of Medicine, Infectious Diseases Research Center, Gonabad University of Medical Sciences, Gonabad, Iran
3. Department of Pediatrics, School of Medicine, Gonabad University of Medical Sciences, Gonabad, Iran

ABSTRACT

Background and Aim: The evaluation of the publishing trend of articles in various scientific fields provides an insight into the efforts of researchers in the field of knowledge. Accordingly, the present study has evaluated and analyzed the scientific publications on brucellosis conducted by Iranian researchers using scientometrics methods and analysis of social networks.

Materials and Methods: The present study is practical research that has been performed using the scientometric method and analysis of social networks. All Iranian scientific publications on brucellosis published until 2020 were extracted from the Scopus citation database. Excel, VOSviewer, and Gephi software were applied to analyze the data.

Results: A total of 816 scientific publications on brucellosis conducted by Iranian researchers were extracted from the Scopus citation database. Keramat F. and Mirnejad R. have the highest degree centrality of 16 among other authors of Iranian scientific publications on brucellosis. Mirnejad has the highest closeness centrality and betweenness centrality, equal to 0.43 and 1153.61, respectively. The United States with 22 documents, the United Kingdom with 9 documents, and Germany with 7 documents had the most scientific collaborations in Iranian scientific publications. The prevalence, diagnosis, and treatment are three main topic clusters in this field.

Conclusion: The present study results revealed the topical and content structure and scientific collaborations of the authors in Iranian publications and scientific productions on brucellosis. Accordingly, authors and researchers can develop a network of scientific collaborations in the region and the world to collaborate in producing new knowledge, solve problems, and provide appropriate solutions.

Keywords: Brucellosis, Iran, Scientometrics, Social Network Analysis

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1 Introduction

Brucellosis is one of the common bacterial infectious diseases in humans and animals, known as malta fever in humans and brucellosis in animals. This disease has a broad global spread due to the spread of infection among domestic and wild animals **(1)**. Many areas in the eastern Mediterranean basin are endemic to brucellosis. In Iran, despite a proper health care system, brucellosis is still an important endemic disease and highly prevalent **(2)**. Although the mortality riak of this disease is extremely low, it causes great economic costs due to the lengthy treatment processes. **(3, 4)**.

Researchers have published many articles about various aspects of this disease. Scientific production is

of great importance in countries and greatly impacts economic growth, which indicates the importance of investment in research and development **(5)**. This issue is even more important in developing countries competing in scientific fields **(6)**. Iran is one of the developing countries in the Middle East with a rapid growth in scientific publications globally **(7, 8)**. Therefore, it seems necessary to provide a proper perspective of the research process in each of the scientific fields **(9, 10)**.

An evaluation of the trend of publishing articles in various scientific fields can provide an insight into the efforts of researchers, especially in life sciences. By reviewing published articles in the fields related to life sciences, in addition to updating information, it is possible to access biological changes and take action to prevent, fetch data, intelligently categorize data, and identify different areas of information. One of the most important steps in reviewing scientific articles is collecting up-to-date scientific information **(11)**. Therefore, it is necessary to use methods and techniques to present different types of analysis on scientific publications by reviewing scientific publications.

Scientometrics is one of the evaluation methods of scientific activities. This approach is a useful and efficient method to evaluate scientific progress and identify various features of scientific publications. These methods are applied to quantify the growth of research productivity and significantly active countries and institutions, develop research materials, and determine important research gaps **(12)**. Regular identification and assessment of scientific outputs are considerably important to understanding the current situation. Scientometrics is also a common statistical method that completely analyzes scientific backgrounds in a particular field **(13)**. Consequently, in order to better understand the quantitative data and relationships between them in a scientific field, visualization by drawing scientific maps is an excellent solution. A scientific map demonstrates how disciplines, subject areas, specialties, and individual or group articles relate to each other, which are represented by physical closeness or relative positions. Drawing the scientific and social structure of researchers in a scientific area provides valuable information about the position of each researcher in the body of that science and somehow expresses their power **(14)**. Scientific maps can be drawn by different methods, such as word co-occurrence, co-citation, or co-authorship analyses **(15)**.

