ORIGINAL ARTICLE

Study of co-authorship network of papers in the Journal of Research in Medical Sciences using social network analysis

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Background: Co-authorship is one of the most tangible forms of research collaboration. A co-authorship network is a social network in which the authors through participation in one or more publication through an indirect path have linked to each other. The present research using the social network analysis studied co-authorship network of 681 articles published in Journal of Research in Medical Sciences (JRMS) during 2008-2012. **Materials and Methods:** The study was carried out with the scientometrics approach and using co-authorship network analysis of authors. The topology of the co-authorship network of 681 published articles in JRMS between 2008 and 2012 was analyzed using macro-level metrics indicators of network analysis such as density, clustering coefficient, components and mean distance. In addition, in order to evaluate the performance of each authors and countries in the network, the micro-level indicators such as degree centrality, closeness centrality and betweenness centrality as well as productivity index were used. The UCINET and NetDraw softwares were used to draw and analyze the co-authorship network of the papers. **Results:** The assessment of the authors productivity in this journal showed that the first ranks were belonged to only five authors, respectively. Furthermore, analysis of the co-authorship of the authors in the network demonstrated that in the betweenness centrality index, three authors of them had the good position in the network. They can be considered as the network leaders able to control the flow of information in the network compared with the other members based on the shortest paths. On the other hand, the key role of the network according to the productivity and centrality indexes was belonged to Iran, Malaysia and United States of America. **Conclusion:** Co-authorship network of JRMS has the characteristics of a small world network. In addition, the theory of 6° separation is valid in this network was also true.

Key words: Centrality, density, Journal of Research in Medical Sciences, mean distance, social network analysis

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INTRODUCTION

Now-a-days, talking about the research activities is associated with some issues such as extremely specialized sciences, high speed of technological changes, the dynamicity nature of the knowledge, decrease of the research budgets and appearing the interdisciplinary and cross-disciplinary areas. Thinking about these subjects figure out that these days, one person cannot be expert in all the sciences and techniques like the past and not be able to track the path of knowledge and research lonely. Today, authors interaction is recognized as the basis of the research practice.[1] Acedo *et al*. with pointing to the rare academic papers with more than one author in the first half of the twentieth century, mentioned the increasing desire to the co-authorship in scientific publications in recent decades.[2] In fact, co-authorship is one of the most tangible forms of research collaboration.[3] Multiplicity and diversity of group writings in a field led to the formation of a common authorship or co-authorship network, which has many similarities with the scientific community and knowledge structure in the academic environments in point of view of[4] and in this network, the authors as the correlated entities form the global system of knowledge production. A co-authorship network is a social network in which the authors through participation in one or more publication through an indirect path have linked to each other. In a co-authorship network, the authors are the nodes of the network and their links are the number of their common writings which are connected by a line. Co-authorship networks are the best bibliometric indicators to illustrate different patterns of co-authorship of academic disciplines,[5] which can examine the characteristic of this network using various measures of social network analysis (SNA). SNA is a sociologic approach to analyze the relationships and interactions

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patterns of social factors such as central nodes that act as hubs, leaders or gatekeepers; the groups that are highly interconnected; and interaction patterns between groups[6] is to discover their basic social structure. As yet, many studies were carried out on the co-authorship network using SNA measures in different subject areas. Some instances of these types are: Some researches in nanotechnology,[7] the study of co-authorship network of Iran University of Medical Sciences,[8] the area of Iranian Emergency Medicine[9] and the visualizing of the co-authorship network of the Journal of Scientometrics.[10] Such studies, besides visualizing the social structure of the scientific interactions can consider as a tool for self-evaluation of journals.[11]

Thus, the present study, using SNA measures, aimed to observe the co-authorship network of authors that published their articles in Journal of Research in Medical Sciences (JRMS). Hence, the published articles in this journal between 2008 and 2012 were examined in order to fulfill the following objectives:

- Visualizing and analyzing the co-authorship network of the authors of JRMS using macro-level metrics;
- Investigating the performance of authors based on the productivity and centrality measures;
- Investigating the performance of countries based on the productivity and centrality measures.

MATERIALS AND METHODS

This research was a scientometrics study that used the co-authorship network analysis method and SNA measures. The study population consisted of 681 published articles in JRMS between 2008 and 2012. The data collection was done by referring to Web of Science database[12] and looking for the journal title of "Research in Medical Sciences"; 681 records were retrieved and loaded as the plain text format on a computer system. The first-step to draw the co-authorship network of authors and countries was constructing their co-authorship matrix. Coauth.exe and Intcoll.exe softwares were used to provide co-authorship and countries co-authorship matrix, respectively. Then in the second step, UCINET software version 6.421[13] and NetDraw[14] were used to assess the co-authorship network of the articles.

