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Patterns of Iran's Research Collaboration in the field of Pharmacology and Pharmacy: A Bibliometric Study

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Abstract

Purpose: This research aims to analyze and visualize the structure of Iranian scholarly networks in the field of "pharmacology and pharmacy". This study includes an overview of co-authorship, efficiency and ranking of the researches, visualizing the co-authorship network, changes in the main core of the publications and macro and micro-level metrics such as social influence.

Methods: This research utilizes social network analysis (SNA). The preliminary data of this research includes all the Iran's documents in Web of Science in "Pharmacology and Pharmacy" during the period of 2005 to 2016. After the preprocessing of 6204 records and creating relational matrix, a combination of bibliometric software (including UCINET, NetDraw, HistCite and VOSviewer) were used to analyze and uncover network features.

Results: Results indicated that most papers are multi-authored. Four-authored articles are the main common authorship pattern. Some measures such as author frequency, multi-authored papers, and single-authored papers in each time interval are ascending. Moreover, "density" reduction of the scientific collaborations indicates that fragmentation level has increased based on the "clustering coefficient" in each period. Besides, Iranian researchers of the field has the most collaboration with the scholars of England (%2.85), U.S.A. (2.61%) and Canada (1.76%), respectively.

Conclusions: Fragile structure and low closeness of the network imply low maturity of Iran's research in the field of "pharmacology and pharmacy". Also, test of the correlation coefficients indicates that with increasing "degree centrality" and "betweenness centrality", the "number of articles" increases as well. However, there is no correlation between "closeness centrality" and "number of articles".

Keywords: Research collaboration; Social network analysis; Co-authorship patterns; Pharmacology & Pharmacy; Centrality; Author productivity.

1. Introduction

Science is the product of curiosity, thinking, reasoning as well as individual and group experience. Scientific development and achievement of major research achievements require collaboration of all scholars and scientists; therefore, collaboration and cooperation are one of the mechanisms of scientific development and play a key role in all scholarly fields and provide prosperity (Su et al., 2017). Over the past decades, scientific collaboration between individuals, research organizations, and various countries has grown exponentially. Scientific cooperation facilitates the provision and dissemination of knowledge and has attracted the attention of researchers in various fields (Ye, Li, & Law, 2013).

On the other hand, high level of quality and quantity of research works is so essential for most researches. They expect– after a long and hard process- to be able to publish their findings and also to some extent affect the knowledge of the society. However, due to diversity, breadth and interdisciplinary of some scholarly subjects and also limited cognitive abilities and intelligence level for each person (Li, Liao, &

Yen, 2013), there is no ability to execute these plans individually (Ding, 2011; Elango & Rajendran, 2012; Khalid, Ibrahim, Selamat, & Kadir, 2016).

This kind of scholarly collaboration can solve research problems which cannot be resolved by a researcher lonely (Jiang, 2008), so that, researchers would be able to achieve a common goal (Hauptman, 2005), specific skill as well as new supplies or equipment by dividing their workload (Khalid et al., 2016).

Analysis and evaluation of the network structure of the scientific collaborations are developed via macro and micro-level metrics through the network analysis technique (Yan & Ding, 2009). Micro metrics uncover the performance of each researcher in the network. Macro metrics investigates topology and general properties of network such as density, fragmentation, clustering coefficient, centralization, components, connectedness, diameter and average of the shortest distance (Geodesic) (Wang et al., 2014).

"Density" represents the ratio of available scientific collaboration to possible scientific collaboration in the network and is always between zero and one. "Connectedness" indicates the connection of researchers together through co-authorship. The network "diameter" represents the farthest distance of researchers of a network. "Fragmentation" implies disconnection level of researchers. "Clustering coefficient" or the "sociality" indicates willingness of individuals in the network to form different clusters through co-authorship. "Centralization" signifies the organization of a set of researchers around one or more central researcher in the network. "Number of components" and "average of distance [Geodesic)" refer to the shortest distance between two researchers; the less average distance, the fast information dissemination (DeNooy, Mrvar, & Batagelj, 2011; Sadatmoosavi, Nooshinfard, Hariri, & Mohammadesmaeel, 2015).

In addition to analyzing the general structure and the evolution process of network of scientific collaboration through macro metrics, the performance of each researcher in the network can be studied using micro metrics. Centrality measures (social influence) study the importance and impact of individuals in a network. Degree,

closeness and betweenness are the most important metrics of centrality (Abbasi, Hossain, & Leydesdorff, 2012; Bengtsson & Holfve-Sabel, 2016).

The “Degree centrality” refers to direct links of a node (a researcher) to the other nodes regardless of link weight (frequency of the link). Each direct link is considered as a unique co-authorship. A high degree central actor signifies more collaboration with other researchers (Otte & Rousseau, 2002). The “closeness” implies average of the shortest distance of a node to other nodes (Lu & Feng, 2009) and also the average of sum distance between two nodes (Li et al., 2013). The “betweenness” presents the ratio of the shortest paths where a specific research can pass among pair of other researches (Borgatti, 2005). The “betweenness centrality” indicates the ability of a researcher to control information flow in the network and play as information interface for the other researches (Freeman, 1979).

