REVIEW ARTICLE

Contribution of Iranian researchers in Alzheimer's disease research: A 10 years scientometric analysis

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Abstract
Background Alzheimer's disease is the most common form of dementia and is a rising issue for global health. Iran is struggling with a growing number of the elderly population and also a decrease in fertility rate. The goal of this study was to review and evaluate Alzheimer's disease publications by Iranian researchers.
Methods We searched for Alzheimer and all its related keywords in the *Web of Science* to find related documents published by Iranian researchers from 2010 until 2019. Bibliometric parameters at the level of documents, authors, and organizations were assessed. The co-authorship matrix was computed using *Bibexcel*, and visualizations were performed by *VOSviewer*.
Results Totally, 1042 documents from 4949 researchers (8.6 authors per document) were retrieved from *Web of Science*. Original articles (77.06%) and reviews (16.21%) were the most common document types for Iranian publications and also one article was retracted. As results, the average citation per document was 20.68. Iranian researchers mainly collaborated with researchers from the United States, Italy, Australia, and Canada, respectively. The co-occurrence networks for keywords represented five publication clusters in the collection. The largest cluster was related to studies on oxidative stress in Alzheimer's Disease, followed by in-vivo studies in the field of brain neurons destruction.
Conclusion We found that Iranian researchers made significant impacts in the field of Alzheimer's disease and covered a wide range of related areas over the last 10 years.

Keywords Tauopathy · Dementia · Alzheimer · Scientometrics · Bibliometrics · Publications

Introduction

Alzheimer's disease (AD) was first characterized by *Alois Alzheimer* in 1906 and today we consider it as the most common progressive neurodegenerative disorder in elderly population, responsible for 75% of all dementia cases [1]. Aging,

family history, and genetic factors (carrying the APOE-e4 gene) are the main risk factors of this disease [2, 3]. Nearly all individuals diagnosed with AD, experience neuropsychiatric symptoms (NPS) with different degrees. NPS can vary from intellectual and personality disorder, depression, and apathy which can be observed in the early stage of AD

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to more complicated symptoms such as delusions, hallucinations, and aggression that tends to have a later onset as the disease progresses [1, 4].

The percentage of individuals with dementia and related disorders such as AD, increases significantly as the population age grows and this increase in the number of AD cases is even more concerning given that there is currently no effective disease-modifying cure or treatment for the disease [5, 6]. AD can seriously affect the quality of life and impose a great financial and clinical burden on the healthcare system [7, 8]. Recent research estimate that the number of AD will increase worldwide from 35 million in 2015 to almost 107 million in 2050 [9, 10].

Ascending growth of the elderly population and also an unprecedentedly decrease in fertility rate has became an issue to the Iran's healthcare system [11, 12]. Recent research indicates that more than 500,000 individuals with dementia are living in Iran, which is higher than the estimates stated by the global burden of disease study in 2013 [6]. Iranian researchers expected that 8–10% of the elderly community in Iran will be affected by AD over the future decades [10]. As research in different areas of AD (such as Epidemiology, Neurology and Pharmacology) advances expeditiously, it is important to keep abreast with the outputs and capture the trends of AD research.

The significant volume of medical information publish in scientific journals require to be stored and organized into bibliographic databases such as *Scopus* and *Web of Science* (*WoS*). The information contained on these databases (such as citation distribution, keywords, journals, etc.) provides a useful sample for researchers to carry out "science evaluation research" by using scientometric approach. Deficiencies and strengths of scientific outputs in a particular subject can be pursued via scientometric methods that quantify and evaluate research activities in the scholarly communication framework [13]. Hence, scientometrics has become an essential tool for assessing scientific productions in different levels [14].

Additionally, Network Analysis has emerged as a useful approach for the assessment of scientific productions by analyzing different sorts of networks, such as co-authorship networks and co-occurrence networks. This technique can be useful for learning networking trends and may serve as an effective tool for planning future research collaborations in the field of medical sciences [15, 16].

The present scientometric evaluation with the purpose of exploring Iran's research activities on AD can help researchers and policymakers to identify gaps and strengths of the current research projects in order to plan future research strategies and also, to identify prolific individuals and institutions. By identifying the mentioned factors, research on AD will be organized and moving toward controlling the disease could be more fluent.