The analysis of social networks is used to describe the scientific collaboration defined as co-authorship relationships **(16)**. The co-authorship network is a type of social network, which is also called a scientific collaboration network. A social network can be defined as a set of nodes (social entity) and edges (communication) related to these nodes **(17)**. In this regard, various studies have been conducted using scientometrics methods and analysis of social networks. Popp *et al.* (2017) analyzed the published articles in the field of food policy using the analysis of social networks **(18)**. Moreover, Lin *et al.* (2017) and Cabral *et al.* (2018) analyzed the studies on cancer using bibliometrics methods and social networks analysis **(19, 20)**. Furthermore, some investigations have used scientometrics methods and network analysis in the areas of parasitology **(14)**, analysis of the collaboration networks of Iranian medical researchers **(21)**, Coronavirus disease 2019 (COVID-19) **(22)**, Chagas cardiomyopathy **(23)**, and dengue outbreaks **(24)**.

Reviewing previous studies shows that bibliometrics, scientometrics, and social network analysis methods are extensively applied in the analysis of scientific publications, especially in various fields related to diseases and health. The identification and analysis of scientific contributions and topical clusters of scientific publications in different fields would enable researchers to gain a more accurate knowledge of the relevant scientific fields. Furthermore, it leads to the development of scientific relations and as a result, the growth of the scientific realm in the studied fields.

Regarding brucellosis, Bakri *et al.* (2018) identified and analyzed the most cited articles in the field of brucellosis in Scopus and Web of Science **[25]**. Moreover, Ghavidel *et al.* (2021) applied a scientometrics method to map the co-authorship network of researchers in the field of brucellosis in the Web of Science Core Collection (WoSCC) database during 1901-2019 **[26]**. In another investigation, Danesh and Ghavidel (2021) identified the productivity and efficiency of the network of scientific collaborations of researchers about Brucella and brucellosis over 100 years in the WoSCC database based on the centrality degree and the investigation of co-authorship and co-citation networks **[27]**.

No research has analyzed scientific publications on brucellosis by Iranian researchers. Furthermore, previous studies in the global scientific publications on brucellosis have used the WoSCC database to extract data. In the present investigation, the scientific publications concerning brucellosis have been extracted from the Scopus database. Accordingly, the present study aimed to identify scientific collaborations and the topical structure of scientific publications about brucellosis in the Scopus database employing social network analysis and word co-occurrence approaches. Therefore, the study questions are as follows:

1- How is the growing trend of scientific publications of Iranian researchers in the field of brucellosis over time?

2- Who are the top Iranian researchers in the field of brucellosis based on the centrality index (degree, betweenness, and closeness)?

3- Who are the top Iranian institutions related to scientific publications of Iranian researchers on brucellosis?

4- Which countries have the most scientific cooperation in the scientific publications of Iranian researchers on brucellosis?

5- What are the topical clusters of the scientific publications of Iranian researchers on brucellosis based on word co-occurrence?.

2.Materials and Methods

The present practical research applied scientometrics techniques and the analysis of social networks. The research population consists of all scientific products of Iranian researchers in the field of brucellosis indexed in the Scopus citation database. An appropriate search strategy was utilized to retrieve the record. In order to identify the main keywords for designing the search strategy, the Medical Subject Headings (MESH) Database was used, along with consultations with microbiology experts. Next, the publications related to brucellosis were extracted on June 2, 2021, by advanced search on the Scopus database using the following keywords:

((TITLE (brucelloses) OR TITLE (malta AND fever) OR TITLE (gibraltar AND fever) OR TITLE (rock AND fever) OR TITLE (cyprus AND fever) OR TITLE (brucella AND infection) OR TITLE (brucella AND infections) OR TITLE (undulant AND fever) OR TITLE (brucellosis) OR TITLE (bangs AND disease) OR TITLE (bang AND disease) OR TITLE-ABS-KEY (brucella) OR TITLE (pulmonary AND brucellosis) OR TITLE (Mediterranean AND fever)) AND (LIMIT-TO (AFFILCOUNTRY , "Iran"))

The time considered for searching was before 2020. Scopus citation database was taken into account as an appropriate database for scientometrics studies due to its comprehensiveness for different fields of science and also indexing many articles (28-30). The retrieved records were extracted as a CSV file. Afterward, Microsoft Excel 2013, VOSviewer Ver.1.16.16, and Gephi Ver. 0.9.2 were used to perform scientometrics analysis and visualization. VOSviewer is one of the most important and extensively used software for analyzing the data of citation databases, which clusters the most relevant documents and their relationships (31). VosViewer allows drawing maps based on Terms (32). Gephi is also an open-source software capable of analyzing and mapping a variety of social networks (33), including the networks of scientific collaboration or co-authorship between authors, organizations, and countries (18, 20).