The necessity to investigate the scholarly collaboration in the field of pharmacy and pharmacology is clear and tangible due to the advancement of chemistry and biology, various science communication, the human need for treating diseases, presenting new therapeutic approaches by using more recent effective drugs, strengthening the aspect of research, adding information, creating the necessary attitudes and achieving hidden creatures. Thus, analyzing the structure of this network can determine the scope and vastness of the collaboration and also identify prominent researches in the field of pharmacology and pharmacy.

Therefore, this research aims to analyze and visualize the structure of the network of the Iranian scientific collaboration in the field of pharmacy and pharmacology by using macro and micro metrics. It is necessary to focus on the evolution process of the Iranian social network analysis in this field, because a comprehensive study in this context and statistical community has not been developed yet. To achieve this goal, this study attempts to answer the following questions:

1. How is the Iranian network of scientific collaboration in the field of pharmacy and pharmacology in terms of size, density, components, average of path length, diameter, centralization, connectedness and fragmentation?

2. How is the Iranian network of scientific collaboration in the field of pharmacy and pharmacology in terms of centrality metrics (degree, closeness and betweenness)?
3. What is average of the number of authors and multi-authors of the network?
4. What is the ratio of internal collaboration to external collaboration of the network?
5. Which countries do have the most collaboration with Iran in the network?
6. Which organizations and research centers do have the most published articles in the network?

2. Research Hypothesis

1. There is a significant relationship between the “degree centrality” and the “numbers of articles” in the network structure of scientific collaboration in the field of pharmacy and pharmacology?

2. There is a significant relationship between the “closeness centrality” and the “numbers of articles” in the network structure of scientific collaboration in the field of pharmacy and pharmacology?

3. There is a significant relationship between the “betweenness centrality” and the “numbers of articles” in the network structure of scientific collaboration in the field of pharmacy and pharmacology?

3. Methods

The present paper applies bibliometrics and utilizes SNA approaches to visualize the network. Bibliometrics is describes as studying communication patterns of authors, publishers and texts through various statistical methods (Lancaster & Joncich, 1977). Bibliometric methods are divided into 2 groups (Benckendorff & Zehrer, 2013; Hall, 2011): the first group is called “evaluation techniques” which include

productivity measures (number of articles in each year, number of articles for each author).

In this research, some evaluation techniques (productivity measures) such as number of author(s), number of articles for each author, multi-authored articles, authors of multi-authored articles, collaboration index, collaboration patterns as well as factor of dominance (FD) are used.

The second group is called "relationship techniques" (Benckendorff & Zehrer, 2013) like co-authorship. A researcher considers content, structure, symmetry, asymmetry and quality of relationships and also strength and weakness of links based on his/her theoretical framework through using this kind of technique (Chalabi, 1994). It is worth mentioning that due to influence of network topology on structure and performance of network nodes via this technique, the structure and content between researchers are more important than attributes and properties of actors (Albert & Barabasi, 2002).

Preliminary data of this study included all Iranian documents in the field of pharmacy and pharmacology indexed in Web of Science (WoS) Core Collection during 12 years (2005-2016). 255 journals are categorized in the category of "pharmacy and pharmacology" in WoS which totally 6204 documents belonged to the Iranian researchers as the sample of this study. Search strategy via advanced search in WoS was as following:

WC= (Pharmacology & Pharmacy) DocType=All document types; Language=All languages

Indexes=SCI-EXPANDED Timespan=2005-2016

Then, data saved as full records (500 records) in plain text format, after that all separated files were integrated in a final file. After preprocessing, false and repeated items were eliminated and modified. Names of researchers were standardized, modified, refined and arranged alphabetically in an excel file.

Then, names of researches were developed in a relational matrix of co-authorship to utilize for UCINET software. Each cell of the relational matrix indicates the number of collaboration between two nodes (researcher/ country/ organization). Co-

authorships were drawn using NetDraw and VOSviewer software. The mentioned matrix was a kind of weighted matrix, because it determines relationships as well as their frequency. Moreover, HistCite software and Excel software (as formulating) were utilized to determine number(s) of authors of each article. 12 surveyed years (2005-2016) were divided to equal 3 time-intervals of 4 years for analyzing.

4. Results

Authorship and co-authorship status

As table 1 shows, all the articles during 12 years are 6204 papers. The findings show that the number of articles published in 3 time intervals increases as the time passes. Also, some measures such as Author frequency (including repetitive writers), number of authors (not including repetitive writers), number of multi-authored papers, number of single-authored papers, and number of authors of multi-authored papers are ascending during these 3 time intervals. However, there is not an incremental trend about some measures like articles per author, authors per article, and collaboration index.

Table 1: Authorship Data: General View

	2005-2008	2009-2012	2013-2016	Total
Articles	**923**	**1941**	**3340**	**6204**
Author appearances	**4176**	**9638**	**17176**	**30988**
Unique Authors	**2672**	**5968**	**9967**	**15833**
Articles per author	**0.35**	**0.33**	**0.50**	**0.39**
Authors per article	**2.89**	**3.07**	**2.99**	**2.55**
Multi authored articles	**895**	**1906**	**3305**	**6106**
Single-Author articles	**28**	**35**	**35**	**98**
Authors of multi authored articles	**2644**	**5933**	**9932**	**15735**
Collaboration index	**2.95**	**3.11**	**3.01**	**2.58**

Despite the dramatic increase of articles in each time interval and the number of multi-authored articles, the number of single-authored articles has not changed (figure 1).