Methods

Data Source & Inclusion Criteria

In the current investigation, the *WoS* database was considered as the data source to retrieve reliable data. *WoS* is known as the most accurate source for scientific assessment with the highest quality indexing [17]. The search process was performed on 28 August 2020. Our search strategy contained Alzheimer and all its related keywords which were selected from *Medical Subject Heading (MeSH)* and other similar research. The search strategy was limited to studies performed during 2010–2019 with at least one author affiliated to Iranian organizations to retrieve all documents from *WoS* developed by Iranian researchers in the field of AD during the last decade. The following is the query that we used for our search:

TS = ("Alzheimer Disease" OR "Alzheimer's Disease" OR "Alzheimer Syndrome" OR "Alzheimer Dementia" OR "Senile Dementia" OR "Presenile Dementia" OR "Alzheimer Type Dementia" OR "Dementia Due To Alzheimer" OR "Primary Senile Degenerative Dementia" OR "Alzheimer Sclerosis") AND CU = Iran*
Indexes = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, Timespan = 2010–2019
TS: Topic, CU: Country, SCI-EXPANDED: Science Citation Index Expanded, SSCI: Social Sciences Citation Index, A&HCI: Art and Humanities Citation Index, CPCI-S: Conference Proceedings Citation Index-Science, CPCI-SSH: Conference Proceedings Citation Index-Social Science Edition, ESCI: Emerging Sources Citation Index.

Bibliometric parameters

Threre are various scientometrics methods to analyze bibliographic datasets such as co-citation analysis, bibliographic coupling analysis, co-authorship networks analysis, and keywords co-occurrence analysis [18–21]. Based on the purpose of our study, the co-authorship networks for Iranian researchers at three different levels (authors collaboration, organizational collaboration, and countries collaboration) were analyzed and also, the co-occurance network for keywords were assessed and visualized. We evaluated the bibliometric indicators at the level of documents (number of documents, document type, number of citations, highly cited documents, average citation and h-index), authors (number of authors, average author per document, the most prolific authors according to number of papers and received citations), journals (the most

prolific journals), and organizations (the most prolific organizations).

Networks visualization

During recent years, different software were used for information visualization in bibliometrics and scientometrics, such as *BibExcel*, *CiteSpace*, *VOSviewer*, *HistCite,* etc. In this study, *VOSviewer v1.6.15* software was used to analyze the co-occurrence network for keywords. Also, we visualized the co-authorship network for authors, organizations and countries which contributed in at least 5 documents. *VOSviewer* is a free software that can draw scientometric networks at different levels of countries, organizations, journals, researchers, and individual publications by using bibliometric data. Also, the text mining feature of this software has made it possible to visualize the co-occurrence network for keywords. *VOSviewer* has been formulated in the *Java programming language*. Because *Java* is platform-independent, *VOSviewer* is able to run on most of the operating systems. Although *VOSviewer* is primarily used to analyzing bibliometric networks, it can indeed be used to create, visualize, and explore maps based on any other sorts of network data [22].

With the purpose of constructing the co-occurrence network, keywords from different documents were first integrated in terms of various forms of writing and then keywords that appeard in at least 5 documents were extracted. The co-occurrence network was constructed for extracted keywords. To better clarify the network, general words seen in most studies, such as demographic characteristics (male, female, elderly, adult, etc.) and study designs (case report, systematic review, cross-sectional study, etc.) were removed from the keyword network.

In order to determine the co-authorship network, the co-authorship matrix for authors was calculated by *Bibexcel V2016-02–20* software and the *VOSviewer* was used to visualize the network. *Bibexcel* is a versatile bibliometric toolbox that makes most types of bibliometric assessments possible. *Bibexcel* is a flexible program and provides easy interaction with other software, such as *Microsoft Excel*, *Pajek*, and *SPSS* [23].

Results

We found 1042 documents published by the contribution of 4949 independent Iranian authors in the field of AD in the journals indexed in WoS database during 2010–2019 and globally, Iran ranked 20th in the *WoS,* in terms of the frequency of publications. As shown in Table 1, original articles and reviews, accounting for 803 (77.1%) and 169 (16.2%) of the publications, respectively, were the most

Table 1 Characteristics of AD research by Iranian researchers indexed in WoS

Description	Finding
Document Type	
Original Articles	803 (77.06%)
Review	169 (16.21%)
Meeting Abstract	30 (2.87%)
Proceedings Paper	19 (1.82%)
Letter	10 (0.96%)
Editorial Material	7 (0.67%)
Correction	3 (0.28%)
Retracted	1 (0.09%)
Total	**1042**
Authors	
Total Authors	4949
Avg. Authors per Document	8.6
Citation	
Total Citations	21549
Avg. Citations per Documents	20.68
H-index	50

common form of publications. The rest of the documents were published in the form of meeting abstract, proceedings paper, letter, editorial material, correction, and also one article was retracted. Time trend analysis of the frequency of publications and received citations on AD by Iranian researchers demonstrated an ascending growth in the number of publications and citations during the study period (Figs. 1 and 2).

