

## ORIGINAL ARTICLE

# Artificial intelligence based on falling in older people: A bibliometric analysis

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**Abstract**

**Objectives:** This study aimed to analyze publications on artificial intelligence (AI) for falls in older people from a bibliometric perspective.

**Methods:** The Web of Science database was searched for titles of English-language articles containing the words “artificial intelligence,” “deep learning,” “machine learning,” “natural language processing,” “neural artificial network,” “fall,” “geriatric,” “elderly,” “aging,” “older,” and “old age.” An R-based application (Biblioshiny for bibliometrics) and VOSviewer software were used for analysis.

**Results:** Thirty-seven English articles published between 2018 and 2024 were included. The year 2023 is the year with the most publications with 16 articles. The most productive research field was “Engineering Electrical Electronic” with seven articles. The most productive country was the United States, followed by China. The most common words were “injuries,” “people,” and “risk factors.”

**Conclusion:** Publications on AI and falls in the elderly are both few in number and the number of publications has increased in recent years. Future research should include relevant analyses in scientific databases, such as Scopus and PubMed.

**KEYWORDS**

artificial intelligence (AI), falling, geriatrics, older adults, web of science (WoS)

## 1 | INTRODUCTION

Artificial intelligence (AI) refers to computer systems that simulate or exhibit a specific aspect of human intelligence or intelligent behavior, such as learning to reason and solve problems.<sup>1</sup> AI is a set of intelligent processes and behaviors created by computational models and algorithms. It is important for health care professionals to understand AI technologies and how these technologies can be used to improve the efficiency, safety, and access of health care.<sup>1</sup>

AI and machine learning changes our world with their effects on sectors, such as health, education, employment, finance, and law.<sup>2</sup> The intersection of the aging population with rapid technological

developments has led to the emergence of new ideas in the field of AI and an increase in the adoption of AI technologies in elderly health care services worldwide.<sup>2,3</sup> However, the type and roles of developing AI technologies in elderly health care are not completely clear.<sup>3</sup>

A fall is defined as an event in which a person accidentally falls to the ground or a lower level.<sup>4</sup> It is highly common among older adults in clinical care settings, such as hospitals, subacute and rehabilitation units, assisted living settings, and nursing homes.<sup>5</sup> Falls, a significant cause of morbidity and mortality among older adults, are also a leading cause of fatal and nonfatal injuries.<sup>6</sup> Falls in the older people often occur as a result of the interaction of risk factors, also it can be a symptom of underlying health disorders.<sup>4</sup> The clinical importance

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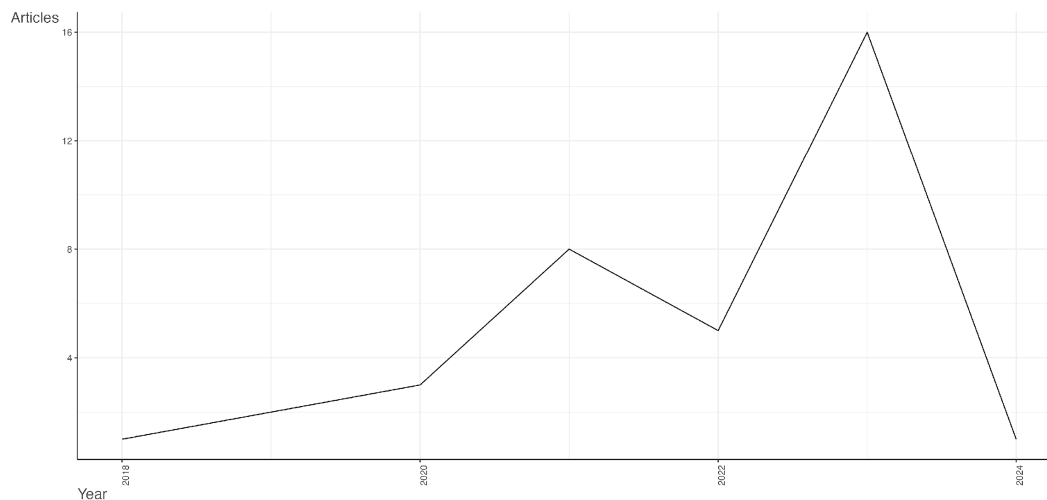


FIGURE 1 Annual scientific production.