3.Results

According to the findings of the current research, 816 Iranian scientific publications on brucellosis disease have been indexed in the Scopus database. Figure 1 shows the publishing trend of these scientific products. Figure 1 indicates that the Iranian scientific publications on brucellosis have been indexed in the Scopus database since 1967. The publishing trend of brucellosis has grown since 2001, and the highest number of these publications was published in 2019 and 2020.
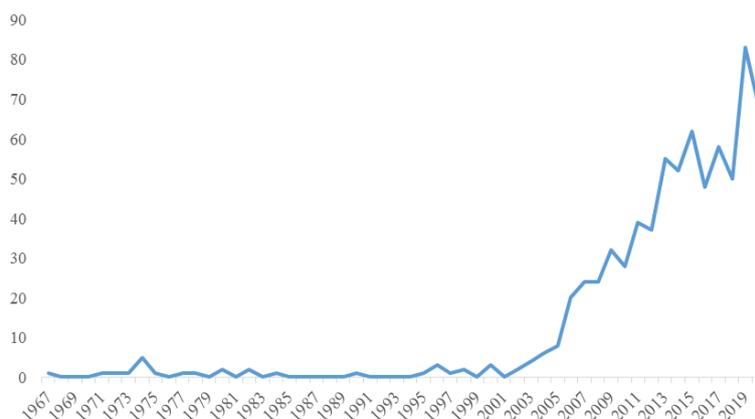

Figure 1. Publishing trend of Iranian scientific publications on brucellosis disease

Figure 2 indicates that most Iranian scientific publications on brucellosis disease have focused on

"medicine", "immunology and microbiology", and "biochemistry, genetics, and molecular biology".
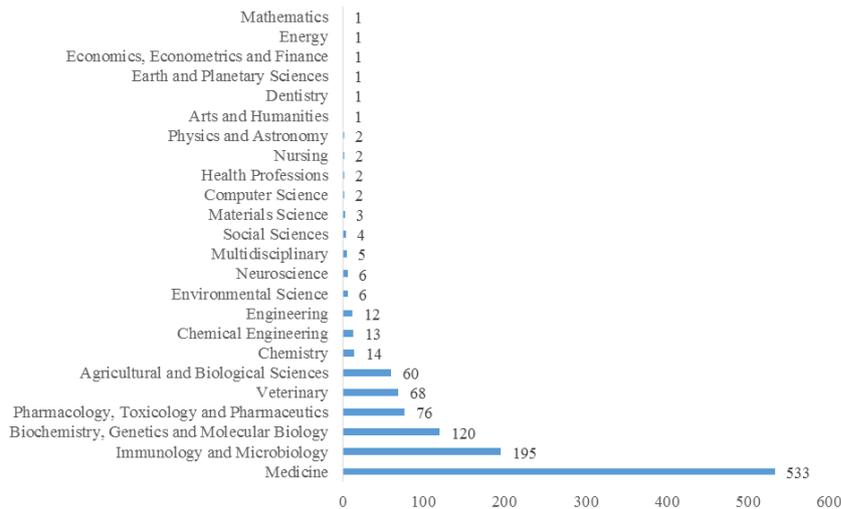
Figure 2. Subject areas of Iranian scientific publications on brucellosis disease

Table 1 presents the top authors in scientific publications about brucellosis based on degree centrality, betweenness centrality, and closeness centrality.

The degree centrality is the simplest type of centrality in which the value of each node is obtained by counting the number of its neighbors. The number of neighbors is calculated based on the interfaces connected to that node. If an individual has a high degree of centrality, they are effective and have more communications and networks. In other words, in a co-authorship network, the degree of centrality of each person indicates the number of their co-authorships with other people in the network **(14, 34)**.

Table 1. Top authors of Iranian scientific publications on brucellosis disease based on centrality indicators

	Degree Centrality			Closeness Centrality			Betweeness Centrality	
No.	Authors	Degree	No.	Authors	Closeness	No.	Authors	Betweeness
1	Keramat F.	16	1	Mirnejad r.	0.43	1	Mirnejad R.	1153.61
2	Mirnejad R.	16	2	amani j.	0.37	2	Zahraei Salehi T.	546.91
3	Hashemi S.H.	14	3	Fasihi-Ramandi M.	0.37	3	Behroozikhah A.M.	390.00
4	Mamani M.	12	4	Keramat F.	0.37	4	Fasihi-Ramandi M.	375.62
5	Alikhani M.Y.	12	5	Mobarez A.M.	0.36	5	Mobarez A.M.	334.40
6	Alamian S.	9	6	Alikhani M.Y.	0.36	6	Alamian S.	304.11
7	Karami M.	9	7	Zahraei Salehi T.	0.36	7	Keramat F.	303.87
8	Amani J.	9	8	Hashemi S.H.	0.35	8	Amani J.	290.75
9	Majzoobi M.M.	8	9	Piranfar V.	0.35	9	Bouzari S.	225.06
10	Ghasemi A.	8	10	Karami M.	0.34	10	Shapouri R.	213.66

