Original Article
http://mjiri.iums.ac.ir
Medical Journal of the Islamic Republic of Iran (MJIRI)

Med J Islam Repub Iran. 2021(31 Dec);35.194. https://doi.org/10.47176/mjiri.35.194

International Scientific Collaboration on Pituitary Research: A Social Network Analysis

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Received: 1 May 2021 Published: 31 Dec 2021

Abstract

Background: Social network analysis (SNA) evaluates the connections and behavior of individuals in social groups. The scientific collaboration network is a kind of SNAs. A social network could be defined as a collection of nodes (social existence) and links (connections) associated with the nodes. The aim of this study was to evaluate the scientific outputs and collaboration networks of the countries and authors using indicators of SNA in the field of pituitary disorders between 2000 and 2020.

Methods: This is a practical study performed by applying a scientometric approach and SNA. We retrieved 31257 papers in the field of pituitary disorders between 2000 and 2020. Data were analyzed using scientific software, namely, VOSviewer, UciNet, and Netdarw.

Results: Based on degree centrality, Colao and Pivonello in the world, Shimon and Kadioghlu in the Middle-East (ME), and Khamseh, Ghorbani in Iran achieved the top ranking. Based on the betweenness centrality, Pivonello, Colao, and Chanson in the world, Laws, and Kadioghlu in the Middle-East, and Larijani, Mohseni, and Khamseh in Iran were known as the top authors. According to closeness centrality, Pivonello, Colao, and Chanson in the world, Kadioghlu and Kelestimur in the Middle-East, and Mohseni, Khamseh, and Larijani in Iran were the top authors. The map of the authors' collaboration in the field of pituitary disorders consists of 92 nodes. A total number of 77313 authors had global collaboration. The global collaboration network was comprised of 129 nodes (country) and 2694 links (country's collaboration). The Middle-East collaboration network revealed 69 nodes and 1708 links. The collaboration network of the Middle-East countries consists of 13 nodes and 50 links.

Conclusion: Authors with a higher degree, betweenness and closeness centrality have greater efficiency (the number of articles) and effectiveness (the number of received citations). Moreover, the authors and countries that published more scientific products received more citations. In addition, in the Middle-East countries, the interdisciplinary scientific collaboration between the researchers in the fields of endocrinology, neurosurgery, pathology, and radiology has a significant impact on improving scientific outputs.

Keywords: Scientometric, Scientific Collaboration Network, Co-Authorship, Social Network Analysis (SNA), Pituitary Disorders

Conflicts of Interest: *None declared*
Funding: *This paper was supported by Iran University of Medical sciences, Tehran, Iran.*

Cite this article as: Hashemi-Madani N, Emami Z, Khamseh ME. International Scientific Collaboration on Pituitary Research: A Social Network Analysis. *Med J Islam Repub Iran.* 2021 (31 Dec);35:194. https://doi.org/10.47176/mjiri.35.194

Introduction

Considering the increasing growth of information, publishing articles in valid international journals is one of the most important information tools. Articles usually show researchers' views on the latest achievements in the related

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↑What is "already known" in this topic:
Evaluations of scientific outputs in some fields of endocrinology, including diabetes and thyroid, have been previously performed. But such studies have not been done in the field of pituitary neither in the world nor in the Middle-Ease countries.

→What this article adds:
Based on centrality indicators, the utmost authors and countries in the global world as well as in the Middle-East countries have been determined. There is an increasing trend in scientific outputs on pituitary diseases at the international and Middle East levels during the period under study.

[DOI: 10.47176/mjiri.35.194]

field (1). Researchers share their ideas during in scientific collaboration and contribute to the qualitative and quantitative improvement of scientific outputs (2). With regard to the scientific collaboration in research environments, co-authorship is the most visible and accessible index used to measure the degree of scie ntific collaboration. Co-authorship networks are actually a type of social network, which are also called scientific collaboration networks. A social network can be defined as a set of nodes (social entities) and links (connections) related to each of these nodes (3).

Co-authorship networks are examined and analyzed based on various metrics. One of the most useful and common metrics used for examining these networks is centrality, which refers to the position of a certain node in the network (4). People who are at the center of the network are more powerful than other people and usually have more influence on other people in the network. They also have access to most resources within the network and are considered as powerful people in that network. A set of measures of centrality such as degree centrality, betweenness centrality, and closeness centrality can be obtained using SNA (5). The degree centrality of a node in a network indicates the number of connections between that node with the other nodes that make up the network. In other words, the degree centrality of each person in a co-authorship network indicates the number of his/her co-authorships by other people in the network. The betweenness centrality index of a node indicates the number of times that node is placed in the shortest distance between the other two nodes in the network. The closeness centrality index of a node indicates the average length of the shortest distance between that node and other nodes in the network (6).

There have been many studies in the field of co-authorship networks using SNA indices in thematic areas. Study of co-authorship network of Iranian neuroscience (7), co-authorship network of emergency medicine (8), co-authorship network of scientific outputs of Iran University of Medical Sciences (9), co-authorship network of Iranian researchers in the field of pharmacology and pharmacy (10), a study of endocrine and metabolism performance based on socioeconomic indices (11), scientific collaboration between Iranian dentists (12), co-authorship and the relationship between social influence, efficiency, and productivity of researchers in the field of chronic cardiovascular failure (13), collaboration network in the field of informetrics (14), scientific collaboration in the field of social computing using SNA (15), scientific co-authorship in Spanish universities (16) are among the related examples.

The health care system plays an important role in improving health, and medical research makes the health system effective and efficient (17). Endocrinology is considered as one of the clinical science fields which is of great importance due to the existence of common and important diseases such as pituitary diseases, including acromegaly, Cushing's syndrome, prolactinoma, pituitary tumors, etc.