of multifactorial correlates of disorders causing falls in older adults is that improvement in modifiable factors may help compensate for functions or factors that are irreversibly affected.<sup>7</sup>

Health research, especially in the fields of geriatrics and gerontology, requires the analysis of biological, psychological, and social situations in the complex aging process with advanced statistical tools.<sup>8</sup> Health professionals and scientists need a variety of theoretical and practical tools to assess data.<sup>9</sup> Bibliometric analysis enables quantitative examination of the literature and network analysis identifies multifactorial conditions and multiple variables within the context of complex data structure.<sup>8,9</sup>

There are some AI-based systematic review and meta-analysis studies<sup>10-13</sup> and a review<sup>14</sup> in the literature about falling in elderly adults. However, there was no AI-based bibliometric and network analysis study on falling in older people. AI-based bibliometric and network analysis in studies on falls in older adults is important in terms of presenting the clinical and academic perspective of falls, which constitute an important problem for the geriatric population with current AI technologies. Therefore, this study was aimed to analyze the studies in this subject from a bibliometric perspective.

## 2 | METHODS

### 2.1 | Data collection and search strategy

Web of Science (WoS) is a platform based on web technology created in 1960 and owned by Thomson Reuters. It offers a wide range of bibliographic databases, citations, and references of scientific publications in all fields of knowledge. The WoS database was designed for interdisciplinary research and in-depth exploration of specialized subfields within an academic or scientific discipline. It can be obtained by selecting the literature that shows the greatest impact in a field or multiple disciplines within the WoS database. It provides a platform where one can access quality literature through curated keywords and uniquely discover new knowledge through meticulously captured metadata and citation links.

The keywords “artificial intelligence”\* OR “deep learning”\* OR “machine learning”\* OR “natural language processing” OR “neural artificial network” (Title) AND fall\* (Title) AND geriatric\* OR elderly\* OR aging\* OR older\* OR old age\* (Title) were searched in the WoS database on January 7, 2024. There is no restriction on the start date for the literature search. A total of 57 publications were found. Only English language publications and articles as document type were included, and 36 articles were included in the data analysis.

Exclusion criteria were also defined with source types, such as conference papers, reviews, data papers, editorial materials, and retractions.

### 2.2 | Analysis

The bibliometric analysis was performed using the Bibliometrix package of the R studio version (2023.06.1+524).<sup>15</sup> Biblioshiny – a web interface for bibliometrics is a Java software developed by Massimo Aria of the University of Naples Federico II (Italy) in 2019.<sup>9,16</sup> The analysis options are divided into seven categories: overview, sources, authors, documents, conceptual structures, intellectual structure, and social structure.<sup>15</sup>

VOSviewer (The Centre for Science and Technology Studies, CWTS, Leiden, The Netherlands; version 1.6.19),<sup>9,17</sup> freely available software, was used to perform the analysis and mapping. VOSviewer creates maps that can be linked based on co-authorship relationships, co-occurrence citation, bibliographic coupling, or co-citation link.<sup>18</sup> The search result records were exported to VOSviewer in plain text format.

## 3 | RESULTS

Thirty-seven English articles published between the years 2018 and 2024 were included in the study. The year 2023 is the year with the most publications with 16 articles (Figure 1).