In this study, co-authorship network of JRMS' papers were investigated at the macro and micro levels. Macro-level metrics of SNA assesses the topology and the possible performance of the social structure, performance of authors as well as overall characteristics of the networks. Among the existed criteria for the network analysis at the macro level, we assessed density, clustering coefficient, network components and mean distance. Proportion of the number of links in the network to the possible links shows the density measure and is always a value between zero and one. Density measures the degree of the nodes cohesion; closer to one represents more cohesive network and closer to zero indicates the less coherence of the network. Clustering coefficient index specifies the ratio of the numbers of links around a node and possible links in the network. This index also possesses a value between zero and one. The values close to one represent the high rates of relationships with the colleagues, as well as within colleagues, themselves. The values close to zero indicate that the nodes only connect the colleagues.[15] Network components measure is defined as a set of nodes where each node via a straight link or a series of links connected to the other node. In other words, all the nodes constituted a component are connected to each other either directly (through co-authorship) or indirectly (through a series of co-authorship).[16,17] Network mean distance is also measured based on the longest path distance in the network to the shortest one between any two nodes (in terms of a number of links or connections). The smaller network mean distance will be associated with the faster communications and higher data disseminations.[1]

In addition to the overall analyzing of the co-authorship network of articles by using macro-level metrics, the performance of each node in the network was evaluated using micro-level metrics. Centrality which is one of the classic measures of SNA at the micro-level deals with the individuals importance and effectiveness in the network. Network nodes centrality can be assessed using three measures of degree centrality, betweenness centrality and closeness centrality. In a social network, degree centrality of a node represents the number of the node connections with the other constituent nodes of the network. In other words, in a co-authorship network, degree centrality of any individual represents the number of his/her co-authorship with the other persons in the network. A betweenness centrality index indicates the number of the times that a node will be located between any two other nodes in the network in the shortest path. The nodes with a high betweenness centrality play an important role in connecting the network and the information flow in it; they also have a central position in the network. Closeness centrality index of a node represents the average length of the shortest paths between the node and other nodes in the network. The nodes with high closeness centrality make more impression in the network and play more centrally role and have more accessibility for other nodes.[18]

RESULTS

First of all, JRMS authors co-authorship network in the micro and macro levels was analyzed. Co-authorship network of authors involved links and nodes. Each node

represents an author and the links between two nodes specifies co-authorship between the two authors. Authors co-authorship network of JRMS consisted of 98 authors (nodes) and 510 co-authorships (links) [Figure 1]. Density of this network was 0.0806; this means that only 8.06% of the total potential relationships in the network have been actualized. The network clustering coefficient was equal to 0.807 (80.7%); it means that if A and B have co-authorship with C separately, about 80.7% A and B is possible that will have a co-authored together in the near future. Authors co-authorship network of JRMS is composed of seven components. The main component of this network includes 91 authors (nodes) and 508 co-authorships (link) that constitutes 92% of co-authorship network and conform the overall structure of the network [Figure 1] and is very similar to it. The mean distance of JRMS co-authorship network of authors was four. Accordingly, we can say that the mean distance between two nodes in the network was only four nodes and two authors of JRMS in this network can be connected through four intermediates or another authors of JRMS.

Micro-level metrics point to the centrality, which is one of the most important and common measures used in NSA. Centrality measure gives useful information to evaluate the authors performance according to their performances and roles in the network.[17] Three common centrality measures named degree centrality, closeness centrality and betweenness centrality were applied to analyze co-authorship network of authors in JRMS at the micro level. Based on the measure of degree centrality, five authors had the highest co-authorship with other authors. According to betweenness centrality measure, three of those five authors were in a good position in the network; and the possibility of being in the shortest path between two other authors is likely to be much. They also played an important role in controlling the distribution of information in the network. Related to the closeness centrality index, three of those five authors had the minimum distance to other network nodes. The high index of closeness centrality of them represents their effectiveness, centrality and key role in the distribution and circulation of information between other nodes in the network. Considering all the three measures, it can be apprehended that the three last mentioned authors had the greatest impact on the co-authorship network of the authors in JRMS.