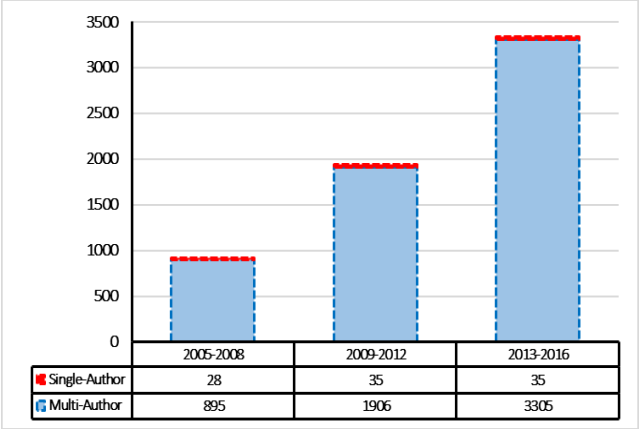


Figure 1: Single-authored versus multi-authored articles

Furthermore, as figure 2 presents, from the total of 6204 papers, 6106 articles are multi-authored and only 98 articles are single-authored. In this regard, results of the other fields such as Bioinformatics (Amsaveni, Manikandan, & Manjula, 2013), Veterinary (Arya, 2012), Marine Sciences (Elango & Rajendran, 2012), Psychology (Zafrunnisha & Pullareddy, 2009), and Medicine (Weeks, Wallace, & Kimberly, 2004) confirm the results of this study as well. They signify multi-authored articles have dominated the majority of research. The results indicate that group research plays a major role in scientific development.

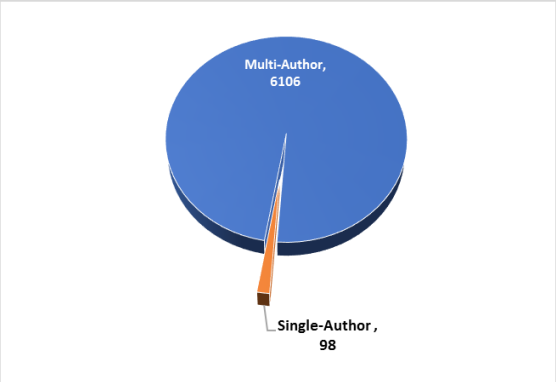


Figure 2: Frequency of single-authorship and co-authorship

Figure 3 indicates authorship patterns of Iran's pharmacy and pharmacology research during the timeline (2005-2016). Four-author pattern is dominated in this

filed (1239 papers). Five-authored pattern (1157 papers) and three-authored pattern (1017 papers) ranked second and third, respectively. It is considerable that 1 paper with 20 co-authors is allocated the most number of authors.

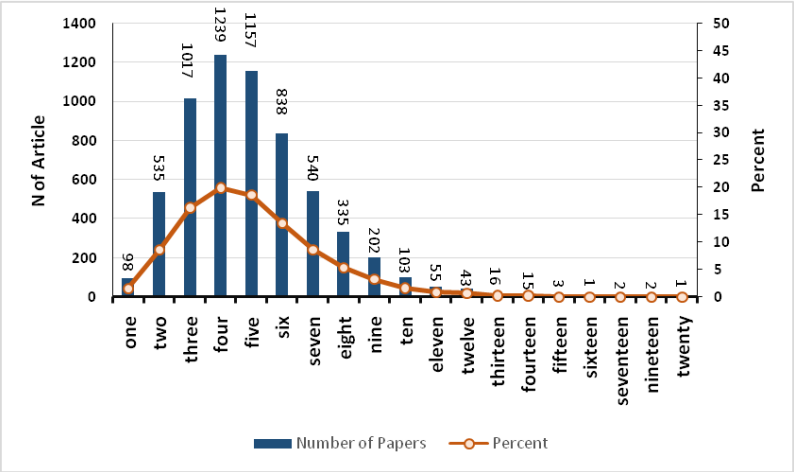


Figure 3: Authorship patterns of Iran's pharmacy and pharmacology research

The Iranian networks of scientific collaboration in the field of pharmacy and pharmacology in comparison with 3 time intervals show that there are 15833 nodes (authors) and 134654 links (co-authorship) during period (2005-2016). The time interval (2013-2016) has the highest number of authors and links (9967 nodes and 78896 links) and the time interval (2009-2012) has the lowest ones (5968 nodes and 41900 links).

General density of the network equals 0.001 and the time interval 2005-2008 has the most density (0.002). it implies power reduction of the network. On the other hand, this reduction represents that the level of fragmentation in each period has increased based on clustering coefficient. The density indicates week relationships of the researchers among the network. This result is consistent with the research results in the field of "management and organization" (Acedo, Barroso, Casanueva, & Galán, 2006) as well as in the field of "strategic management" (Koseoglu, 2016).