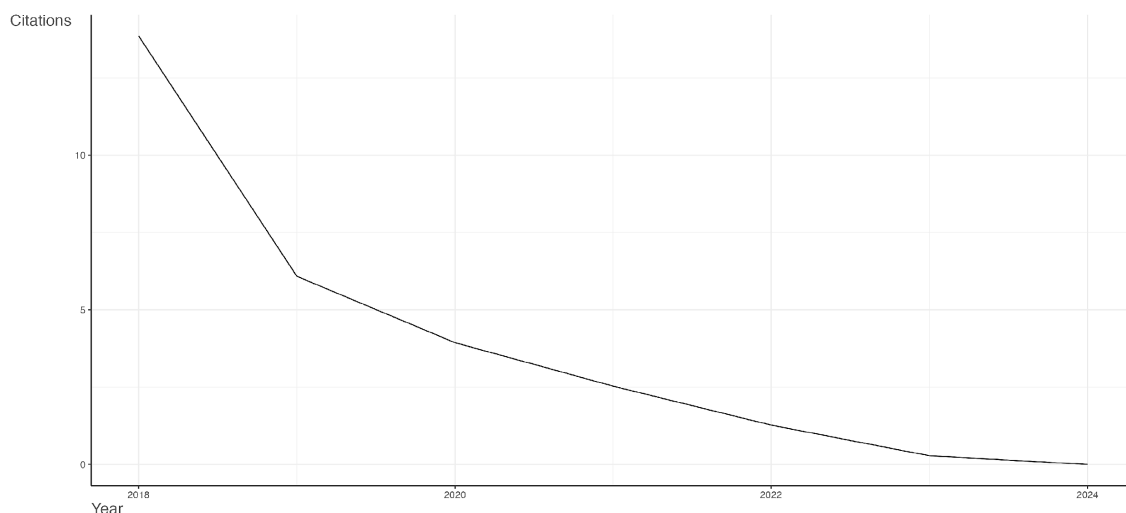


FIGURE 2 Average citations per year.

TABLE 1 The most 10 productive research fields.

	Record count	Percentage
Engineering electrical electronic	7	18.92
Computer science information systems	6	16.22
Health care sciences services	5	13.51
Medicine general internal	5	13.51
Telecommunications	5	13.51
Chemistry analytical	4	10.82
Geriatrics gerontology	4	10.82
Instruments instrumentation	4	10.82
Public environmental occupational health	4	10.82
Medical informatics	3	8.11

The average citation per document was 9.389 between 2018 and 2024, and the average citations per year was the highest in 2018 (13.9 citations), and the lowest in 2024 (0 citation; Figure 2).

### 3.1 | Research fields

The most productive research field was “Engineering Electrical Electronic” with only seven articles, followed by “Computer Science Information Systems” with six articles (Table 1).

### 3.2 | Authors

Biblioshiny-R output showed that the most relevant author was Chen X (Table 2). Chen X and Lin S are two of the top three authors, and they started publishing in 2023. Chen X, a well-known author

who has published two articles and total citations per year was two on AI-based falling studies in older people, can be considered as one of the most influential authors in this field. Patterson BW and Shah MN were the first authors in this field by their publications in 2019. It can be seen that the number of authors reached maximum between 2020 and 2021 (Figure 3).

The average number of co-authors per document is 5.14, and only 22.22% of the articles had international co-authorship.

### 3.3 | The most relevant authors, journals, and affiliations

The most relevant authors, journals, and affiliations about AI-based falling studies in older people are listed in Table 2. According to the number of relevant articles and citations, *Sensors* seems to be the most influential journal, and the Wisconsin University in the United States seems to be the most relevant institution in this field (Table 2).

### 3.4 | Country-specific analysis

The top 10 most productive and cited countries are shown in Table 3. The most productive country was the United States with 56 publications followed by China (Table 3). The most cited country was the Netherlands, which also ranks third among the top most productive countries.

### 3.5 | Citation and co-citation analysis

The most highly cited paper was written by Ahmed Nait Aicha et al, in 2018 with 97 citations, and published in the “*Sensors*” journal<sup>19</sup> (Table 4). Deep learning was investigated to predict falls in older adults in this study.<sup>19</sup>

TABLE 2 The 10 most relevant authors, journals, and affiliations.

	Author	Number of documents	Journal	Number of documents	Affiliation	Number of documents
1	Chen X	2	Sensors	4	Univ Wisconsin	12
2	Cuaya-Simbros G	2	IEEE Access	3	Vrije Univ Brussel	6
3	Lin S	2	Frontiers in Medicine	2	Dong A Univ	5
4	Nunez-Carrera L	2	Age and Aging	1	Natl Ctr Geriatr and Gerontol	5
5	Patterson BW	2	AI & Society	1	Univ Amsterdam	5
6	Perez-Sanpablo A	2	American Journal of Preventive Medicine	1	Xiamen Univ	5
7	Shah MN	2	American Surgeon	1	Edith Cowan Univ	4
8	Yang R	2	Archives of Gerontology and Geriatrics	1	Tunhai Univ	4
9	Adams SD	1	Biomedical Signal Processing and Control	1	Univ Alberta	4
10	Ahmad A	1	BMC Medical Informatics and Decision Making	1	Univ Texas Hlth Sci Ctr Houston	4