Pituitary tumors are the second most common intracranial tumor, accounting for about 15% of all primary intracranial neoplasms (18). In a study in the Netherlands, Van der Klaauw et al. referred to prolactinoma as the most common type of pituitary adenoma (19). In the study of the registry of pituitary tumors in Iran, Khamseh et al. showed that prolactinoma was the most common tumor, followed by acromegaly, nonfunctioning pituitary adenomas (NFPAs), and Cushing's tumors (20). Results of a study in Saudi Arabia reported that prolactinoma had the highest prevalence among pituitary patients (21). In another study in Turkey, researchers examined pituitary diseases (including pituitary tumors and other pituitary diseases). In this study, NFAs were identified as the most common cause of hypopituitarism (22). Considering the prevalence of pituitary diseases, analysis of co-authorship networks in scientometric studies helps to improve the research process, identify different areas and identify the structure of science and knowledge. For this reason, the study of scientific collaboration in the scientific outputs of pituitary diseases can determine the dimensions and scope of collaboration in this field and identify individuals and countries that are superior in various aspects and indices.

Studies in the field of scientific collaboration are conducted at both macro and micro levels. At the macro level, they are part of bibliometric and scientometric studies which examine the joint articles of countries. At the micro-level, it is a detailed study of the factors affecting the level of collaboration between researchers (23).

The main problem stated in the present study is to determine the structure of the scientific collaboration network and the status of the co-authorship network in terms of pituitary diseases among researchers at the international level, Middle East, and Iran based on the network analysis indices.

The results of this research can be effective in improving scientific policies, decision-making at the scientific collaboration level, and improving the current situation. Therefore, co-authorship network mapping and analysis by researchers in the field of pituitary diseases can help identify top authors in this field at the international and Middle Eastern levels. It also reveals scientific collaboration patterns to identify strengths and weaknesses in this field and provide solutions to academic planners and policymakers of the university and answer the following questions.

1. What is the trend of scientific outputs in the world, the Middle East, and Iran in the field of pituitary diseases between 2000 and 2020?

2. Which are the top countries based on the most scientific outputs and the number of citations of pituitary diseases in the world and the Middle East between 2000 and 2020?

3. Which are the top countries in the Middle East in the world according to the centrality indices on pituitary diseases in the Web of Science database during the years 2000 to 2020?

4. What is the map of scientific collaboration (co-authorship) of countries in the field of pituitary diseases in the Web of Science database in the world and the Middle East during the years 2000 to 2020?

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5. What are the authors with the highest scientific outputs and the citation rate and the h index status regarding pituitary diseases in the Web of Science database in the world, the Middle East, and Iran?

6. Who are the top authors based on the centrality indices on pituitary diseases in the Web of Science database in the world, the Middle East, and Iran during the years 2000 to 2020?

7. What is the scientific collaboration map (co-authorship) of authors in the field of pituitary diseases in the Web of Science website in the world, the Middle East, and Iran during the years 2000 to 2020?

Methods

This is applied research that has been performed using scientometric methods and network analysis. The research data were collected by retrieving the scientific outputs of the above database. Scientific outputs can be assessed based on the documents indexed in citation indexes. Web of Science is one of the most important citation indexes in the world, and most scientometric studies are based on the information contained in this database. Indexing the scientific outputs of the world, mapping citation relations between them, and performing quantitative and qualitative measurements of scientific outputs using scientometric indices are important characteristics of this database (24).

TI (Title)=(Descriptor or Entry Term) AND Publication Year (PY)=(2000-2020)

In order to access the members of the research community, i.e., the articles in this research, there was a need to descriptors to retrieve the articles. For this purpose, the pituitary disease was first searched as the Medical Subject Heading (MeSh), and entry term as well as related keywords. To complete the keywords with the opinion of an endocrinologist, the main reference, Williams Textbook of Endocrinology (25), was used. Attempts were made to search for articles published during the period 2000 to 31 December 2020.

To access the data, we referred to the Advanced Search of the Web of Science database and performed the search process based on the titles of the articles. According to studies conducted by Alexander (26, 27) published in the Journal of Scientometrics, López-Muñoz (28), and other similar studies, it was found that simultaneous searches for the title, abstracts, and keywords of articles often lead to retrieval of irrelevant records. To this end, we used keywords and descriptors to search for the titles of articles focused mainly on a specific field. Moreover, according to studies, a keyword-based search was carried out to search for 90% of the results. The search results were then saved as a plain-text file.

In this study, in addition to identifying the most scientific outputs on pituitary diseases and scientific collaboration between countries, the co-authorship networks of countries and authors were evaluated using SNA metrics at the micro-level. The centrality of the network nodes was analyzed using three indices: degree, betweenness, and closeness. VOSviewer software was used to map the co-authorship relations between researchers and countries. The extracted data was then converted into a UCINET compatible file format. Meanwhile, UCINET software was used to analyze the centrality indices. After analyzing the centrality-related data, the top authors with central roles were identified.

Results

Question 1

What is the trend of scientific outputs in the world, the Middle East, and Iran in the field of pituitary diseases between 2000 and 2020?

Response 1

A search of Web of Science led to retrieval of a total of 31,257 documents on pituitary diseases published between the years 2000 and 2020. Table 1 and Figure 1 show the growth trend in scientific outputs on pituitary diseases by year. The highest and lowest international scientific outputs were published during the years 2018-2020 (n= 5441 articles) and 2000-2002 (n= 3590 articles), respectively. In Middle Eastern countries, the highest and the lowest scientific outputs were published during the years 2018-2020 (n=478 articles) and 2000-2002 (n=133 articles), respectively. In Iran, the highest and the lowest scientific outputs were published during the years 2018-2020 (n=64 articles) and 2000-2002 (n=6 articles). Iran ranked fourth, third, and second in terms of the number of sci entific outputs in the Middle East countries during the years 2000-2002, 2003-2017, and 2018-2020, respectively. Iran also ranked 45th and 25th in terms of the number of scientific outputs on the pituitary gland in the world during the years 2000-2002 and 2018-2020, respectively, which shows the growing trend in scientific outputs in the world, the Middle East, and Iran in recent years.