In total, AD studies by Iranian researchers received 21549 citations in the *WoS*. The average citations per document in this collection was 20.7 and the h-index was 50. Table 2 indicates the top ten most frequently cited documents, along with the number of citations and their document type. Despite the fact that original articles were the most dominant form of publications, reviews on *Global Burden of Disease* Studies were the top-cited articles over the last 10 years.

Iranian researchers had the most scientific collaboration on AD with the researchers from the United States by 100 (9.6%), Italy by 41(3.9%), Australia by 39 (3.7%) and Canada by 39 (3.7%) (Fig. 3).

The organizational analysis of AD research by Iranian researchers demonstrated that *Tehran University of Medical Sciences* was the pioneer organization with 286 records (27.4%) followed by *Shahid Beheshti University of Medical Sciences* with 183 records (17.5%) and *Islamic Azad University* with 123 (11.8%). Figure 4 illustrates the collaboration network of organizations in AD studies.

The authorship distribution pattern indicated that the average number of authors per document was 8.6. Overall, 617 (59.2%) documents were published in small groups of

Fig. 1 Frequency of publications by Iranian researchers in the field of AD by the year of publication (2010–2019)
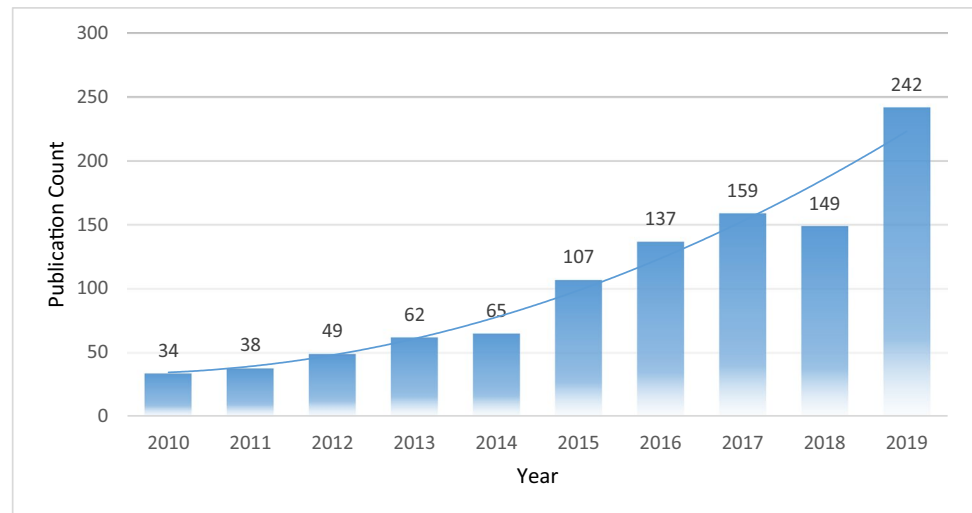
Fig. 2 Total ciatations of Iranian documents in the field of AD per year (2010–2019)
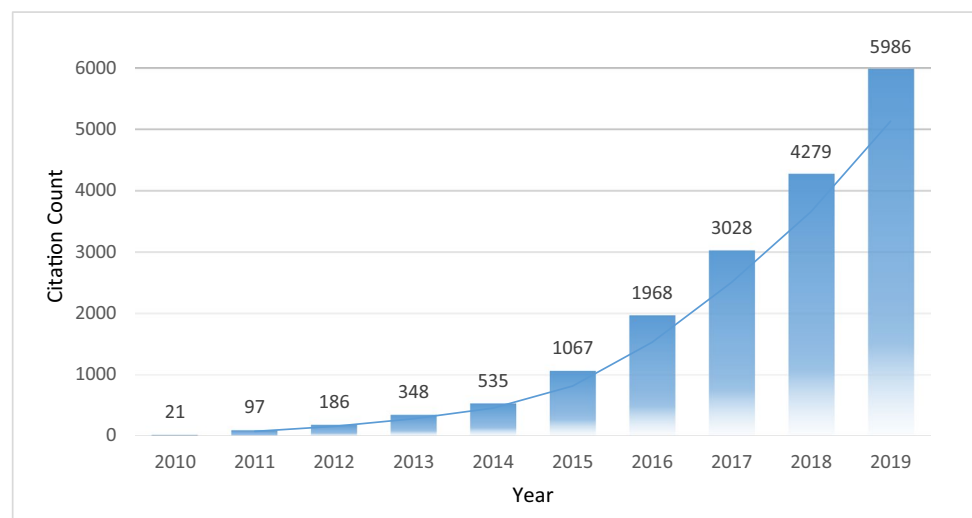
1 to 5 authors, 360 (34.6%) in groups with 6 to 10 authors, and 65 (6.2%) in groups with more than 10 authors. Among Iranian authors, *Khodagholi F.* with 57 (5.4%), *Foroumadi A.* with 48(4.6%), and *Nadri H.* with 45 (4.3%) documents were the most prolific authors and *Mahdavi M.* with 2043, *Foroumadi A.* with 1069, and *Khodagholi F.* with 1068 citations were the highly cited authors in the field of AD over the last decade. Table 3 presents Iranian top 10 researchers with the highest number of documents and citations and Fig. 5 shows the co-authorship network of the documents.