The closeness centrality of this indicator measures the distance of one person from all other people in the network. The closer one person is to others, the more selected and famous they are. The closeness centrality of a node represents the average length of the shortest path between that node and other nodes in the network. The nodes with high closeness centrality have more effective power in the network, play a

more important role in the network, and have more access to other nodes **(14, 34)**. Betweenness centrality indicates the node's importance in terms of its location on the map and information transmission in the network. This index indicates the number of times that a node is located in the shortest path between the other two nodes in the network. If a person is placed between a great number of nodes with the communication nodes of other nodes passing through it, they have the greatest betweenness centrality **(14, 34)**.

Table 1 demonstrates that Keramat F. and Mirnejad R., with a degree centrality of 16, have the highest degree centrality among the other authors of Iranian scientific publications on brucellosis. The latter finding shows that these people have the highest level of scientific collaboration with other authors. Moreover, Mirnejad R., with a closeness centrality of 0.43 and betweenness centrality of 1153.61 has the highest closeness and betweenness centrality among other authors of Iranian scientific publications on brucellosis.
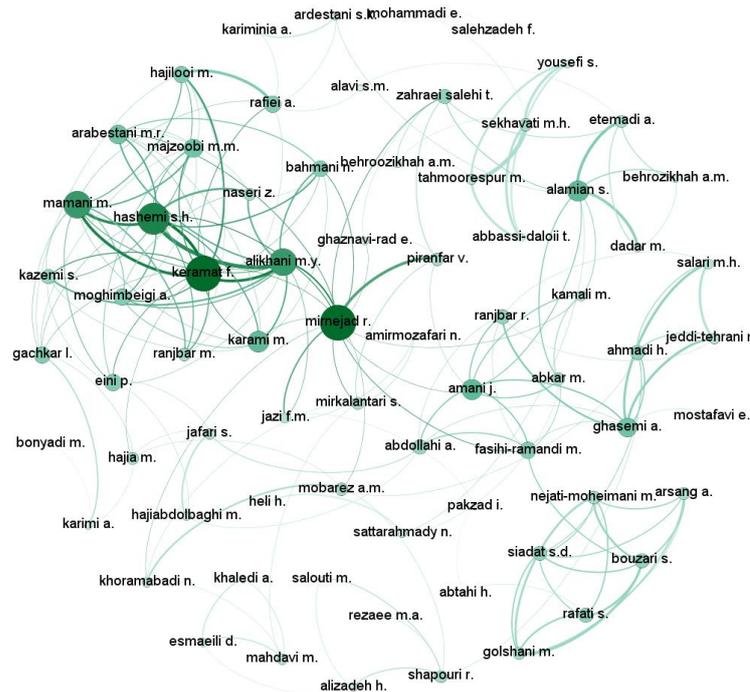
Figure 3. Scientific collaboration networks of Iranian researchers on brucellosis based on degree centrality

Figures 3 , 4, and 5 illustrate the scientific collaboration networks of Iranian researchers on brucellosis based on degree centrality, closeness centrality, and betweenness centrality, respectively. In Figure 3 , each author is shown with a circle (node), and the lines between the circles represent the connections and co-authorship between the authors. Larger and bolder circles have a higher degree of centrality, and bolder and thicker lines indicate strong co-authorship connections as well as the rate of co-authorship between authors. Larger and bolder circles

indicate that researcher have a great deal of connection with other authors.. In Figure 4 , each author is shown with a circle (node), the larger and bolder circles have a higher closeness centrality, and the lines between the circles show the co-authorship connections between the authors. In Figure 5 , each author is depicted with a circle (node), the larger and bolder circles have a higher betweenness centrality, and the lines between the circles show the co-authorship connections between the authors.

Figure 4. Scientific collaboration networks of Iranian researchers on brucellosis based on closeness centrality

Figure 5. Scientific collaboration networks of Iranian researchers on brucellosis based on betweenness centrality

Table 2 shows the top Iranian institutions related to scientific publications on brucellosis based on degree centrality, betweenness centrality, and closeness centrality. Table 2 indicates that Tehran University of Medical Sciences, with a degree centrality of 18 and a closeness centrality of 0.61, has the highest degree centrality and closeness centrality among other Iranian institutions related to scientific publications on brucellosis. Moreover, Hamadan University of Medical Sciences, with a betweenness centrality of 214.72, has the highest betweenness centrality among Iranian institutions performing scientific publications on brucellosis.