Table 1. The trend of scientific output in the field of pituitary disorders in the global world, Middle-East and Iran during 2000-2020

	Global		ME		Iran			
Year	Pub	% of Pub	Pub	% of Pub	Pub	% of Pub	Iran's Ranking in the global	Iran's Ranking in the ME Countries
2000-2002	3590	11.4	133	6.2	6	2.7	45	4
2003-2005	3622	11.5	156	7.3	8	3.6	41	3
2006-2008	4010	12.8	232	10.9	23	10.3	32	3
2009-2011	4625	14.8	276	13	29	13	31	3
2012-2014	4615	14.7	340	16	29	13	31	3
2015-2017	5354	17.1	497	23.5	63	28.3	24	3
2018-2020	5441	17.4	478	22.6	64	28.8	25	2
Total	31257	-	2112	-	222	-	-	-

Pub: Publications; ME: Middle-East

[DOI: 10.47176/mjiri.35.194]

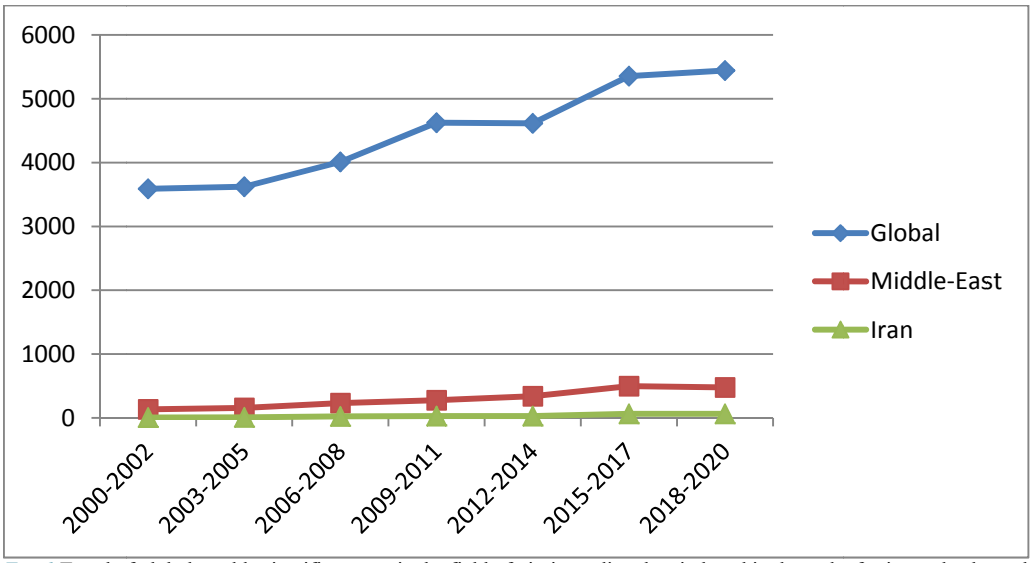

Fig. 1 Trend of global world scientific output in the field of pituitary disorders indexed in the web of science database during 2000-2020

Question 2

Which are the top countries based on the most scientific outputs and the number of citations of pituitary diseases in the world and the Middle East between 2000 and 2020?

Response 2

The results of the survey of the number of scientific outputs showed that the United States ranks first in terms of the number of scientific outputs on pituitary diseases (n=8081 documents) and (n=711446 citations), and (h index=143), followed by Japan, Italy and the England. With regard to the Middle Eastern countries, Turkey ranks first with 1212 documents and 6927 citations, followed by Israel with 354 documents and 5518 citations, and since it has h index=39, they are in the same ranking. Iran also ranks third with 222 scientific outputs, 1045 citations, and h index=17 (Table 2). The United States accounts for a total of 21% of scientific outputs on pituitary diseases and Turkey is also the leading country in the Middle East accounting for 3.8% of the total scientific outputs (Table 2).

Question 3

Which are the top countries in the Middle East in the world according to the centrality indices on pituitary diseases in the Web of Science database during the years 2000 to 2020?

Response 3

In this research, social network micro-indices, including centrality indices, have been used. In these indices, important, effective, and central nodes in each network are determined. Centrality is measured by three indices: degree, closeness, and betweenness. The degree centrality index refers to the number of co-authorship links given or removed from each node (6).

The degree centrality of each country indicates the number of co-author relations of that country with other countries present in the network. The degree centrality value is indicated by an integer that is unique to each node. The results of the study of the co-authorship network of countries in the field of pituitary diseases showed that the highest degree centrality value belonged to the

Table 2. Top-ranked countries in the pituitary scientific outputs in the global world and Middle-East during 2000-2020

Global Countries	Pub	% of Pub	Cit	H	Average Citations per Year	ME	Pub	% of Pub	Cit	H	Average Citations per Year
USA	8081	21.6	71446	143	2175.63	Turkey	1212	3.8	6927	39	436.00
Japan	2687	8.5	21731	70	1502.45	Israel	354	1.1	5518	39	297.59
Italy	2618	8.3	28135	106	2863.64	Iran	222	0.7	1045	17	62.78
England	2222	7.1	30531	100	2675.59	Egypt	105	0.3	811	16	41.10
Germany	1934	6.1	23242	88	1840.91	Saudi Arabia	101	0.3	736	14	36.48
China	1889	6	10080	42	651.00	UAE	32	0.1	172	8	9.75
France	1743	5.5	24462	100	2044.91	Lebanon	28	0.08	402	7	21.21
Spain	1216	3.8	13573	67	965.27	Jordan	22	0.07	311	9	17.55
Turkey	1212	3.8	6927	39	463.00	Qatar	22	0.07	375	5	22.24
Brazil	1172	3.7	10460	56	780.91	Cyprus	15	0.04	88	6	4.24
Canada	1162	3.7	17271	79	1208.95	Kuwait	15	0.04	83	6	5.19
Netherland	1052	3.3	15180	81	1275.59	Oman	13	0.04	162	6	8.79
India	775	2.4	3823	31	228.05	Iraq	12	0.03	25	3	1.92

Cit=Citation; Pub=Publication; ME=Middle-East Countries

[DOI: 10.47176/mjiri.35.194]

United States (n=4119), followed by England (n=2298), and Germany (n=2124). Among the Middle Eastern countries, Israel ranks first with (n=415), followed by Turkey (n=373) and Egypt (n=111), and Iran ranks sixth (n=47) (Table 3).

With regard to the betweenness centrality index, the United States, England, and France in the world, and Egypt, Turkey, and Saudi Arabia in the Middle East rank first to third. Iran ranks 10th in terms of the betweenness centrality index (Table 3).

With regard to the closeness centrality index, the United States, England, and Italy, and among the Middle East countries, Turkey, Israel and Egypt rank first to third. Iran also ranks seventh in this regard (Table 3). These countries are the closest to other countries in terms of the number of scientific outputs in the field of pituitary diseases, so they had the most influence in the network.