A review on journals indexed in *WoS* showed that among the journals hosting publications related to AD by Iranian researchers, *European Journal of Medicinal Chemistry* published the most significant number of documents 23 (2.2%). Table 4 shows a list of ten journals with the highest number of documents related to AD along with the subject area, their subject quartile, and the number of citations received from AD related documents.

Analyzing time trend of changes in keywords shows no significant alterations during the last decade. Figure 6 illustrated the time trend of changes in keywords during 2010–2019 and their number of occurrences during different years. The co-occurrence network for keywords consisted of five different intertwined clusters of keywords (Fig. 7). The dominant topics of each were:

Cluster 1 (Red): With 35 keywords such as "Antioxidant activity", "flavonoids", "mitochondrial dysfunction", and "Neuroinflammation", represented studies on anti-oxidant effect and oxidative stress in AD (Neurology).

Cluster 2 (Green): With 31 keywords such as "caspase-3", "signaling pathways", "hippocampus", "autophagy" represented in-vivo studies in the field of neurons destruction in AD (Neurobiology).

Cluster 3 (Blue): With 30 keywords such as "cognitive impairment", "dementia", "Alzheimer's disease", "risk

Table 2 Iranian authors top 10 cited publications in WoS in the field of AD

Rank	Authors	Title	Source title	Q	Cited by	Document type
1	Naghavi et al. (2015)	Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013	The Lancet	1	3764	Review
2	Wang et al. (2016)	Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015	The Lancet	1	2290	Review
3	Vos et al. (2017)	Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016	The Lancet	1	1422	Review
4	Feigin et al. (2017)	Global, regional, and national burden of neurological disorders during 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015	The Lancet Neurology	1	507	Review
5	Ahmadlou et al. (2010)	New diagnostic EEG markers of the Alzheimer's disease using visibility graph	Journal of Neural Transmission	2	186	Original Article
6	Akbari et. Al (2016)	Effect of probiotic supplementation on cognitive function and metabolic status in Alzheimer's disease: A randomized, double-blind and controlled trial	Frontiers in Aging Neuroscience	1	169	Original Article
7	Nichols et al. (2019)	Global, regional, and national burden of Alzheimer's disease and other dementias, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016	The Lancet Neurology	1	160	Review
8	Sadigh-Eteghad et al. (2015)	Amyloid-Beta: A crucial factor in Alzheimer's disease	Medical Principles and Practice	3	144	Review
9	Ghasemi et al. (2013)	Brain Insulin Dysregulation: Implication for neurological and neuropsychiatric disorders	Molecular Neurobiology	1	138	Review
10	Maqbool et al. (2016)	Review of endocrine disorders associated with environmental toxicants and possible involved mechanisms	Life Science	2	136	Review

Q: WoS Subject Area Quartile (2019)

factors", represented research on effective factors (such as elderly) and outcomes of AD (Epidemiology).

Cluster 4 (Yellow): With 28 keywords such as "acetylcholinesterase inhibitors", "binding", "docking", mostly represented studies on drug effects and synapse function in AD patients (Pharmacology).

Cluster 5 (Purple): The smallest network cluster, with 26 keywords, including "expression", "protein", "amyloid beta", "precursor protein", represented research on AD biomarkers, amyloid plaques effects, protein production, and neurons destruction in AD patients (Pathophysiology).