Table 2. Top Iranian institutions related to scientific publications on brucellosis based on centrality indicators

	Degree Centrality			Closeness Centrality			Betweeness Centrality	
No.	Institute	Degree	No.	Institute	Closeness	No.	Institute	Betweeness
1	Tehran University of Medical Sciences	18	1	Tehran University of Medical Sciences	0.61	1	Hamadan University of Medical Sciences	214.72
2	Iran University of Medical Science	15	2	Hamadan university of medical sciences	0.55	2	Tehran university of medical sciences	183.04
3	Baqiyatallah University of Medical Sciences	15	3	Iran University of Medical Science	0.54	3	Baqiyatallah University of Medical Sciences	101.23
4	Hamadan University of Medical Sciences	15	4	Baqiyatallah University of Medical Sciences	0.54	4	Kurdistan University of Medical Sciences	93.24
5	University of Tehran	12	5	Kurdistan University of Medical Sciences	0.48	5	University of Tehran	83.74
6	Pasteur Institute of Iran	11	6	University of Tehran	0.47	6	Iran University of Medical Sciences	72.44
7	Tarbiat Modares University	11	7	Pasteur Institute of Iran	0.47	7	Mazandaran University of Medical Sciences	46.85
8	Kurdistan University of Medical Sciences	8	8	Tarbiat Modares University	0.47	8	Ferdowsi University of Mashhad	45.12
9	Mazandaran University of Medical Sciences	8	9	Shahid Beheshti University of Medical Sciences	0.47	9	Shiraz University of Medical Sciences	44.40
10	Islamic Azad University	7	10	Islamic Azad University	0.46	10	Shahid Beheshti University of Medical Sciences	40.62