Question 4

What is the map of scientific collaboration (co-authorship) of countries in the field of pituitary diseases in the Web of Science database in the world and the Middle East during the years 2000 to 2020?

Response 4

In this research, a scientific collaboration or co-authorship network between countries in the field of pituitary diseases has been mapped and analyzed. The co-authorship network of these countries is shown in Figure 2. In this network, each node represents a country, and the links between the two nodes are co-authorship relations between researchers from those countries. The co-authorship network of countries in the world consists of 129 nodes (countries) and 2694 links (co-authorship countries).

A comparison of the co-authorship network of Middle

Table 3. Ranking of the global world and Middle-east countries based on degree, betweenness, and closeness centrality

	Global		Middle-East		Global		Middle-East		Global		Middle-East	
Rank	Country	Degree	Country	Degree	Country	Betweenness	Country	betweenness	Country	Closeness	Country	Closeness
1	USA	4119	Israel	415	USA	1571.784	Egypt	76.966	USA	75.74	Turkey	80.952
2	England	2298	Turkey	373	England	1015.792	Turkey	70.672	England	71.91	Israel	73.913
3	Germany	2124	Egypt	111	France	672.754	Saudi Arabia	35.1	Italy	69.945	Egypt	64.151
4	France	1981	Saudi Arabia	54	Italy	554.966	Lebanon	28.683	France	68.817	Lebanon	59.649
5	Italy	1853	Qatar	50	Netherland	507.306	Israel	20.578	Germany	68.085	Saudi Arabia	59.13
6	Netherland	1309	Iran	47	Germany	466.07	UAE	18.981	Spain	67.016	UAE	56.667
7	Spain	1126	Lebanon	45	Japan	403.669	Cyprus	5.345	Netherland	65.306	Iran	55.285
8	Canada	1097	UAE	37	Belgium	402.28	Kuwait	2.766	Belgium	64	Kuwait	53.125
9	Belgium	910	Oman	16	China	335.439	Oman	1.237	Japan	63.054	Cyprus	52.713
10	Switzerland	893	Jordan	14	Brazil	298.252	Iran	1.113	Canada	62.745	Jordan	52.713
11	Sweden	799	Cyprus	12	Spain	247.886	Qatar	1.025	Poland	62.745	Oman	52.713
12	Brazil	777	Kuwait	10	India	154.145	Jordan	0.387	Switzerland	62.745	Iraq	49.635

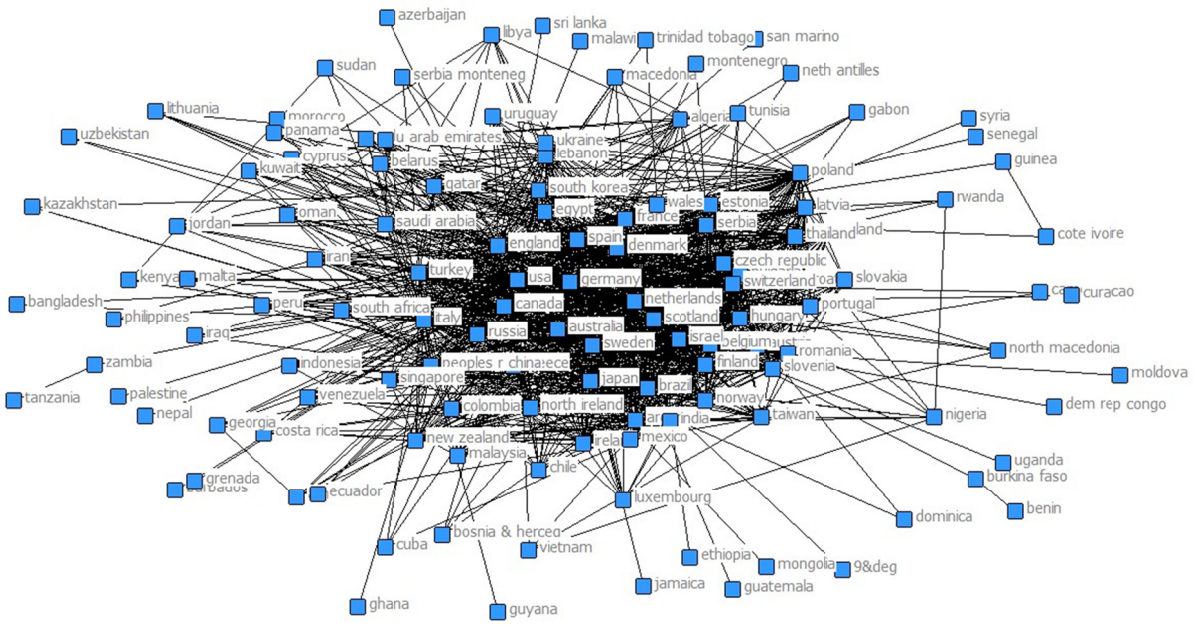

Fig. 2. Co-authorship network of the world countries in the field of pituitary disorders during 2000-2020

[DOI: 10.47176/mjiri.35.194]

Eastern countries with the countries of the world showed that a total of 69 countries have collaborated with each other, including 69 nodes (countries) and 1708 links. The size of each node, the number of co-authorship by that node and the diameter of the links between the two nodes indicate the number of co-authorship relations between the two countries.

However, in the co-authorship network of Middle Eastern countries, 13 out of 17 Middle Eastern countries have collaborated with each other, including a network consisting of 13 nodes (countries) and 50 links (Fig. 3).

Question 5

What are the authors with the highest scientific outputs and the citation rate and the h index status regarding pituitary diseases in the Web of Science database in the world, the Middle East, and Iran?

Response 5

Examination of the extracted data shows that Colao (n=319 articles), Stratakis (n=248 articles), and Coax (n=210 articles) are the three top authors in terms of scientific outputs in the clinical field of pituitary disease in the world, respectively. Shimon (n=64articles), Kadioglu (n=63 articles), and Erbas (n=41 articles) are the most productive researchers in the field of pituitary disease in the Web of Science database in the Middle East. In Iran, Khamseh (n=11 articles), Ghorabi (n=9 articles), and Karamizadeh (n=8 articles) have been the top three authors in terms of the number of scientific outputs in pituitary diseases. Based on the number of citations and H index in the world, Colao with 7406 citations and H index=64 and Melmed with 6870 citations and h index= 57 have been the top authors. In the Middle East, Shimon with 1121 citations, h index=20, and Erbas with 668 citations and h index=18 are the two top authors in terms of the number of scientific citations. In Iran, Larijani with 132 citations, h index=4 and Khamseh with 41 citations and h index=3 have been the top two authors in the field of pituitary diseases. Table 4 shows the top 10 authors with the highest citations and h index status (Table 4).