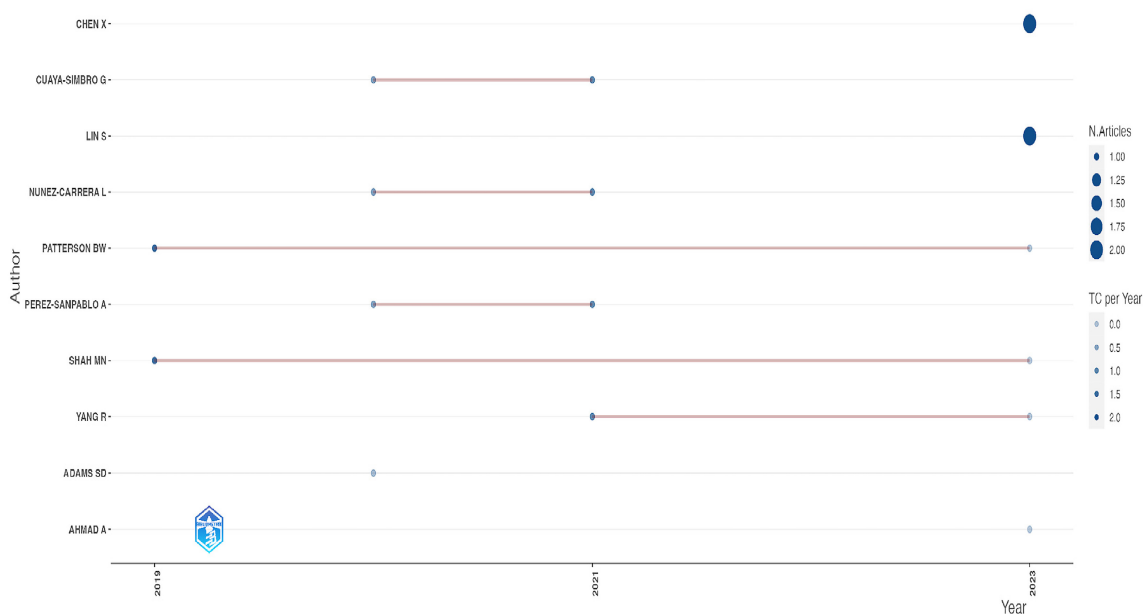


FIGURE 3 Authors's production over time.

### 3.6 | Co-citation analysis of authors

The minimum number of citations of an author was determined as five in VOSviewer. Accordingly, 11 authors met the threshold among 1184 authors.

The co-citation analysis of the authors visualization map had three clusters as red, blue, and green (Figure 4). The green cluster contains three authors, and the red cluster has six authors. The last cluster was blue with two authors. The core author appeared as the World Health Organization had 17 citations with 32 total link strength (Figure 4). There were four link strengths among B. W. Patterson, C. R. Carpenter,

and J. A. Stevens. It can be seen that J. A. Stevens had a very close cooperative relationship with B. W. Patterson and C. R. Carpenter.

#### 3.6.1 | Co-authorship networks of the authors

The co-authorship of authors with a minimum number of two documents of an author was three. Among 201 authors, eight authors met the threshold. There was one cluster with 12 total strength links. The authors with only two documents were "Chen and Xiadong," "Fang and Ya," "He and Lingxiao," and "Lin and Shaowu" (Figure 5).

### 3.7 | Countries

#### 3.7.1 | Co-authorship analysis of countries

The co-authorship analysis of countries reflects the collaboration relationship between countries. The co-authorship of countries with a

minimum number of documents of a country was determined as three. Among 24 countries, four met the thresholds. The green cluster had the United States (with 1 link and 12 documents) and China (with 1 link and 4 documents), and the red cluster has Spain (with 1 link and 3 documents) and India (with 1 link and 3 documents; [Figure 6](#)).

TABLE 3 The top 10 most productive countries.

	Most productive countries	Frequency	Most cited countries	Number
1	United States	56	Netherlands	99
2	China	25	Ecuador	66
3	Netherlands	18	Poland	55
4	Japan	16	United States	45
5	South Korea	14	Korea	20
6	India	10	China	15
7	Australia	9	Saudi Arabia	13
8	United Kingdom	9	India	11
9	Mexico	8	Mexico	7
10	Spain	8	Japan	4

TABLE 4 The 10 most cited papers.