The year average of keywords appearance in AD research by Iranian researchers during 2010–2019 indicated that AD research subjects has changed from Epidemiological research in early years of the decade toward
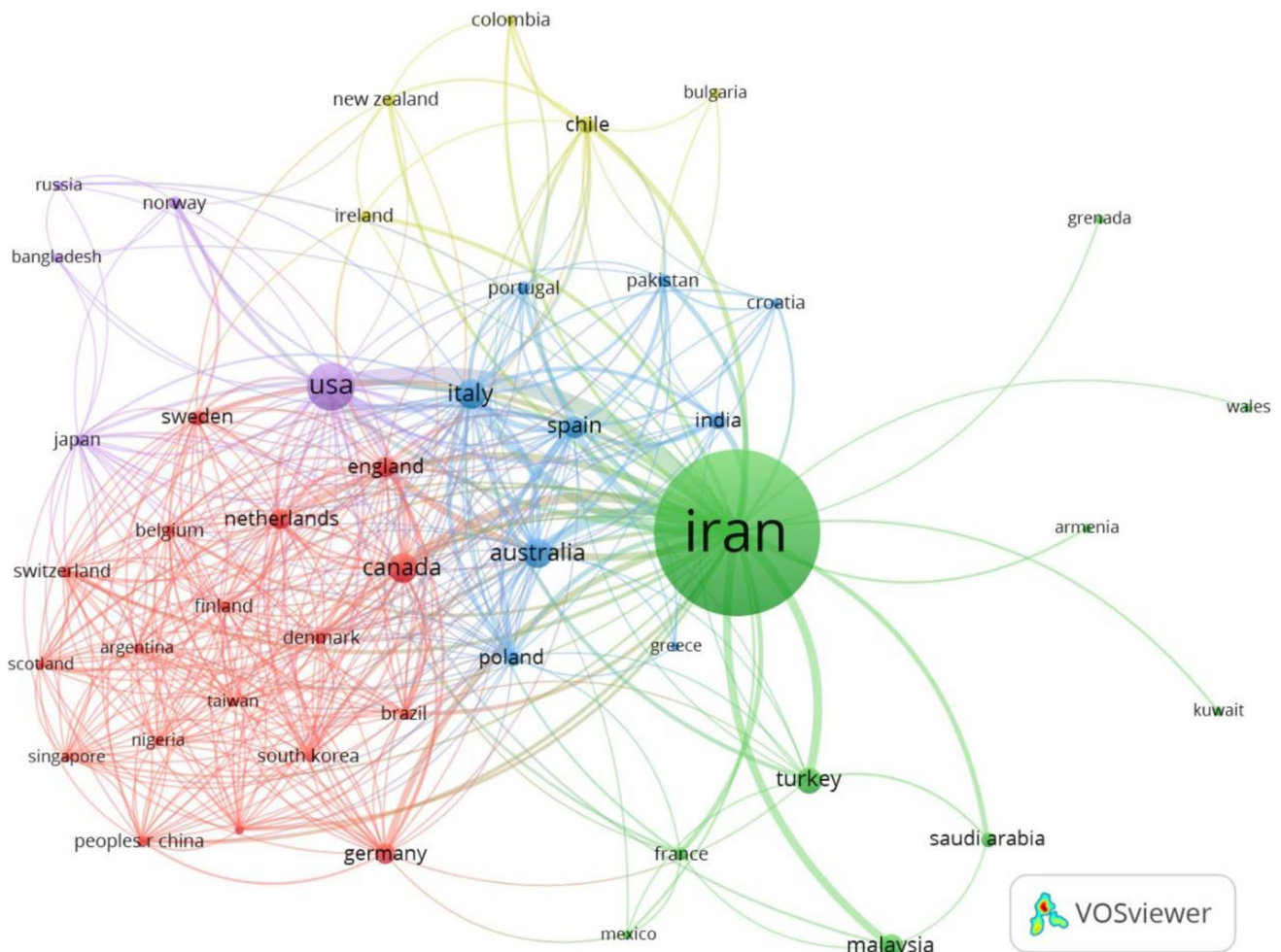
Fig. 3 Iranian researchers international collaboration map in AD research during 2010–2019

Pathophysiological and Pharmacological research projects (see Fig. 8).

Discussion

Iranian researchers published 1042 documents in the field of AD and received 21,549 citations over the last 10 years and Iran's rank in the *WoS* was 20th in total and 6th in Asia. Original articles and reviews were the most dominant form of publications. The most prolific organization was *Tehran University of Medical Sciences* with 286 records.

The number and quality of publications in the field of AD by Iranian researchers had a significant promotion during the last decade. This is in line with the growth of scientific productions in the general field of medicine in Iran [24]. Moreover, The average citations of AD documents published by Iranian researchers was 4 times greater than the average citations of their documents in all fields of medical sciences [25]. It appears that neurological and

psychological research will continue to increase in the future by implementing encouraging plans and policies such as "Iran *strategic plan for cognitive sciences and technologies"* [26].