Question 6

Who are the top authors based on the centrality indices on pituitary diseases in the Web of Science database in the world, the Middle East, and Iran during the years 2000 to 2020?

Response 6

Surveys on the types of centrality indices of international authors show that Colao and Pivonello rank first and second, respectively, in terms of degree centrality index. Pivonello, Colao, and chanson rank first to third, respectively, in terms of betweenness and closeness centrality

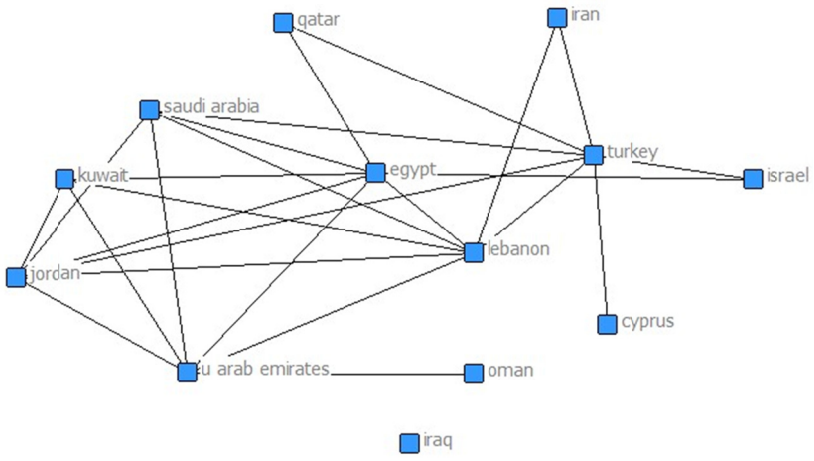

Fig. 3. Co-authorship network of the Middle-East countries in the field of pituitary disorders during 2000-2020

Table 4. The authors with the highest scientific output and citations in the field of pituitary disorders

	Global				Middle-East				Iran			
Rank	Author	Pub	Cit	H	Author	Pub	Cit	H	Author	Pub	Cit	H
1	Colao A	319	7406	64	Shimon Ilan	64	1121	20	Khamseh ME	11	41	3
2	Stratakis CA	248	3571	47	Kadioglu P	63	420	11	Ghorabani M	9	18	2
3	Kovacs K	210	2333	36	Erbas T	41	666	18	Karamizadeh Z	8	22	2
4	Pivonello R	196	4209	49	Tanriyerdi F	35	577	15	Akbari H	8	14	2
5	Chanson P	180	4557	52	Yarman S	35	179	8	Sharifi G	8	19	3
6	Laws ER	171	3650	43	Unluhizarci K	31	544	15	Kajbafzadeh AM	7	14	2
7	Melmed S	161	6870	57	Gazioglu N	30	279	10	Malek M	7	32	3
8	Buchfelder M	159	3481	38	Dagdelen S	29	164	7	Kashef S	7	11	1
9	Grossman AB	154	5358	46	Greenman Y	29	430	12	Larijani B	6	132	4
10	Pereira AM	154	2893	41	Berker D	23	135	6	Noori-Daloii MR	6	18	2

[DOI: 10.47176/mjiri.35.194]

indices. These authors are the closest to other authors in the field of pituitary diseases, so they have the most influence in the network. Most researchers have co-authorship relations with Pivonello, Colao, and Chanson (Appendix 1).

Surveys based on centrality indices of authors in the Middle East show that Shimon and Kadioglu rank first and second, respectively, in terms of degree centrality index. With regard to the betweenness centrality index, Laws and Kadioglu rank first and second, respectively. Also, Kadioglu and Kelestimur rank first and second based on the closeness centrality index. These authors are closest to other authors in the field of pituitary disease, so they have the most influence on the network (Appendix 2).

Surveys based on the types of the centrality of authors in Iran show that Khamseh, Ghorbani, and Akbari rank first to third, respectively in terms of degree centrality index. Larijani, Mohseni, and Khamseh rank first to third, respectively in terms of the betweenness centrality index. Finally, Mohseni, Khamseh, and Larijani are the top three authors in terms of closeness centrality index. These authors are the closest to other authors in the field of pituitary diseases. Therefore, they have the most influence in the network (Appendix 3).

Question 7

What is the scientific collaboration map (co-authorship) of authors in the field of pituitary diseases in the Web of Science website in the world, the Middle East, and Iran during the years 2000 to 2020?

Response 7

The map of authors' scientific collaboration in the field of pituitary diseases consists of 92 nodes, each of which represents an author. Authors with more scientific outputs and communication are at the center of the map. A total of 77,313 authors collaborated worldwide (Fig. 4).

Figure 4 shows a map of scientific collaboration between Middle Eastern authors in the field of pituitary disease, with each node representing one author. Authors with more co-authorship relations and communication are at the center of the map (Fig. 5). A total of 7,288 authors collaborated throughout the Middle East.

Figure 6 shows the map of scientific collaboration in the field of pituitary diseases among Iranian authors, where each node represents an author. Authors with co-authorship relations and communication are at the center of the map. A total of 849 authors collaborated throughout Iran.