	Title	First author	Journal	Year	Total citation
1	Deep learning to predict falls in older adults based on daily-life trunk accelerometry	Ahmed Nait Aicha	Sensors	2018	97
2	Fall detection system for elderly people using IoT and ensemble machine learning algorithm	Yacchirema D	Pers Ubiquitous Comput	2019	64
3	Fall detection in older adults with mobile IoT devices and machine learning in the cloud and on the edge	Mrozek D	Inf Sci	2020	55
4	Machine learning in aging: An example of developing prediction models for serious fall injury in older adults	Speiser JL	The Journals of Gerontology: Series A	2021	21
5	XGBoost based machine learning approach to predict the risk of fall in older adults using gait outcomes	Noh B	Scientific Reports	2021	20
6	Machine learning prediction of fall risk in older adults using timed up and go test kinematics	Roshdibenam V	Sensors	2021	14
7	Internet of things and deep learning enabled elderly fall detection model for smart homecare	Vaiyapuri T	IEEE Access	2021	13
8	Development and validation of a pragmatic natural language processing approach to identifying falls in older adults in the emergency department	Patterson BW	BMC Medical Informatics and Decision Making	2019	9
9	Vision based real time monitoring system for elderly fall event detection using deep learning	Anitha G	Computer Systems Science and Engineering	2022	6
10	Elderly fall due to drowsiness: detection and prevention using machine learning and IOT	Kumar V	Modern Physics Letters B	2021	5

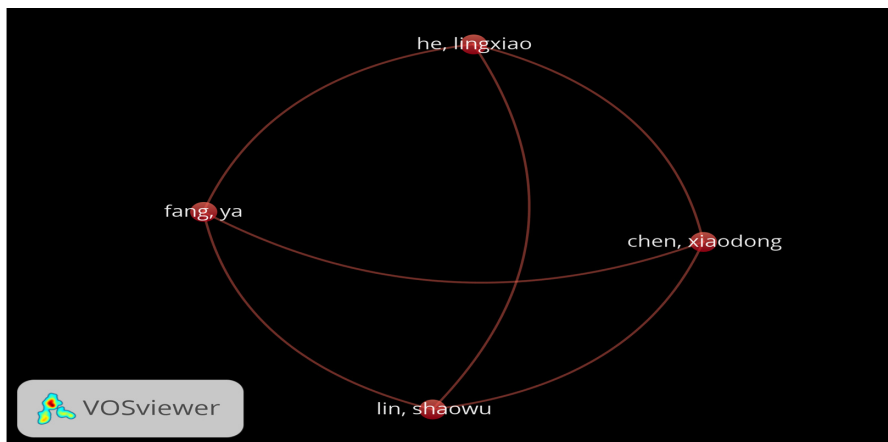
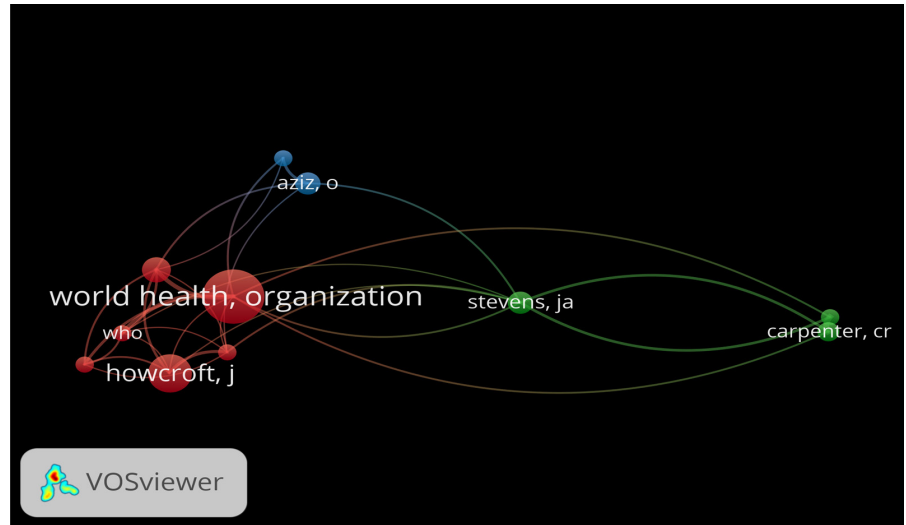
#### 3.7.2 | Citation of countries

The citation of countries was analyzed by VOSviewer with a minimum number of three documents and one citation per country. Among 24 countries, four met the thresholds. Accordingly, the three clusters were identified as red (the United States and China), green (Spain), and blue (India). The United States (12 documents), Spain, and India (3 documents) have demonstrated the highest number of publications ([Figure 7](#)).