In order to assess the international co-authorship of the countries participated in publishing articles in JRMS; co-authorship network of countries was visualized by UCINET and NetDraw softwares. JRMS co-authorship network of countries is consisted of 29 countries (nodes) and 42 co-authorships (link) [Figure 2]. The network density was 0.3892, i.e., 38.92% of all the potential relationships in the network have been actualized. The network clustering coefficient was equal to 0.807 (80.7%); it means that if two authors of countries A and B have co-authorship with the author of country C separately, about 80.7% is possible that the authors of countries A and B will have a co-authored together in the near future. Co-authorship network of countries in JRMS is made of eleven components. The main component of the network includes 18 countries (nodes) and 40 co-authorships (link) that constitutes 62% of co-authorship network. The mean distance of JRMS co-authorship network of countries was 4. Accordingly, we can say that the mean distance between two nodes in the network was only 4 nodes and two countries in this network can be connected through four intermediates.

In order to evaluate the performance of the participating countries in producing papers of JRMS, centrality measures (degree centrality, closeness centrality and betweenness centrality) was used. Based on the degree centrality Iran (142), USA (38) and Australia (37) have the highest co-authorship with other countries. According

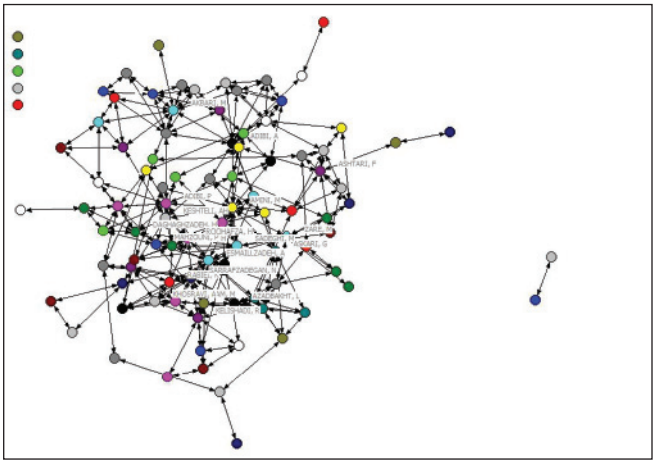

Figure 1: Co-authorship network of authors

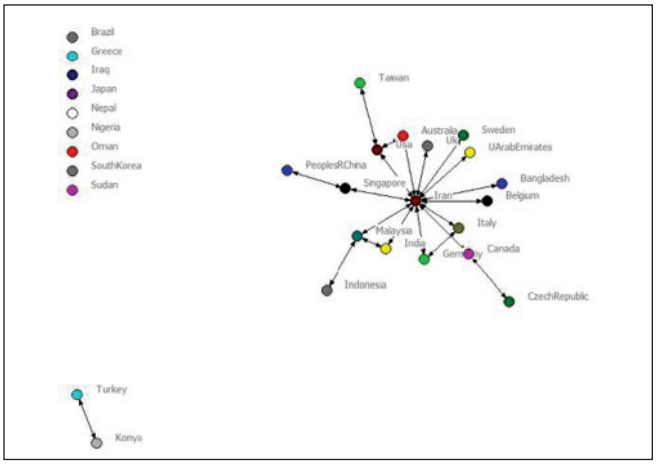

Figure 2: Co-authorship network of countries

to the betweenness centrality, Iran (127), Malaysia (16), USA (16), Canada (16) and Singapore (16) were in a good position in the network and the possibility of being in the shortest path between the two countries is likely to be much; also they play an important role in controlling the distribution of information in this network. According to the closeness centrality measure, Iran (8.235), Malaysia (7.932) and USA (7.932) have the shortest distance to the other nodes of the network. The high closeness centrality index of them represents their effectiveness and key role in the distribution of information between other nodes in the network (Table 1).

DISCUSSION

The present study have examined co-authorship network of the authors in JRMS. A total of 681 articles published in the journal during the years 2008-2012 were reviewed. SNA of the journal using macro and micro-level metrics by UCINET network analysis software showed that co-authorship network of authors is consisted of a total of 98 authors (nodes) through 510 co-authorships. Although the clustering coefficient of the journal network was 0.807, indicating a relatively high willingness to cooperate with other members of the network and form the multiple clusters, but a low density network (8.06%) showed the low cohesion of the network and inconsistency between the authors; so that only 8.06% of the total potential relationships in the network has been actualized.

Assessment of the components constituted co-authorship network of the authors of JRMS demonstrated that the network consists of seven components. The main component of the network includes 91 authors (nodes) and 508 co-authorships (link), which constitutes 92% of co-authorship network. Newman besides the study of the co-authorship network of the various research areas stated that 82-92% of the total nodes forming a network placed in the main component.[16] Kretschmer also declared that the most productive authors are usually in the main component of the network and have less distance to other authors in comparison to the less creative authors.[19] However, many pairs of authors due to the lack of connection with the rest of the network have been separated.