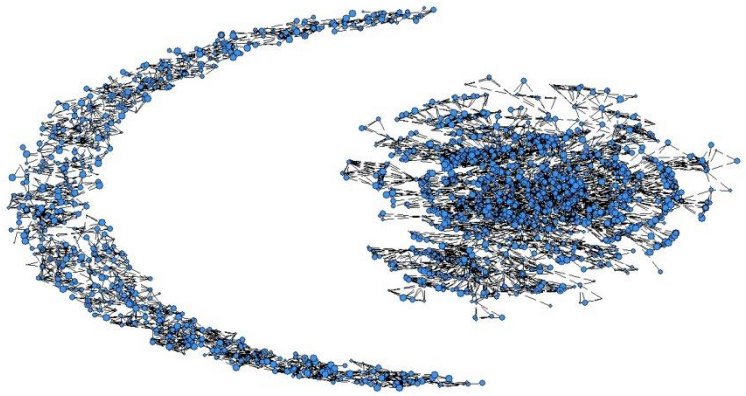
The network during 2005-2016 contains 466 components (0.029) and 12566 authors as members of major component. The average path length equals 5.009, the least average is allocated to the 1st period (5.440) and the most is related to the 2nd period (5.531).

The fragmentation of the network during 2005-2016 equals 0.259, the least is allocated to the 3rd period and the most one is related to the 1st period. The diameter metric or the farthest distance of nodes of major component equals 15.

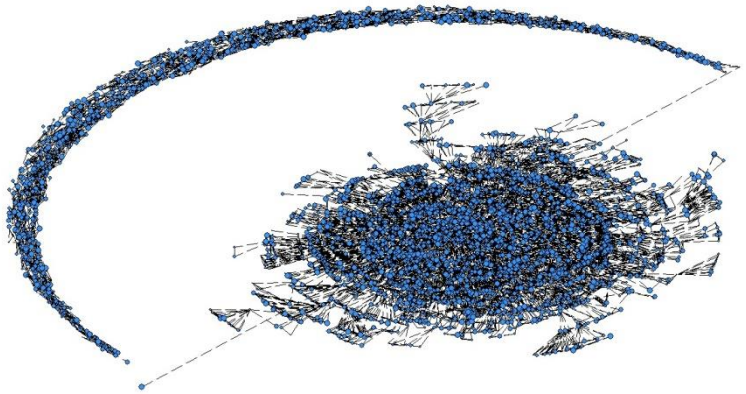
Table 2: The topological structure of the co-authorship network

	2005-2008	**2009-2012**	**2013-2016**	**2005-2016**
Nodes	2682	5978	9977	15833
Ties	16534	41900	78896	134654
Density	0.002	0.001	0.001	0.001
Components	186	319	392	466
Component Ratio	0.070	0.053	0.039	0.029
Number of Nodes in main components	1698	4420	8018	12566
Avg Distance	5.440	5.531	5.497	5.009
Fragmentation	0.591	0.448	0.351	0.259
Diameter	13	15	16	15
Clustering coefficient	0.505	0.515	0.495	0.381
Avg Degree	6.216	7.042	7.663	8.174

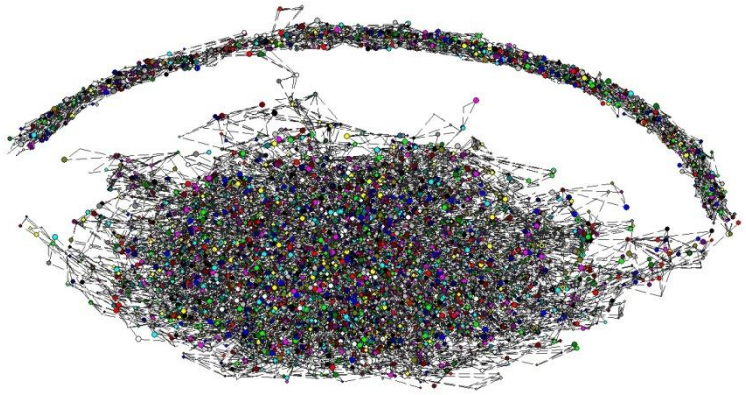
Figure 4 shows the visualization of the co-authorship network for each time interval. As it is visible, number of authors and scientific communication have increased dramatically as time passes.



2005-2008



2009-2012



2013-2016

Figure 4: Co-authorship network of Iran's Pharmacology and Pharmacy research

Table 3 presents "dominance factor", number of the 1st author or corresponding author and also number of single-authored papers of 15 top researchers during 2005-2016 in the field of pharmacy and pharmacology. It is worth mentioning that

dominance factor (DF) is calculated via the formula which is formulated by Kumar and Kumar as the following (Kumar & Kumar, 2008):

DF = [the number of multi-authored articles 1of an author as first author (Nmf)/total number of multi-authored articles (Nmt)]

Moreover, dominance factor (DF) is a sign of collaboration. Generally, DF less than 0.5 signifies a good scientific collaboration (Koseoglu, 2016). As a result, "Mohammadreza Zarrindast" and “Abolghasem Jouyban” are on the first rank, “Hossein Hosseinzadeh” is on the 2nd and “Mehrdad Iranshahi” on the 3rd ranks. In addition, “Ahmadreza Dehpour”, “Mohammad Abdollahi”, “Mohammadreza Zarrindast” have allocated the first to the third ranks of the most prolific authors. Whereas their DF values are respectively 5, 9 and 1. According to the table 3, the most productive researchers of the field have the average level of scientific collaboration. Because the most values of their Df are more than 0.5.