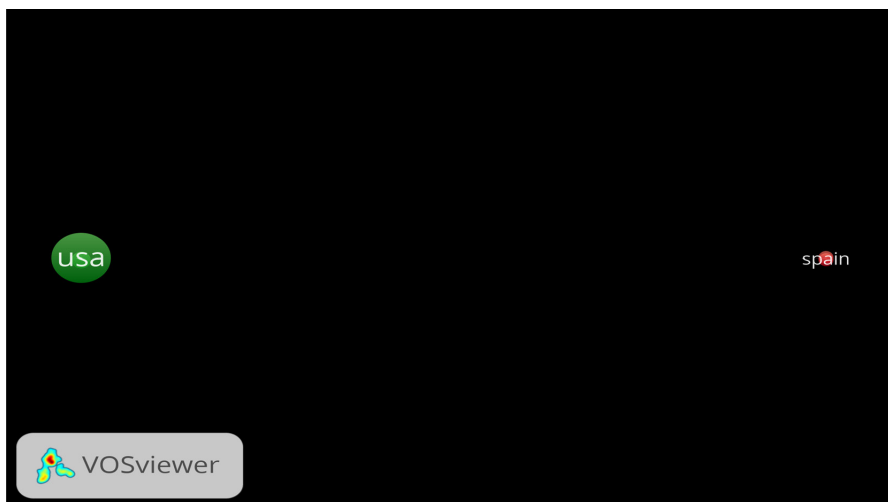
### 3.8 | Words

Word cloud creates images of different sizes depending on the frequency of use of words. The placement of words is random, with dominant words placed in the center to make them more visible as their

**FIGURE 4** Co-citation analysis of the authors.



**FIGURE 5** Co-authorship network of the authors.



**FIGURE 6** Co-authorship analysis of countries.

size increases.<sup>20</sup> A word cloud was created with Biblioshiny (R). The most frequent words were “injuries” (5 occurrences), “people” (5 occurrences), and “risk-factors” (5 occurrences) as trend topics words (Figure 8A).

Among the 125 keywords, three met the threshold of a minimum of five occurrences for mapping in VOSviewer. There was one cluster that had “machine learning,” “fall detection,” and “artificial



FIGURE 7 Citation of countries.

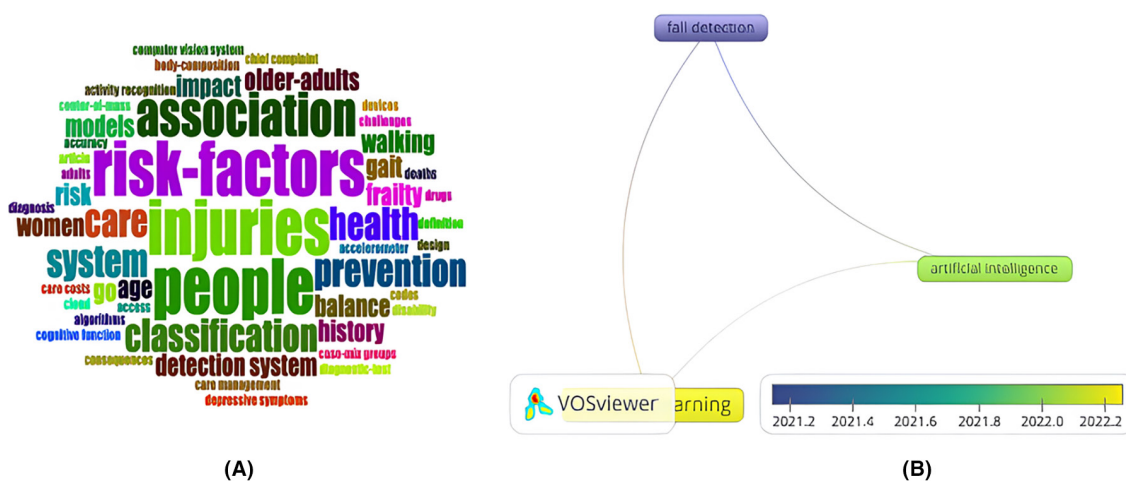


FIGURE 8 (A) Word cloud of keywords. (B) Co-occurrence of keywords.

intelligence” with four total link strength, and 14, six, and five occurrences, respectively.