The mean distance of the co-authorship network of the authors in JRMS was 4. Accordingly, it can be said that the mean distance between two nodes in the network was only 4 nodes and the two authors in the network can be connected through four intermediates. This number was lower than that was expected from a "small world" network. One of the main features of the small world is "6° separation" phenomenon, which asserts that each two human beings on the planet by the approximately six intermediates are related to each other.[20] In other words, the information will disseminate more easily for effective co-authorship in the network, because the mean distance in the network was less than optimal number (4 instead of 6).

Individual performance of each author contributed in the co-authorship network of JRMS also examined using productivity and centrality measures. Azadbakht (17), Amini (14) and Kelishadi (14) allocated in the first ranking of productivity index. In the degree centrality index, Sarrafzadegan, Kelishadi, Amini, Esmaillzadeh and Adibi had the highest co-authorship with other authors. They are active authors in the network and use various ways to meet their academic and research needs; therefore they may be less dependent on other people.[21] According to the betweenness centrality, Amini, Esmaillzadeh and Adibi had a good position in the network and were likely to be in the shortest path between two other authors. They also play an important role in controlling the flow of information in the network. Based on the closeness centrality measure, Amini, Esmaillzadeh and Adibi had the minimal distance to the other nodes of the network. Their high closeness centrality index of them represented their effectiveness, central and key role in the distribution of information between other nodes in the network.

Table 1: Top 10 countries in centrality and productivity

Rank	Papers		Degree centrality		Betweenness centrality		Closeness centrality	
	Country	Frequency	Country	Frequency	Country	Frequency	Country	Frequency
1	Iran	579	Iran	142	Iran	127	Iran	8.235
2	India	31	USA	38	Malaysia	16	Malaysia	7.932
3	Turkey	29	Australia	37	USA	16	USA	7.932
4	USA	12	Germany	34	Canada	16	India	7.910
5	Peoples R. China	10	UK	13	Singapore	16	Canada	7.910
6	Canada	6	Canada	11	Others countries	0	Singapore	7.910
7	England	5	Singapore	8	–	–	Australia	7.910
8	Germany	5	Malaysia	7	–	–	Italy	7.887
9	Italy	5	Sweden	5	–	–	Germany	7.887
10	Australia and Nigeria	4	Czech Republic	4	–	–	Belgium	7.865

In order to assess the international co-authorship of the countries participated in publishing papers in JRMS; co-authorship network of countries was drawn by UCINET and NetDraw softwares. JRMS co-authorship network of countries is consisted of 29 countries (nodes) and 42 co-authorships (link). The network clustering coefficient of the network was equal to 0.807 (80.7%); indicating a relatively high tendency to cooperate with other members of the network and form the multiple clusters. The density of the co-authorship network of countries was 0.3892 that showed moderate low cohesion of the network as only 38.92% of all the potential relationships in the network have been actualized. Co-authorship network of countries in JRMS is made of eleven components. The main component of the network included 18 countries (nodes) and 40 co-authorships (link) that constitutes 62% of co-authorship network. The mean distance of co-authorship network of countries was four. Accordingly, we can say that the mean distance between two nodes in the network was only four nodes and two countries in the network can be connected through four intermediates.

In order to assess the performance of the participating countries produced papers in JRMS, centrality measures (degree centrality, closeness centrality and betweenness centrality) were used. Iran (579), India (31) and Turkey (29) were in the first rankings based on the productivity index of published articles in JRMS. According to the degree centrality, Iran, USA and Australia had the highest co-authorship with other countries. According to the betweenness centrality, Iran, Malaysia, USA, Canada and Singapore were in a good position in the network and they played an important role in controlling the flow of information in the network. According to the closeness centrality measure, Iran, Malaysia and USA had the shortest distance to the other nodes of the network. The high index of closeness centrality of them represents their effectiveness and key role in the distribution of information between other nodes in the network.

CONCLUSION

The co-authorship network of authors in JRMS showed the authors willing to co-operate with other members of the network, but there is low cohesion of the network and inconsistency between the authors; so that only 8.06% of the total potential relationships in the network have been actualized. The co-authorship network of countries also was showed a relatively high tendency to co-operate with other countries of the network, but there is moderate low cohesion of the network as only 38.92% of all the potential relationships in the network have been actualized. It must be mentioned that only a few authors and countries have an important role in controlling the flow of information in this network.

Each two authors in this network can be connected through only four intermediates that are lower than that was expected from a "small world" network and "6° separation" phenomenon which asserts that each two human beings on the planet by the approximately six intermediates are related to each other.[20] In other words, the dissemination and distribution of information in studied network is more easily and faster.

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