Scientometric analysis of co-authorship network indicated that most of the documents have been published by research groups with a small and medium number of authors. However, it was greater than the average number of authors of documents indexed in MEDLINE/PubMed during 2015–2019 [27] and similar scientometric research in Iran [28, 29].

Most of the documents authored by Iranian researchers, published in journals with Q2 and Q3 subject area quartiles. It indicates that the quality of research in this area needs to be improved. Nevertheless, this finding might be partly due to the difficulties that the Iranian researchers are facing for publishing in high impact journals because of the sanction imposed to Iran by the United States [30, 31]. However, most of the highly cited documents were published in non-Iranian journals.
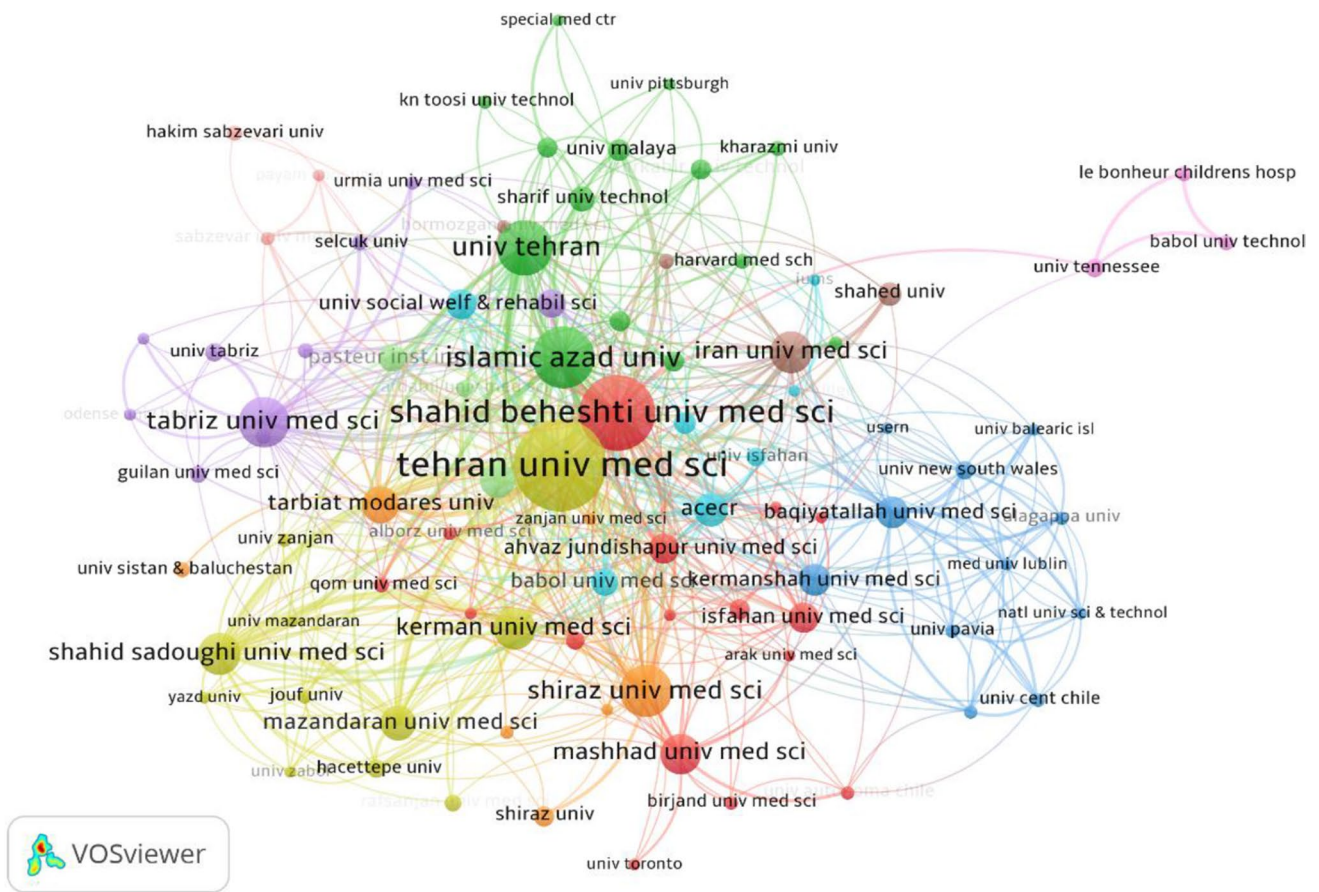
Fig. 4 Organizational collaboration network in AD research