#### 4 | DISCUSSION

The results show that the AI-based articles about falling in elderly adults, are relevant studies that have started to be published in recent years. Although the fact that 16 articles were published in 2023, the year with the highest number of publications, indicates that the field is open to development in recent years, the number of publications is thought to be insufficient.

The most productive research field, *Engineering Electrical Electronic* and followed by *Computer Science Information Systems* in this study. AI is an integration of computer science and physiology.<sup>21</sup> Widespread dissemination and adoption of AI is driving rapid digital transformation in engineering and management. From this point of view, it is thought that these research fields rank in the first two places in WoS categories.

It was observed that the most interesting authors had a maximum of two articles. This finding indicates that there are not enough research studies in the relevant field.

The analysis of countries showed the most productive country was the United States. In terms of institutes, The University of Wisconsin in the United States has the highest number of publications. Given these consistent findings, it is clear that the United States has researchers more interested in this field and opportunities in the fields such as engineering and computer technologies.

Keywords reflect the basic content of a study. Because co-occurrence analysis can identify high-frequency keywords that appear in different studies, it can help researchers quickly understand key points on a relevant topic. The most frequently used keywords in this study were “injuries,” “people,” and “risk-factors.” The keywords “machine learning,” “fall detection,” and “artificial intelligence” form the same cluster.

The findings of keyword analysis are consistent with the keywords of the most cited articles. The most cited articles were about fall detection, older people, AI, machine learning, and fall detection.

The most cited study published by A. Nait Aicha et al (2018) found that deep learning models, and specifically multi-task learning, effectively assess fall risk based on wearable sensor data.<sup>19</sup> Contributing to the societal challenge of healthy and active aging in the home environment, this study found that machine learning via accelerometer data provides comparable accuracy to traditional

models in assessing the fall risk of older adults, demonstrating the advantage of not relying on hand-crafted features.<sup>19</sup> The use of intelligent systems in the home environment of older patients (creating smart homes) increases their functional independence, comfort, and safety.<sup>22</sup> Deep learning models for fall detection based on acceleration provides and suggests more comprehensive knowledge and practice for fall detection systems to this field.

There are a few systematic review studies about AI for falling in older people in the literature.<sup>23,24</sup> These studies showed wearable device-based technology has shown to be important for subtle changes in biomarkers of gait and balance associated with fall risk and fall detection systems.<sup>23,24</sup>

No bibliometric analysis study has been conducted on this subject, which has recently become more current in this field worldwide. Bibliometric studies, which differ from systematic reviews, are complementary to the research by addressing it from a holistic perspective. It is recommended that future studies examine the more specific issues highlighted in this study through a systematic review.

#### 4.1 | Strength and limitations

This study provides important data on sources, authors, countries, documents, and words, co-occurrence and co-citation networks, and has a comprehensive content from a bibliometric perspective.

The present study also has some limitations. The bibliometric analysis includes only English-language articles. Research in other languages and document types were excluded in data collection. Not performing bibliometric coupling analysis is another limitation.

## 5 | CONCLUSION

This bibliometric analysis of the current literature on falls, which cause serious health problems in older people, within the scope of AI technologies, will guide all health professionals working clinically and academically.

Comprehensive analysis results of this study in the WoS database have shown that publications based on AI and falls in older people are both few in number and that the number of publications has increased in recent years. The results show that the United States is the most relevant country. In the light of the findings of this study, the fact that the number of studies in this field is quite low and there is no research in some countries shows the necessity of strategies and investments in AI technologies within the scope of assessment and treatment in the field of health. In parallel with the development of AI-based strategies by countries, it reveals a remarkable perspective on the use of AI technologies in this field. In future research, relevant analyzes should be conducted in scientific databases such as Scopus and PubMed.

## AUTHOR CONTRIBUTIONS

Concept, design, literature search, collection, analysis and interpretation of data, writing, and revision: Yenişehir.

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## CONFLICT OF INTEREST STATEMENT

No conflict of interest.

## ETHICS STATEMENT

Not applicable.

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