Discussion

Scientific collaboration and participation are one of important topics in scientometric studies and there have been many studies on different models of scientific collaboration and participation. Some studies have investigated the scientific collaboration of researchers in different countries (7, 8, 10), universities (9, 16, 17, 23), fields (7, 8, 10, 11, 12, 13, 24), and journals. The results of the present study showed an upward trend in scientific outputs on pituitary diseases at the international and Middle East levels during the period under study. The highest and lowest scientific outputs at the international and Middle Eastern level were published during the years 2018-2020 and

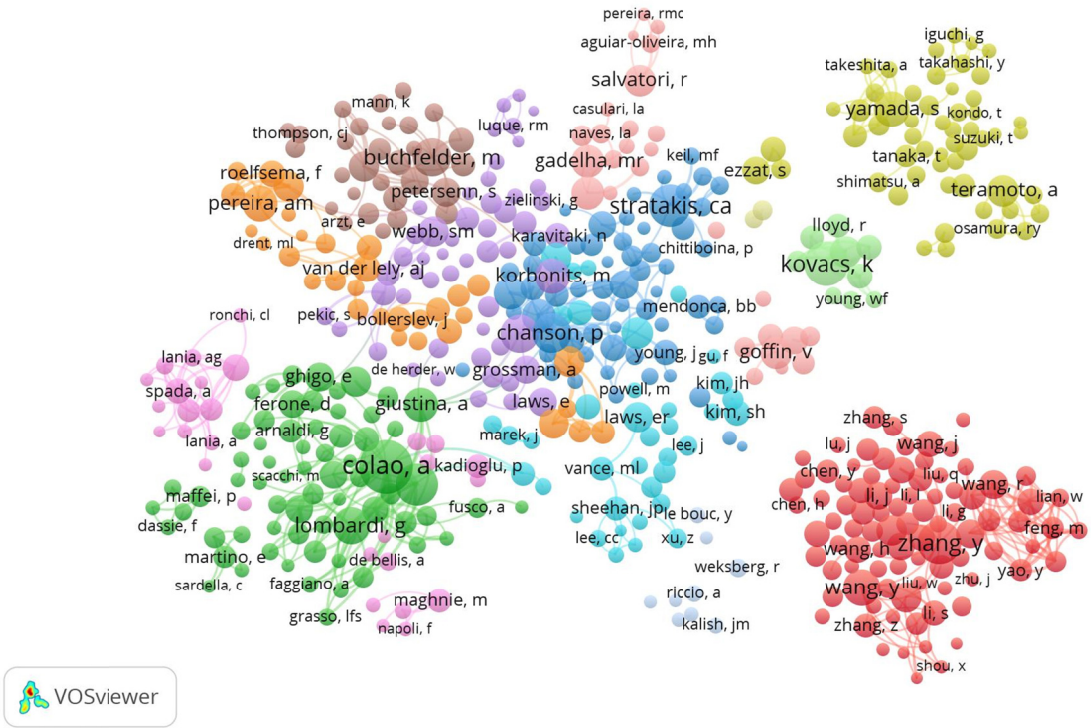

Fig. 4. Mapping of scientific collaboration of the world's authors in the field of pituitary disorders

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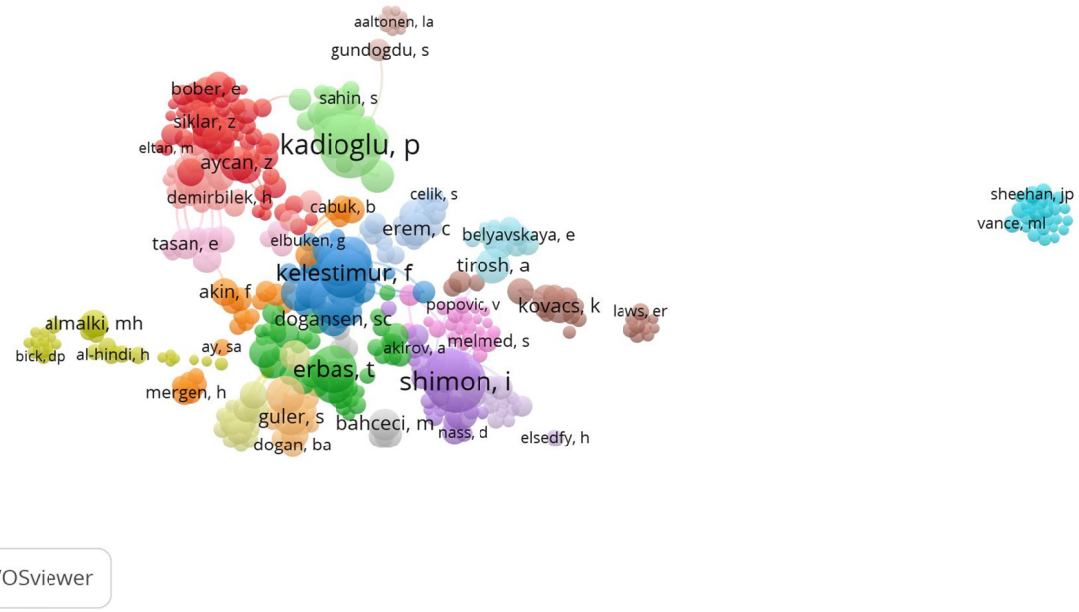

Fig. 5. Mapping of scientific collaboration of the Middle-east's authors in the field of pituitary disorders

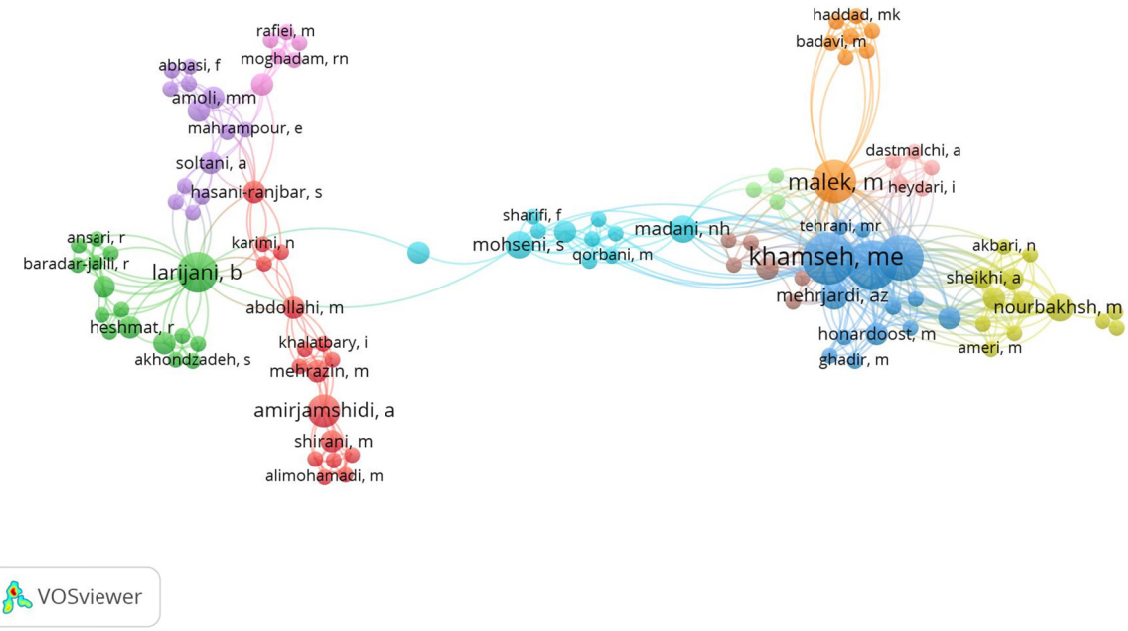

Fig. 6. Mapping of scientific collaboration of Iranian authors in the field of pituitary disorders