Figures 6 , 7 , and 8 illustrate the scientific collaboration networks of Iranian institutions related to scientific publications on brucellosis based on degree centrality, closeness centrality, and betweenness centrality, respectively. In Figure 6 , each institution is shown with a circle (node), and the lines between the circles represent the connections and co-authorship between the institutions. Larger and bolder circles have a higher degree of centrality, and bolder and thicker lines indicate strong co-authorship connections as well as the rate of co-authorship between institutions. The institution with a larger and bolder circle has more connections with other institutions. In Figure 7 , each institution is indicated with a circle (node), the larger and bolder circles have a higher closeness centrality, and the lines between the circles show the co-authorship connections between the institutions. In Figure 8 , each institution is demonstrated with a circle (node), the larger and bolder circles have a higher betweenness centrality, and the lines between the circles show the co-authorship connections between the institutions.
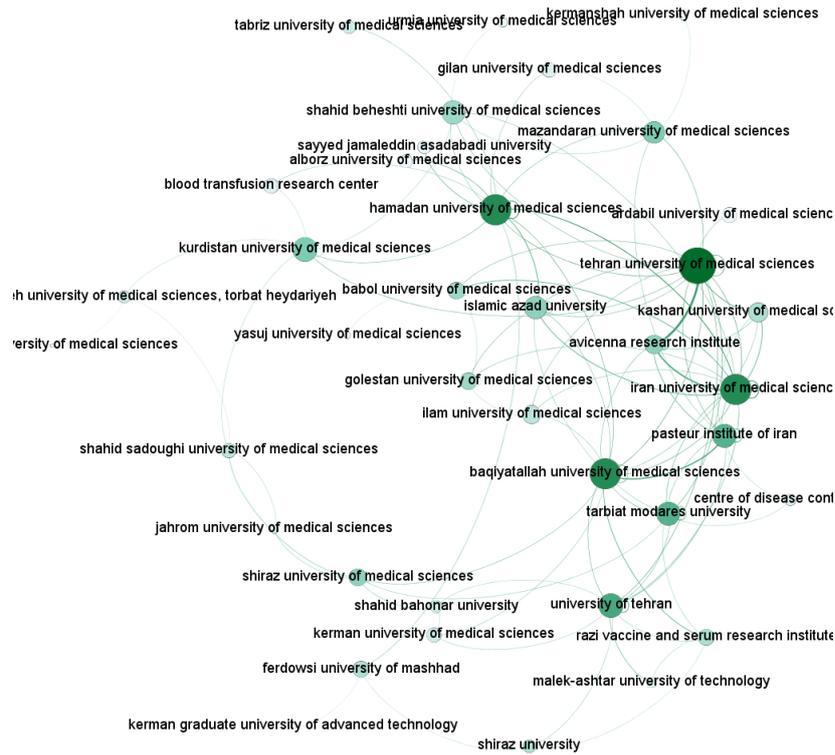
Figure 6. Scientific collaboration network of Iranian institutions related to scientific publications on brucellosis based on degree centrality
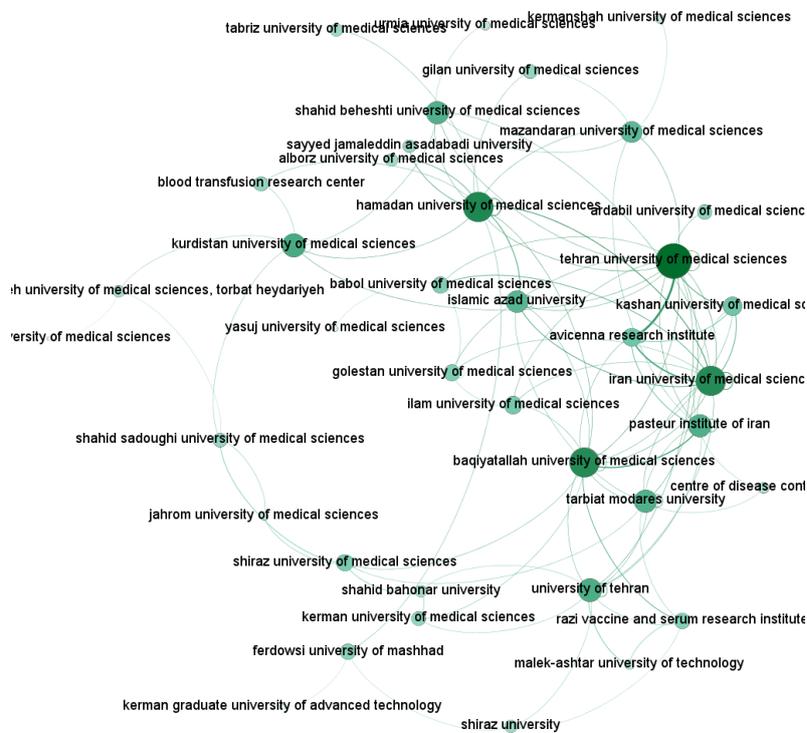

Figure 7. Scientific collaboration network of Iranian institutions related to scientific publications on brucellosis based on closeness centrality
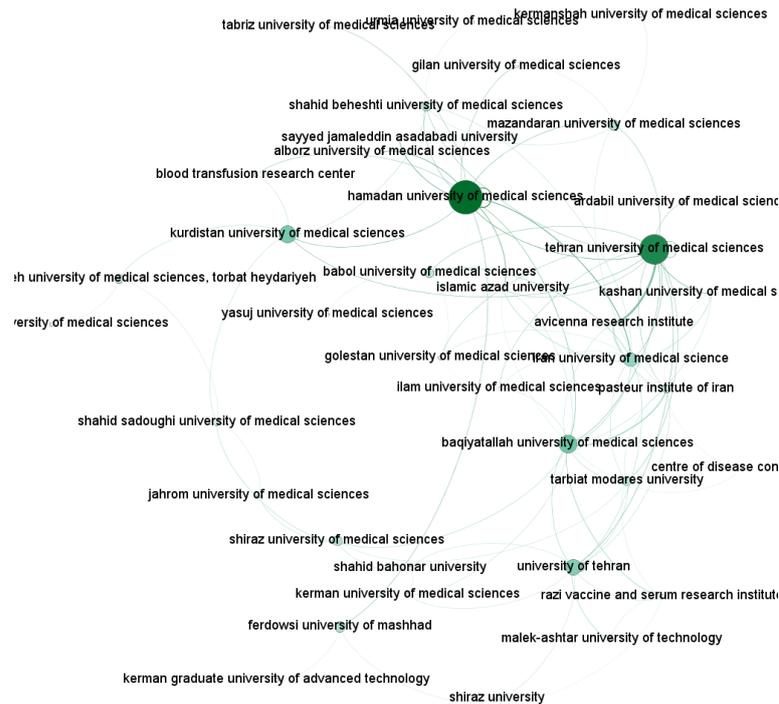
Figure 8. Scientific collaboration network of Iranian institutions related to scientific publications on brucellosis based on betweenness centrality

Figure 9 illustrates the network of the scientific collaborations of Iranian researchers with other countries in the field of scientific publications about brucellosis. In this figure, larger nodes (circles) imply a larger number of publications, and thicker edges (communication lines) indicate a stronger connection between two circles or nodes.