Table 3: Ranking of authors (2005-2016)

Author	Total Article		Single authored	First	First/Corresponding authored	Dominance factor	Rank (DF)	Rank (#Articles)	Corresponding author
	N	%							
Dehpour, Ahmadreza	138	2.22	0	0	79	0.57	5	1	79
Abdollahi, Mohammad	118	1.90	0	1	56	0.47	9	2	55
Zarrindast, Mohammadreza	116	1.85	0	38	116	1.00	1	3	87
Shafiee, Abbas	90	1.45	0	1	25	0.28	13	4	24
Dinarvand, Rassoul	79	1.27	0	2	39	0.49	8	5	37
Kobarfard, Farzad	72	1.16	0	1	27	0.38	10	6	26
Nokhodchi, Ali	73	1.17	0	9	40	0.55	7	7	31
Hosseinzadeh, Hossein	71	1.14	0	21	69	0.97	2	7	48
Jouyban, Abolghasem	71	1.14	4	31	71	1.00	1	12	54
Foroumadi, Alireza	69	1.11	0	7	40	0.58	4	8	33
Valizadeh, Hadi	67	1.07	0	10	37	0.55	6	9	27
Iranshahi, Mehrdad	67	1.07	0	12	43	0.64	3	9	31
Atyabi, Fatemeh	65	1.03	0	5	21	0.32	12	10	16
Varshosaz, Jaleh	60	0.96	1	39	60	1.00	1	11	46
Abnous, Khalil	54	0.87	0	1	19	0.35	11	13	18

The Network of international scientific collaboration of Iran in Pharmacology and Pharmacy

As table 4 shows, the Iranian researchers in the field of pharmacy and pharmacology have the most collaboration with their counterparts in England (2.85%), the U.S.A. (2.61%) and Canada (1.76%).

Table 4: Scientific collaboration of Iran in the field of pharmacy and pharmacology

Row	Country	Article		Row	Country	Article	
		Number	Percent			Number	Percent
1	**Iran**	**6204**	**100**	**11**	**Japan**	**36**	**0.58**
2	**UK**	**177**	**2.85**	**12**	**Sweden**	**34**	**0.55**

3	**USA**	**162**	**2.61**	**13**	**India**	**23**	**0.37**
4	**Canada**	**109**	**1.76**	**14**	**Pakistan**	**22**	**0.35**
5	**Australia**	**82**	**1.32**	**15**	**Spain**	**21**	**0.34**
6	**Germany**	**65**	**1.05**	**16**	**France**	**20**	**0.32**
7	**Italy**	**60**	**0.97**	**17**	**Peoples R China**	**19**	**0.31**
8	**Malaysia**	**59**	**0.95**	**18**	**Syria**	**17**	**0.27**
9	**Netherlands**	**50**	**0.81**	**19**	**Turkey, Austria, Saudi Arabia**	**14**	**0.23**
10	**Switzerland**	**41**	**0.66**	**20**	**New Zealand**	**12**	**0.23**

Figure 5 indicates the visualization of this collaboration for better understanding and more realizing.

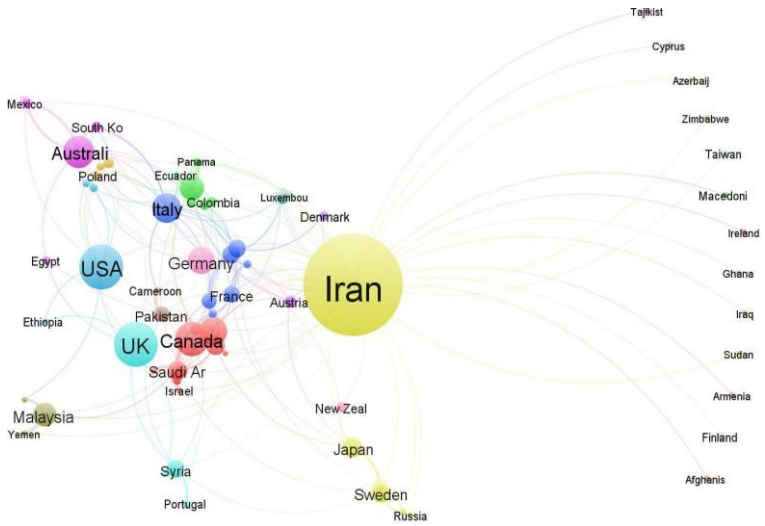


Figure 5: Network of the international scientific collaboration of Iranian researchers

Ratio of Internal Scientific Collaboration in comparison with External Scientific Collaboration

In order to understand the ratio of internal collaboration versus external one, two indicators of INI and NI are needed to be calculated. INI is an indicator to measure

international co-authorship outcome [1]. INI= (number of the international co-authorship papers/all papers) *100

So: INI= 1219/6204*100=19.65

Moreover, NI is an indicator to measure the national co-authorship papers [1]. NI= number of the national co-authorship papers/all papers*100= 80.35

P=80.35/19.65=4.08

During the time interval 2005-2016, of 6204 papers in the field of pharmacy and pharmacology, 1219 papers are considered as the international co-authorship and 4985 papers as the national co-authorship. Therefore, the ratio of both equals 4.08.