2000-2002, respectively. The results are consistent with the research that examined the scientific outputs of 16 Middle Eastern countries during the years 1996-2014 (29). Zhao et al. also pointed to the upward growth and growth rate of 1.09 times of scientific outputs on endocrinology and metabolic science at the international level (30), which is consistent with this finding.

The findings of the present study referred to the United States, Japan, Italy, and the England, at the international level, and Turkey, Israel, Iran, and Egypt, in the Middle East, as the pioneers of scientific outputs in the field of pituitary diseases. Iran ranks fourth, second, and first in terms of the number of scientific outputs among the Middle East countries during the years 2000-2002, 2003-2017, and 2018-2020, respectively. Iran also ranks 45th and 25th in the world in terms of the number of scientific outputs

[DOI: 10.47176/mjiri.35.194]

the field of pituitary diseases between 2002-2000 and 2018-2020 in the world, respectively, which shows the growing trend of scientific outputs in the world, Middle East, and Iran in recent years. The findings of this part of the study are consistent with the results of the studies by Emami et al. on the process of scientific outputs of thyroid disease (31) and diabetes (32). They showed that Iran ranked second in the Middle East only during 2018-2020. However, the results of the present study are inconsistent with the above studies in terms of the above variable during the years 2000-2017. In another study, the number of scientific outputs in the field of polycystic ovary syndrome in the world and the Middle East region in Web of Science was examined. The results showed that Iran ranked eighth in the world and second in the Middle East after Turkey. The results are not consistent with the present study in terms of Iran ranking (33); but the results were consistent with the above study in terms of the above variable only during 2018-2020.

With regard to the Middle Eastern countries, Turkey ranks first with 1212 documents and 6927 citations, followed by Israel with 354 documents and 5518 citations, and since it has h index=39, they are in the same ranking. Iran also ranks third with 222 scientific outputs, 1045 citations, and h index=17. The United States accounts for a total of 21% of scientific outputs on pituitary diseases and Turkey is also the leading country in the Middle East accounting for 3.8% of the total scientific outputs. In a study on the scientific outputs in the field of epidemiology, Erfanmanesh showed that the United States is in the first place with 21,236 scientific documents, followed by the England, China, Canada and. With regard to the Middle Eastern countries, Iran is in the first place with 1196 scientific documents, followed by Turkey, Israel, Saudi Arabia, and Egypt (34). The results regarding the ranking of countries in the world and the Middle East are not consistent with the present study.

The discrepancy between the results of the mentioned researches with the present research can be due to the differences in the fields of study. Some countries, for various reasons such as more prevalence of a particular disease, more investment in a particular field of study, the existence of capable research centers in a particular field, etc., will certainly have more scientific outputs in that field, which lead to different numbers of scientific outputs of countries in various subjects.

In another study on the scientific outputs of diabetes in Scopus in the Middle East (1996-2012), Sweileh et al. emphasized the superiority of Saudi Arabia and Egypt and the low level of scientific outputs in Syria, Yemen, and Palestine, which is consistent with the findings of the present study (35). With regard to scientific outputs in the present study, Turkey is in the first place, followed by Israel and Iran. This level of productivity can be attributed to the population, national income, or general scientific activity of these countries. Israel has been able to improve the quality of its scientific outputs by focusing mainly on the hot fields of endocrinology and metabolism.

The results of the present study showed a high level of desire for scientific collaboration among international medical researchers in the field of pituitary diseases. Some studies have examined scientific collaboration between medical researchers at various levels (36, 37). They have concluded that there is a high level of collaboration between this group of researchers, which is consistent with the results of the present study.

Results also showed that Colao and Pivonello ranked first and second, respectively, in terms of degree centrality at the international level. In the Middle East, Shimon and Kadioglu ranked first and second, and in Iran, Khamseh, Ghorbani, and Akbari are ranked first to third, respectively in terms of degree centrality. The high degree centrality index indicates that authors with the highest scientific outputs play a more active role in the network. These people control the flow of information among network members.

Pivonello, Colao, and Chanson ranked first to third in the world in terms of the betweenness centrality index. In the Middle East, Laws and Kadioglu tanked first and second. In Iran Larijani, Mohseni, and Khamseh ranked first to third, respectively in terms of the betweenness centrality index. A higher betweenness centrality index means that these researchers mediate between researchers in the network. In other words, they keep the co-authorship network of the pituitary glands cohesive by acting as a mediator between the nodes, as a bridge, connects the network members.

With regard to the closeness centrality index, Pivonello, Colao, and Chanson have the highest rankings in the world, Kadioglu, Kelestimur ranked first and second in the Middle East, and Mohseni, Khamseh, and Larijani are the top authors in Iran. These authors are closer to all the other authors of the co-authorship network in the field of pituitary diseases.

After comparing the results of the present study with previous studies, it can be concluded that authors have social power who have a higher centrality score. The reason for such superiority is that they give network members more opportunities to connect with other members by participating in co-authorship relations with stronger groups. These researchers have more alternatives than other network agents and, therefore, have more independence (38, 39).

Considering that the number of scientific outputs of different countries is one of the criteria for ranking countries and shows their scientific potential (40). According to the research findings, Iran ranked third in the Middle East in terms of the number of scientific outputs in the field of pituitary diseases. In order to achieve higher ranks, relevant Iranian authorities need to develop the scientific strength of the country by using the capacities and capabilities of the country's researchers, allocating sufficient funds, supporting public and private sectors in the field of basic and clinical sciences research.