Figure 9. Network of scientific collaborations of Iranian researchers with other countries in the field of scientific publications on brucellosis

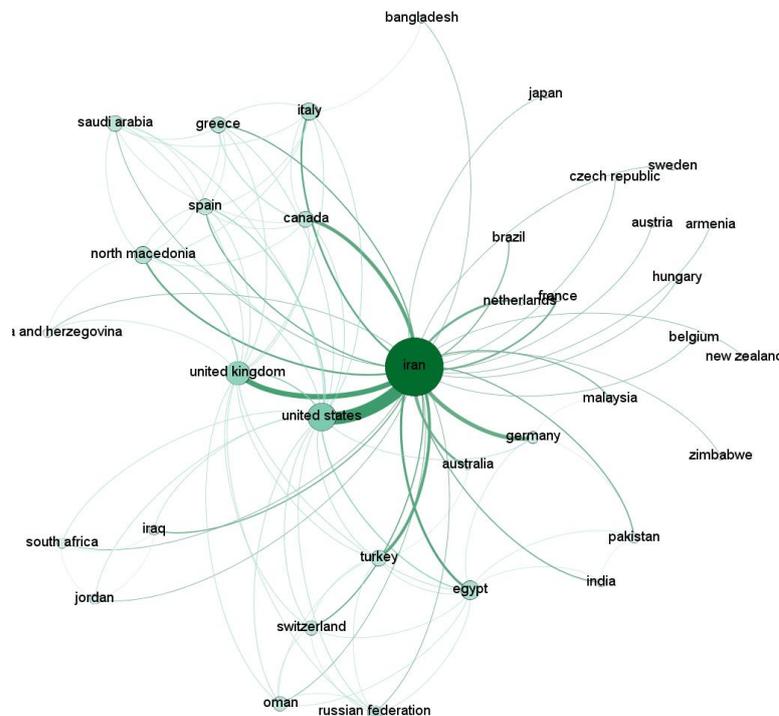Figure 10 demonstrates the topic clusters of Iranian scientific publications on brucellosis based on words co-occurrence. It shows that the Iranian scientific publications about brucellosis consist of three main topic clusters marked with three colors. Cluster (1), marked in red, indicates the subject of prevalence. Cluster (2), marked in green, denotes the subject of diagnosis. Cluster (3), marked in blue, shows the subject of treatment.

Figure 10. Network structure of topic clusters of Iranian scientific publications on brucellosis based on words co-occurrence

4.Discussion

The results of the present study revealed that since 2001 the publishing trend of Iranian research on brucellosis has grown, and the highest amount of these publications were in 2019 and 2020. The previous studies have reported an increase in the annual growth of Iranian scientific publications in other subject areas **(35, 36)**. Peykar *et al.* (2018) concluded that the publications of Iranian researchers about cancers, diabetes, and cardiovascular diseases had a significant increasing trend, and publications related to chronic respiratory diseases had a gradually increasing trend **(37)**. Ghavidel *et al.* (2021), as well as Danesh and Ghavidel (2021), indicated the publishing trend of global publications on brucellosis and Brucella **(26, 27)**.

The results of evaluating co-authorship centrality indicators of Iranian researchers and institutions in scientific publications on brucellosis indicated that co-authorship in scientific research is one of the main symbols of intellectual collaboration and indicates the participation of at least two authors in producing a publishable piece of research. The structure of human knowledge and academic community is visualized by the co-authorship network. In order to analyze the

social networks based on the obtained data, various indicators are employed, the most important of which is centrality **(14)**.

The findings of the present article revealed that Keramat F. and Mirnejad R. have the highest degree centrality among other Iranian researchers in the scientific publications on brucellosis, which indicates the high participation of these researchers in the production of science and Iranian scientific publications on brucellosis. Furthermore, Mirnejad R. has the highest closeness centrality and betweenness centrality among other researchers in scientific publications on brucellosis, which shows that Mirnejad R. is more famous among other authors. Moreover, the high closeness centrality shows the power of greatly influencing content transmission on the network, accessibility to other authors, centrality, and their key role in distributing information among other authors on the network. Mirnejad R. has more connections among other authors and has gained a favorable and strong position in this scientific field in Iran.