Network of the inter-organizational scientific collaboration in the field of pharmacy and pharmacology

As table 5 shows, most of Iranian researchers' affiliation are related to "Tehran University of Medical Sciences" (1651 papers), then respectively to "Islamic Azad University" (917 papers) as well as to "Shahid Beheshti University" (840 papers). On the other hand, the researchers of "Tehran University of Medical Sciences" have allocated more than a quarter of the scientific productions of the field (26.61%), therefore, they have notable and leading roles in the field.

Table 5: Affiliation of the Iranian Researchers in the field of Pharmacy and Pharmacology

Row	Organisation	Article		Row	Organisation	Article	
		Number	Percent			Number	Percent
1	Tehran Univ Med Sci	1651	26.61	11	Pasteur Inst Iran, Mazandaran Univ Med Sci	219	3.53
2	Islamic Azad Univ	917	14.78	12	Iran Univ Med Sci	212	3.42
3	Shahid Beheshti Univ Med Sci	840	13.54	13	Shahid Beheshti Univ	195	3.14
4	Mashhad Univ Med Sci	689	11.11	14	Kerman Univ Med Sci	186	3.00
5	Tabriz Univ Med Sci	637	10.27	15	Baqiyatallah Univ Med Sci	159	2.56
6	Univ Tehran	372	6.00	16	Shahed Univ	144	2.32
7	Isfahan Univ Med Sci	356	5.74	17	Kermanshah Univ Med Sci	135	2.18
8	Shiraz Univ Med Sci	317	5.11	18	Zanjan Univ Med Sci	133	2.14

9	Tarbiat Modares Univ	311	5.01	19	ACECR	126	2.03
10	Ahvaz Jundishapur Univ Med Sci	253	4.08	20	Ferdowsi Univ Mashhad	99	1.60

Furthermore, figure 6 is visualized to present more illustrative perspective of the inter-organizational scientific collaboration of Iran's Pharmacy and Pharmacology research.

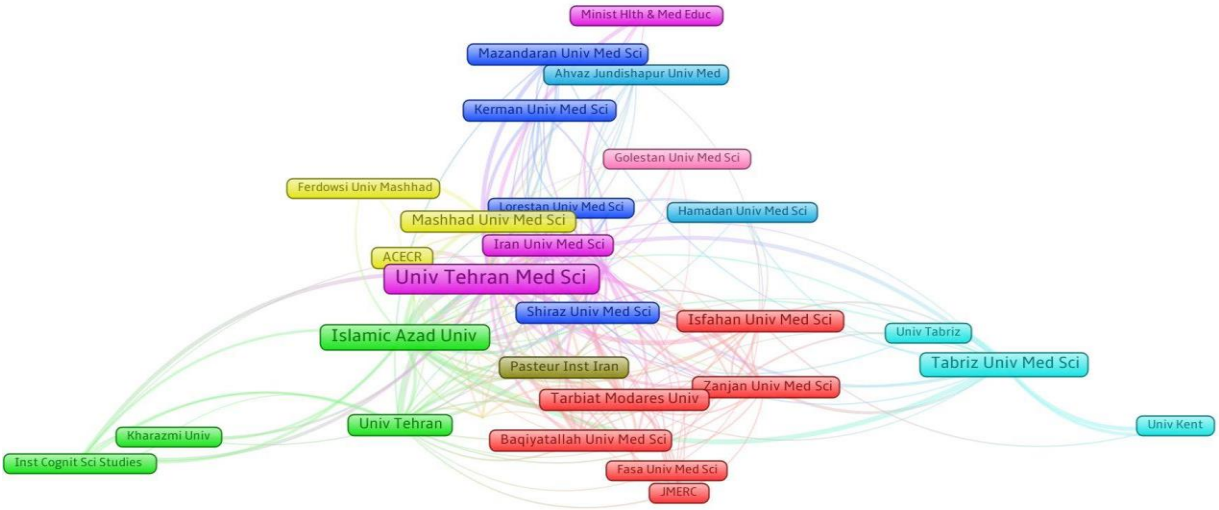


Figure 6: The Network of the inter-organizational scientific collaboration

Table 6 represents top researchers based on the "centrality" measures (degree, betweenness and closeness). "Degree centrality" means that a researcher has scientific collaboration with the other researchers. More collaboration means higher degree of inter-group impact, information flow, exchange and dissemination (Liederbach et al., 2017). Additionally, the metric spotlights researchers who have higher popularity and more scholarly communications (Koseoglu, 2016).

"Closeness centrality" utilizes to calculate the impact of a researcher on the whole network. This metric explains the time of information exchange and information flow from a researcher to the others through a network (Liederbach et al., 2017). on the

other words, it is an alternative scale for communication independence and efficiency (Koseoglu, 2016).

"Betweenness centrality" indicates a researcher's capacity in order to make connections among various available researchers in the network (Acedo et al., 2006). therefore, a researcher who has high "betweenness centrality" is considered as a vital player, an interface and relational bridge through a network to control information flow and make connections (Abbasi et al., 2012; Yin, Kretschmer, Hanneman, & Liu, 2006).

According to table 6, "Ahmadreza Dehpour", "Mohammad Abdollahi", and "Abbas Shafiee", ranked the first to the third respectively in both degree and betweenness centralities. This signifies that mentioned researchers have more influence and impact through the network. Their placements in "closeness centrality" have changed slightly, so that, "Mohammad Abdollahi" ranked the first, "Ahmadreza Dehpour"and "Abbas Shafiee" ranked the 2nd and the third, respectively.