Table 3 Top 10 prolific Iranian authors in the field of AD in the WoS

Rank	Authors	No. of Records	% of 1042	Authors	T. Citation
1	Khodagholi F	57	5.4	Mahdavi M	2043
2	Foroumadi A	48	4.6	Foroumadi A	1069
3	Nadri H	45	4.3	Khodagholi F	1068
4	Moradi A	37	3.5	Shafiee A	1051
5	Shafiee A	33	3.1	Moradi A	957
6	Mahdavi M	32	3.0	Nadri H	882
7	Sharifzadeh M	28	2.6	Emami S	696
8	Emami S	27	2.5	Khoobi M	590
9	Edraki N	24	2.3	Ahmadiani N	570
10	Ahmadiani N	23	2.2	Nabavi SM	539

A significant number of research collaborations in the field of AD was performed by researchers affiliated to Tehran University of Medical Sciences, Shahid Beheshti University of Medical Sciences and Islamic Azad University. This pattern is also noticeable in the other biomedicine scientometric research in Iran [25, 32] which demonstrates the focus of research infrastructures for biomedical research at larger universities located in the capital city, Tehran.

Analyzing the co-occurrence network for keywords indicated that most of the research projects in Iran were on neurology and neurobiology aspects of the AD which is self-explanatory due to the nature of the disease and recent advancements in AD research worldwide [33]. Keywords that represent the AD biomarkers were significant in all clusters which shows the importance of finding reliable biomarkers for AD early diagnosis and the secondary prevention in Iran. Research from other countries shows the same level of necessity [34, 35]. Assessment of the co-occurrence network for keywords demonstrated that AD research by Iranian researchers are switching toward investigations on biomarkers, the effects of herbal derivations on oxidative stress and neurotoxicity, rules of
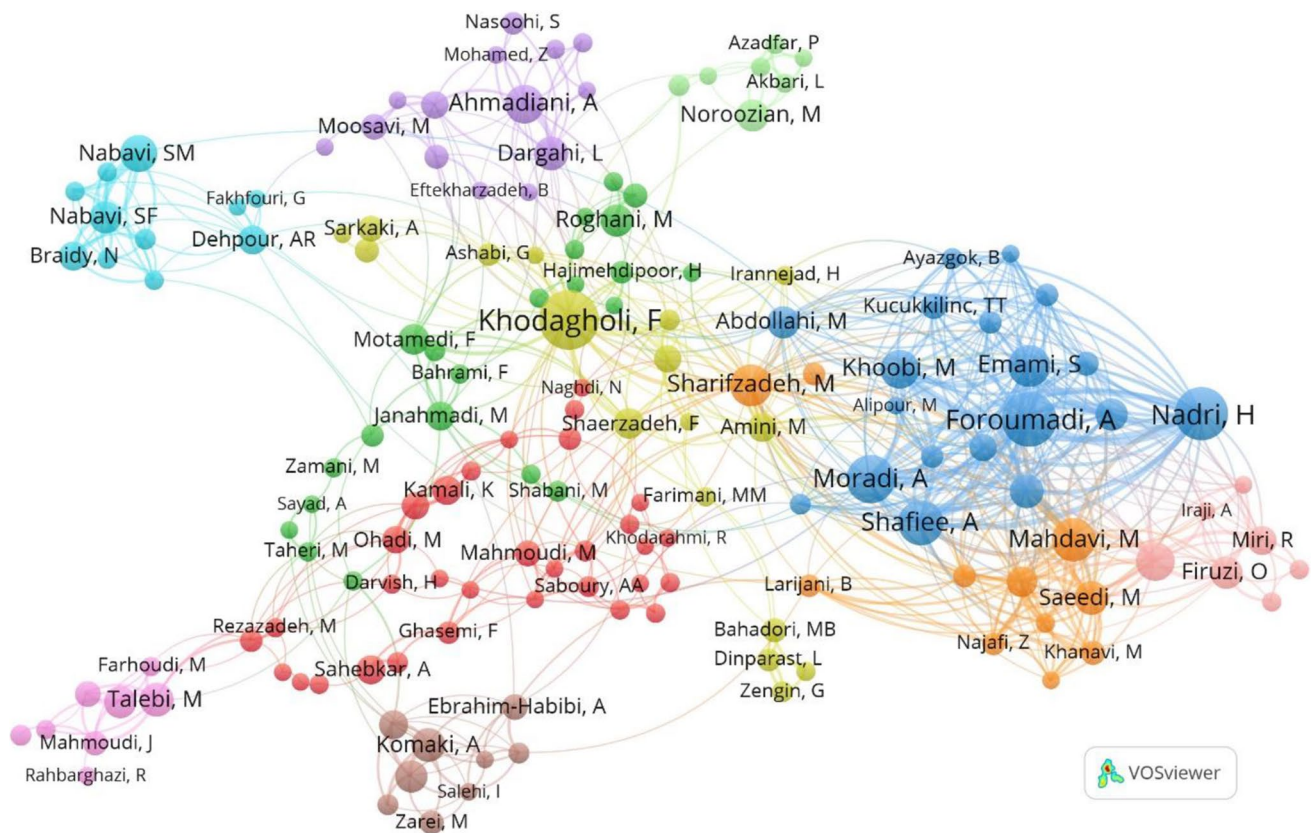
Fig. 5 Co-authorship network of Iranian researchers in AD research during 2010–2019