Moreover, Tehran University of Medical Sciences had the highest degree centrality and closeness

centrality among other institutions, which shows the high participation and reputation of Tehran University of Medical Sciences among other institutions in scientific publications on brucellosis. In addition, Hamadan University of Medical Sciences has the highest betweenness centrality among other institutions in scientific publications on brucellosis, which shows that Hamadan University of Medical Sciences has more connections with other institutions and has gained a favorable and strong position in this scientific field in Iran.

Social networks are always growing by adding new nodes and edges. Consequently, new nodes generally connect to old nodes with high centrality **(38)**. Moreover, given that increasing the level of collaboration is one of the methods to improve the quality of articles **(39, 40)**, researchers with high production and centrality indicators play a very important role in the expansion and evolution of co-authorship networks. Therefore, a great deal of collaboration among key researchers and encouraging young researchers in various scientific fields can be highly effective in the growth and dynamics of social co-authorship networks.

In this regard, Ghavidel *et al.* (2021) have also shown that researchers on the top list of co-authorship networks related to the global research on brucellosis play an important role in connecting authors and transferring data in the network **[26]**. Danesh and Ghavidel (2021) also stated that despite some differences in the top rankings of researchers in the field of brucellosis in the three centralities of degree, closeness, and betweenness, the top researchers have an appropriate position in all three centralities. In addition, researchers with high degree and betweenness centrality indicators have shown high productivity and efficiency **[27]**.

Furthermore, our results revealed that Iranian researchers have the most collaboration with the researchers from the United States, the United Kingdom (UK), and Germany to produce scientific publications on brucellosis. Rezaei and Mohammadi (2018) stated that in the field of ophthalmology, the scientific collaboration of Iranian researchers with researchers from the United States, the UK, and Germany was at the highest level **(41)**. Moreover, the most international collaboration of Iranian authors in publications on COVID-19 was with researchers from the United States, the United Kingdom, and Italy **(42)**. Regarding the network of the scientific cooperation of the countries active in the field of global brucellosis, Ghavidel *et al.* (2021) indicated that the USA was at the center of cooperation with other countries. In respective order, Canada, the UK, France, Spain, Germany, and Greece had the highest number of scientific connections **[26]**.

Keywords of articles can reflect the main topic, content, and direction of research **(43)**. Therefore, in scientometrics studies, the analysis of the keyword co-occurrence can quickly identify the development trends and research topics in a particular research field **(44)**. In this regard, the results of the present study have identified three main topic clusters of prevalence, diagnosis, and treatment for the publications of Iranian researchers on brucellosis. Dastani and Ghorbani (2020) have also identified three topic clusters of "tests and diagnosis", "prevention and health", and "treatment" for the scientific publications of Iranian researchers on COVID-19 **(42)**.

The evaluation of the scientific productions of different countries in various scientific fields can assist in identifying the problems, bottlenecks, and shortcomings in this field. Moreover, the research branches are better understood and the research is directed in line with the macro-policy goals. On the other hand, recognizing the existed scientific space can help countries on their positively and constructively movement toward advancement of science and technology. Moreover, scientometrics studies provide important evidence of the results and effects of research programs for policymakers and planners **(45)**. Therefore, scientific models and maps are appropriate ways to represent the increasing growth of scientific activities and organize the intellectual and scientific structure that forms a subject area **(46)**.

Conclusion

In general, the present research results showed the topic and content structure and scientific collaborations of the authors in the publications and scientific productions of Iranian researchers on brucellosis. Since the most scientific collaboration of Iranian institutions and researchers is with domestic institutions and researchers, the suggestion is that institutions and researchers develop a network of scientific collaboration in the region and the world to collaborate in producing new knowledge, solving problems, and providing appropriate solutions. The policymakers can also pave the way for evidence-based decision-making to overcome challenges by setting appropriate research priorities.

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Ethical Approval

The present article is extracted from a research project with code A-10-1263-8 and research ethics ID IR.GMU.REC.1400.036, approved by the Infectious Disease Research Center and implemented with the financial support of this research center.

Availability of Data and Materials

The datasets used and/or analyzed during the current study would be available from the corresponding author on reasonable request.

Author Contributions

MD.: Conception and design of the research; Statistical analysis; Interpretation of data; Writing of the manuscript. JM., JM: Conception and design of the study; interpretation of data; Writing of the manuscript. All authors approved the final version of the article for submission.

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Conflict of Interest

The authors declared no conflict of interests.

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