Table 6: Centrality measures of Iranian researchers

Row	Author	Degree Centrality	Normalized Degree	Author	Betweenness Centrality	Normalized Betweenness	Author	Farness	Normalized Closeness
1	Dehpour, Ahmadreza	717.00	0.045	Dehpour, Ahmadreza	41953.363	8.675	Abdollahi, Mohammad	34795620	**0.045**
2	Abdollahi, Mohammad	494.00	0.031	Abdollahi, Mohammad	35343.547	7.308	Dehpour, Ahmadreza	34796032	**0.045**
3	Shafiee, Abbas	440.00	0.028	Shafiee, Abbas	23735.363	4.908	Shafiee, Abbas	34796360	**0.045**
4	Foroumadi, Alireza	321.00	0.020	Kobarfard, Farzad	22777.496	4.710	Atyabi, Fatemeh	34796724	**0.045**
5	Dinarvand, Rassoul	320.00	0.020	Amini, Mohsen	21545.617	4.455	Dinarvand, Rassoul	34796836	**0.045**
6	Zarrindast, Mohammadreza	302.00	0.019	Atyabi, Fatemeh	21155.666	4.374	Amini, Mohsen	34796936	**0.045**
7	Akhondzadeh, Shahin	294.00	0.019	Zarrindast, Mohammadreza	18717.559	3.870	Ghahremani, Mohammadhossein	34797340	**0.045**
8	Atyabi, Fatemeh	285.00	0.018	Dinarvand, Rassoul	18009.234	3.724	Sharifzadeh, Mohammad	34797836	**0.045**
9	Sharifzadeh, Mohammad	272.00	0.017	Iranshahi, Mehrdad	17524.113	3.623	Ostad, Seyednaser	34798620	**0.045**
10	Kobarfard, Farzad	267.00	0.017	Ahmadi, Abbas	14528.468	3.004	Foroumadi, Alireza	34799072	**0.045**
11	Iranshahi, Mehrdad	256.00	0.016	Kamalinezhad, Mohammad	13169.263	2.723	Khoshayand, Mohammadreza	34799204	**0.045**
12	Amini, Mohsen	237.00	0.015	Ghahremani, Mohammadhossein	12841.354	2.655	Rezayat, Seyedmahdi	34799332	**0.045**
13	Ghahremani, Mohammadhosse	232.00	0.015	Ramezani, Mohammad	10824.514	2.238	Hassanzadeh, Gholamreza	34799388	**0.045**
14	Ostad, Seyednaser	231.00	0.015	Foroumadi, Alireza	10497.453	2.171	Faramarzi, Mohammadali	34799420	**0.045**
15	Valizadeh, Hadi	207.00	0.013	Ejtemaeimehr, Shahram	9685.965	8.675	Rouini, Mohammadreza	34799440	**0.045**

Hypothesis Testing

Correlation matrix between variables

Results of the analysis of the correlation matrix between variables of the research is presented in table 7. The Correlation coefficients listed in the table 7 show that the research variables have appropriate correlation as well as significant relationships.

Table 7: Correlation matrix between variables

Variable	NO. of papers	Rank	Closeness	Betweenness
Number of papers	**1**			
Rank	**0.67****	**1**		
Closeness	**-0.37****	**0.37****	**1**	
Betweenness	**0.57****	**0.87****	**0.28****	**1**

**** In 0.05 significance level and * in 0.01 significance level**

Hypothesis 1: There is a significant relationship between "degree centrality" and "numbers of articles".

The Spearman's correlation coefficient is used to test the first hypothesis. The results of the spearman's correlation test indicate that there is a significant and positive relationship between "degree centrality" and "numbers of articles" ($r=0.67$, $p<0.05$). It means that with increasing the "degree centrality", the "numbers of articles" also increases (Table 8).

Table 8: The correlation between centralities and numbers of articles

Variable	The published article		The relationship	Type of the relationship
	The Spearman's correlation coefficient			
	Correlation (r)	P		
Degree centrality	0.67**	0.001	Significant	**positive**
Closeness centrality	-0.37**	0.001	Significant	**inversed**
Betweenness centrality	0.57**	0.001	Significant	**positive**

**** In 0.05 significance level**

Hypothesis 2: There is a significant relationship between "closeness centrality" and "numbers of articles".

The Spearman's correlation coefficient is utilized to test the 2nd hypothesis. The results (Table 8), ($r=-0.37$, $p<0.05$) indicates that there is a negative significant between "closeness centrality" and "numbers of articles". This relationship is inverse; in other words, it signifies that with increasing the "closeness centrality, the "numbers of articles" reduces, and vice versa.

Hypothesis 3: There is a significant relationship between "betweenness centrality" and "numbers of articles".

The results of the Spearman's hypothesis test ($r-0.57$, $p<0.05$) indicate that there is a significant relationship between "betweenness centrality" and "numbers of articles" (Table 8). The relationship is directed; it implies that with increasing the "betweenness centrality", the "numbers of articles" also increases.

5. Discussion and conclusions

The main aim of this study was to investigate, evaluate and visualize the structure and trend of the Iranian scientific collaboration in the field of Pharmacy and Pharmacology. Findings show that the number of multi-authored papers are ascending during these 3 time intervals.