Conclusion

The results of this part of the research can be used by the scientific community, especially endocrinologists, and can be effective in policy-making so that authors and countries be aware of the state of scientific outputs and

[DOI: 10.47176/mjiri.35.194]

plan to have more investments in research areas in this particular field and focus on international collaboration. Increasing scientific collaboration at the domestic and international levels can improve the quality of scientific outputs. Careful planning for targeted research by research teams can be effective in improving the ranking of scientific outputs. Although Iran's scientific output shows an increasing trend, it needs more effort, planning and investment in order to bridge the gap with developed countries in the field of pituitary scientific outputs.

The results of this research can be effective for the country's universities and departments in order to plan education and research in various fields, ensure their balanced development, and achieve the goals outlined in the comprehensive scientific map of the country. In this regard, experts and administrators should focus on strengthening the collaboration of Iranian universities with nodes that have a higher closeness and degree of centrality. The country's universities should pay attention to the development of collaboration relations with these countries and individuals because these countries and individuals are of special importance in the scientific network of pituitary diseases and establish communication with other countries and they play an important role as mediators between other countries.

In addition to conveying the messages to researchers in this field, the results of the present research can also be useful for scientific policymakers and will play an important role in improving the quality and quantity of scientific output by identifying key gaps and help adapt better policy-making for the scientific community. Co-authorship relations with researchers from countries that have a central position in this social network can increase the central position of our country in the mentioned network. According to social theories, the formation of participatory links in the social network depends on the cost and usefulness of these relations with active nodes in the network in the short and long term. Therefore, the scientific policymakers of the country can not only examine the advantages of scientific collaboration between our country's researchers with researchers of important and influential countries but also provide facilities for the formation and strengthening of these participatory links in the field of research of pituitary diseases in the future.

Research Executive suggestions

- Collaboration and co-authorship with top countries (Italy, USA, Canada, and France) seem to be effective since many top authors are from these countries. It can be effective to hold scientific conferences, seminars and international conferences with prominent professors in the field of pituitary diseases. It can also be useful for researchers to become familiar with core and reputable journals in their field and to use reputable databases, to introduce top and core authors in the field of pituitary diseases to novice researchers, and to create an opportunity to collaborate with top researchers in their field.
- The close relationship between pituitary diseases and neurosurgery, pathology and radiotherapy, and scientific collaboration between researchers in these fields with researchers from developed countries can be fruitful. Finally, the establishment of a pituitary network in the world and the Middle East is recommended.
- It is also recommended to ensure government and industry planning for future growth and development using the strengths of researchers who are in a strategic position and proper clusters relative to other members in the network.
- Increasing research infrastructure, encouraging and motivating researchers, and increasing funding can be helpful.

Ethics approval and consent to participate

Ethical approval for this study was received from the Iran University of Medical Sciences

Conflict of Interests

The authors declare that they have no competing interests.

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[DOI: 10.47176/mjiri.35.194]

Appendix 1. Ranking of authors based on degree, betweenness and closeness centrality in the world

Rank	Author	Degree	Author	Betweenness	Author	Closeness
1	Colao, A	1167	Pivonello, R	7134.225	Pivonello, R	54.536
2	Pivonello, R	795	Colao, A	6621.619	Colao, A	54.357
3	Lombardi, G	646	Chanson, P	6269.693	Chanson, P	52.471
4	Chanson, P	629	Korbonits, M	4437.058	Korbonits, M	52.416
5	Zhang YZ	561	Wang, Y	4199.831	Melmed, S	52.361
6	Brue T	520	Melmed, S	3982.7	Fleseriu, M	51.022
7	Giustina A	496	Li, Y	3447.403	Petersenn S	50.866
8	Kovacs K	485	Webb, SM	3353.35	Buchfelder, M	50.66
9	Wang, Y	460	Fleseriu, M	2779.69	Biller, Bmk	50.088
10	Wang, H	428	Chen, Y	2675.397	Reincke, M	49.652

Appendix 2. Ranking of authors based on degree, betweenness and closeness centrality in the Middle-East

Rank	Author	Degree	Author	Betweenness	Author	Closeness
1	Shimon, I	248	Laws, E	15863.84	Kadioglu, P	34.034
2	Kadioglu, P	187	Kadioglu, P	15290.92	Kelestimur, F	34.008
3	Kelestimur, F	168	Laws, ER	10355.72	Tanriverdi, F	33.59
4	Tanriverdi, F	154	Vance, ML	9912.412	Canturk, Z	32.539
5	Unluhizarci, K	134	Bronstein, MD	9569.579	Colak, R	31.898
6	Berker, D	118	Tutunculer, F	8304.494	Unluhizarci, K	31.759
7	Siklar, Z	115	Delibasi, T	8032.291	Delibasi, T	31.575
8	Bas, F	113	Tekin, M	7708.972	Hatipoglu, N	31.461
9	Berberoglu, M	112	Glaser, B	6026.659	Karaca, Z	31.416
10	Greenman, Y	112	Casanueva, FF	5737.545	Bronstein, MD	31.371

Appendix 3. Ranking of authors based on degree, betweenness and closeness centrality in Iran

Rank	Author	Degree	Author	Betweenness	Author	Closeness
1	Khamseh, ME	78	Larijani, B	3729	Mohseni, S	42.529
2	Ghorbani, M	70	Mohseni, S	1329	Khamseh, ME	41.418
3	Akbari, H	63	Khamseh, ME	2667.85	Larijani, B	41.418
4	Malek, M	50	Abdollahi, M	1188	Hashemimadani, N	37.124
5	Larijani, B	28	Malek, M	782.3	Mohajeri-Tehrani, M	35.35
6	Nourbakhsh, M	23	Hasani-Ranjbar, S	764	Fooladgar, M	35.127
7	Hashemimadani, N	22	Amirjamshidi, A	630	Zafarghandi, H	35.127
8	Alimohammadi, A	20	Soltani, A	590	Qorbani, M	35.127
9	Zare Mehrjardi, A	20	Hashemimadani, N	530.45	Hemmatabadi, M	35.127
10	Salami, V	20	Rahmanian, M	530	Shirzad, N	35.127

[DOI: 10.47176/mjiri.35.194]