Table 4 Top 10 journals published Iranian studies in the field of AD in WoS over the last decade

Rank	Sources	Subject Area	Q	IF	NP	Citation	Avg. CPP
1	European Journal of Medicinal Chemistry	Chemistry, Medicinal	1	5.573	23	843	36.6
2	Behavioural Brain Research	Neurosciences	3	2.977	20	423	21.1
3	Journal of Molecular Neuroscience	Neurosciences	3	2.678	19	245	12.8
4	Iranian Journal of Basic Medical Sciences	Pharmacology & Pharmacy	3	2.146	19	166	8.7
5	Iranian Journal of Pharmaceutical Research	Pharmacology & Pharmacy	4	1.505	18	95	5.2
6	Metabolic Brain Disease	Neurosciences	3	2.726	15	149	9.9
7	European Journal of Pharmacology	Pharmacology & Pharmacy	2	3.263	13	269	20.6
8	Bioorganic Chemistry	Biochemistry & Molecular Biology	1	4.831	13	181	13.9
9	Basic and Clinical Neuroscience	*ESCI**	-	-	13	74	5.6
10	Molecular Neurobiology	Neurology	1	4.500	12	303	25.2

Q: WoS Subject Area Quartile (2019), *IF:* WoS Impact Factor (2019), *NP:* Number of Publications, *Avg. CPP:* Average Citation per Paper, *ESCI:* Emerging Sources Citation Index

neurotransmitters and related mechanisms in AD, and synapse connections and plasticity. Furthermore, research on molecular mechanisms associated with AD (such as impact of flavonoids and autophagy) is getting more important for Iranian researchers. Results from co-occurrence network for keywords also indicate that recently, the focus has been on reducing Amyloid β and Tau deposition. The mentioned results were also pointed out in other original and scientometric studies [36–41]. The frequency of keywords repetitions was consistent with the findings reported by Feng et al. [42].

Fig. 6 Time trend of chenges in keywords in AD publications during 2010–2019

Fig. 7 Co-occurrence network of keywords in documents related to AD publications by Iranian researchers

Fig. 8 Year average of keywords appearance in AD related research by Iranian researchers

Strengths and limitations

To the best of our knowledge, this is the first AD sciento-metric study in Iran. We retrieved data from the *WoS* which shows the extent of our investigation. Although our methodology has covered a large and important portion of AD publications by Iranian researchers, some publications by Iranian authors indexed in *Scopus*, *PubMed*, Persian databases, and Preprint databases (such as *medRxiv* and *bioRxiv*) have not been retrieved in the present research.

Conclusion

Iranian researchers made significant contributions in publishing documents and left an impressive footprint on studies in the field of AD and related subjects. Also, a variety of disease aspects were covered by Iranian researchers during the last decade. Findings of the current study is useful

for policymakers and passionate researchers in distinguishing the main research trends and modes. By exploring the co-occurrence network for keywords, we identified that the main knowledge domains of the AD research in Iran are the neurology and neurobiology aspects of AD. Besides, research on AD in Iran is switching toward investigations on AD biomarkers and associated molecular mechanisms. Therefore, it is not unpredictable that research on AD biomarkers, associated molecular mechanisms, and other pharmacological research on AD treatment to continue during future decades. However, the quality of Iranian research outputs in the field of AD is quite low compared to all other top 10 countries according to the *WoS*. Based on the ascending growth in the number of AD cases and AD burden on the healthcare system, there is a need to increase both the quantity and quality of research activities by expanding national and specifically, international collaborative research endeavors. Also, allocating appropriate

budget for AD research projects should be on the agenda of research policymakers in the country.

Declarations

Ethical Statement Not Applicable.

Declaration of competing interest All authors affiliated to universities of Iran.

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