Reduction of the network density in Iran's Pharmacy and Pharmacology research shows that the level of fragmentation in each period has increased based on the "clustering coefficient". It implies that the scientific research among researchers has increased. As a result, increase in production, exchange and dissemination of knowledge will be achieved. This part of findings is in a line with the previous reports (Ardanuy, 2012; Elango & Rajendran, 2012; Fischbach, Putzke, & Schoder, 2011; Koseoglu, 2016; Kumar & Jan, 2013).

Iranian Pharmacy and Pharmacology researchers have the most collaboration with the researchers of England (2.85%), U.S.A. (2.61%) and Canada (1.76%). It confirms that political issues have not had notable effect on the scholarly collaboration and interaction of the mentioned countries. On the other hand, it seems that the Iranian researchers have more trend with researchers from English speaking countries. Most of Iran's scientific collaboration in this field is with countries of North America, Europe and some East Asian countries and little attention has been paid to the scientific cooperation with the Islamic countries and the region. The ratio of internal collaboration in comparison with external collaboration equals 4.08. It confirms that the researchers of the field have not succeeded in interactions with overseas and have focused on internal collaborations. It can be a weakness sign of the researches of this field.

Longitudinal comparison of scientific networks of the same time intervals, can inform us of the social structure and occurring changes and evolutions Nerur, Rasheed, and Natarajan (2008). The Social network analysis (SNA) approach was used to analyze co-authorship evolutions in the field of Pharmacy and Pharmacology during 2005-2016. These years were divided to three time intervals (2005-2008, 2009-2012, and 2013-2016). The comparison showed that in addition to the size increasing of the network, also the scope and closeness of scientific collaboration among researches due to adding new researchers to the network have increased. Furthermore, surveying metrics of the periods indicates interdisciplinary nature of the field. Additionally, a large collection of researchers and a wide range of scientific collaboration, fragile structure as well as low closeness of the network imply low maturity of the researches. Findings of the present study is the same as former research (Koseoglu, 2016; Ye et al., 2013).

The results of the correlation test showed that with increasing the "degree centrality", the "numbers of articles" also increases. In a social network, a researcher who has more direct relationships with others (the high degree centrality) is located in the focus of information flow of the network (Freeman, 2006). These kinds of researchers have more opportunities and alternatives due to more options to select

rather than the other scholars. As a result, they can be independent, take advantage of the structure capital and receive more information, knowledge and resources.

On the other hand, these scholars have prominent positions in the network and also due to more collaborators, have more accessible paths through the network to meet their need. As a result, researchers with high centrality have the utmost access to all resources and published information and are able to retrieve the uttermost information.

Since the high degree centrality of a scholar is effected by the number of researchers who the scholar is collaborated with directly, it will naturally eventuated increasing scientific outputs. These findings confirm the results of previous research conducted in Chemistry (Badar, Hite, & Badir, 2012). Their findings showed that there is a correlation between "degree centrality" and "number of papers" of Pakistan scholars in the field of chemistry.

Direct links have advantages such as knowledge sharing and additional skills (Ahuja, 2000). For example, along a published co-authorship paper, each author added a part of the published knowledge, so each author gains new knowledge through direct interaction and intergroup discussion. Authors with the same knowledge background can obtain benefit around in scientific discussions, because these kinds of comments lead up deep debate (Abbasi & Altmann, 2011). Moreover, authors with complementary knowledge can obtain benefit along sharing their experience and also authors with various knowledge background can take advantage of their proficiency without any investing (Ahuja, 2000). Therefore, new knowledge will be created as a result of combination of various knowledge backgrounds.

Knowledge sharing and creation subsequently may promote papers qualitatively and quantitatively (Abbasi, Chung, & Hossain, 2011; Liao, 2010), so direct links can afford increasing, combination and exchange of knowledge and resources, accompanying scholars with new knowledge and experience simultaneously as well as increasing scientific productions.

The results of correlation test showed that with increasing the "closeness centrality", the "numbers of articles" reduces, and vice versa. The "closeness

centrality" means that a researcher can be connected to the other scholars throughout some paths (Otte & Rousseau, 2002) and indicates average of distance between them (Lu & Feng, 2009).

Occupying a central location in a co-authorship network, although gives the researcher a strategic importance in terms of close proximity, but it does not necessarily increase his/her research outcomes. Therefore, a scholar who does not have direct co-authorship but the closeness centrality (the shortest path) and access to the other scholars, may conclude exchange of superfluous knowledge and have a negative impact on his scientific outputs.

The results of the correlation test indicate that with increasing the "betweenness centrality", the "numbers of articles" also increases. These findings are in a line with the previous reports (Abbasi et al., 2012; Li et al., 2013). Additionally, it signifies that eliminating structural holes in a co-authorship network is very necessary. In other words, the acquisition of non-repetitive resources from other research groups is more important than the acquisition of the resources required from immediate colleagues, since it has a competitive advantage from a source-based perspective.

According to the findings, it is suggested that research organizations should support research activities. This kind of academic performance is needed co-authorship with the other researchers from the other organizations, centers or even other majors. More scores on research assessment or more research budget are offered for co-authorship studying. Founders with limited budgets can start with little financial support for launching internal research projects, and based on the research performance of the team, gradually add to these financial contributions.

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