



# Global Trends in the Study of Smart Healthcare Systems for the Elderly: Artificial Intelligence Solutions

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## Abstract

Smart healthcare systems have received increasing attention in recent years; however, a bibliometric analysis of the research on smart healthcare systems for the elderly is lacking. This study aimed to identify scientific results and emerging themes related to smart healthcare systems for older adults. Articles and reviews related to smart healthcare systems for older adults, published between 2013 and 2022, were obtained from the Web of Science Core Collection database using a keyword search. Data collected included the number of publications per year, country/region, institution, author, journal, reference, citation frequency, and keywords. Bibliometric analysis and visualization were performed using the scientometric software VOSviewer and CiteSpace, as well as the bibliometric online analysis platform. In total, 486 articles were retrieved. The number of papers in the field of smart healthcare systems research for older adults has increased every year since 2013. China and the US led in both the number of papers published and total citations. King Saud University was the most prolific institution, while Deen published the highest number of articles and had the highest number of citations. Papers related to smart healthcare systems for the elderly were mainly published in *Sensors*, *IEEE Access*, and *Applied Sciences-Basel* journals. The keyword co-occurrence analysis showed that keywords related to ‘smart home’ appeared most frequently. The top ten common keywords were system, health, smart home, smart homes, Internet of Things, care, older adults, technology, healthcare, and people. The most recent keyword to gather attention was ‘artificial intelligence’. The research on smart healthcare systems for the elderly continues to increase steadily. China and the US maintain a leading position in the world, and institutions such as King Saud University have contributed significantly to the field of smart healthcare for older people. The smart home is the current research hotspot in the field of smart healthcare for older people, and artificial intelligence is likely to be the focus of research in the coming years. There is a need for greater collaboration between countries and institutions to help older people benefit from smart healthcare.

**Keywords** Elderly · Smart health · Bibliometrics · Visualisation · Trends

## 1 Introduction

With the improvement in the living standards and medical conditions, the average life expectancy of people is increasing, as is the ageing global population. The ageing of the body becomes more pronounced as age increases, and the overall health and physical condition tend to deteriorate. The elderly are more likely to develop various diseases gradually,

such as hypertension, diabetes, various cancers, and the resulting complications [1, 2]. Population ageing is a global issue, and healthy ageing is one of the major directions for the research in gerontology in the world today. The treatment of diseases in older people is often costly and consumes a considerable amount of health resources, not only imposing a great burden on national societies and families but also posing a great challenge to the healthcare system [3, 4]. Although older people are faced with growing healthcare needs, healthcare services specifically for older people are under-resourced globally.

Older people may benefit from the use of smart healthcare systems. Smart healthcare has its roots in the ‘smart planet’. Its fundamental starting point is to manage people’s healthcare needs intelligently and to ensure timely

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access to preventive and curative healthcare services with its advanced technologies in system integration, interconnection, and intelligent processing. This is a higher stage of information technology in healthcare [5, 6]. With the goal of a healthy life for people, smart healthcare integrates advanced technologies such as the Internet of Things and artificial intelligence into the medical field to provide people with intelligent medical and health services [7]. The elderly have difficulties participating in the implementation of smart healthcare on an individual basis, and there are barriers to the use of smart terminals. If the implementation of smart healthcare is not understood well, its benefits for older adults may remain unrealised and even lead to adverse outcomes. Scientists have conducted substantial research on the application of smart healthcare systems in the elderly population [8, 9]. However, the existing literature on smart healthcare for older adults remains fragmented and does not provide a clear picture of how older adults benefit from smart healthcare. Therefore, a comprehensive study is necessary to analyse and elaborate on the application of smart healthcare in the elderly population.

Bibliometrics is a valuable scientific tool that is widely used in various fields, including biomedicine. CiteSpace and VOSviewer are common software programmes used for bibliometric analysis [10, 11]. CiteSpace presents relationships between documents in the form of node-link diagrams through a unique visual approach, but is relatively complex to operate [12]. VOSviewer is a software tool for visualizing and analyzing scientific literature information. It helps users extract sharp scientific information from the literature, construct various visualizations such as literature maps and network diagrams, and provides diverse analysis tools to assist users in discovering new insights and trends. Although there has been a certain amount of existing research on smart healthcare for older people, there is a lack of relevant bibliometric and visual analysis [13, 14]. Therefore, this study helps to understand the current state of research by conducting bibliometric and visual analyses of the existing research. Moreover, it assists in identifying the current topics of interest and predicting the future trends in the field of smart healthcare systems research for the elderly from a global perspective for future investigations.

## 2 Methodology

### 2.1 Data Sources and Collection

We extracted literature related to older adults and smart health systems from the Web of Science Core Collection (WoSCC) database published in the last decade (2013–2022). The literature search was conducted on February 25, 2023. Document types were limited to articles

and reviews, with search terms set to (TS=(smart health systems)) AND TS=("old adults" OR "old man" OR "the aged" OR "the elderly" OR "elderly" OR "senior\*" OR "older people" OR "old people" OR "old person" OR "older person" OR "older adult\*"). All retrieved records were downloaded in "plain text" format and basic information extracted including article title, author, abstract, keywords, journal and year of publication and references, etc., for further analysis (Fig. 1).

### 2.2 Data Extraction

To ensure the reliability of the results, two independent researchers selected the literature and extracted the data. Elements from the selected articles were extracted and analyzed, including the number of annual publications, country/region distribution, institutions, authors, journals, keywords, and references.

### 2.3 Data Analysis and Visualization

VOSviewer 1.6.17 (Nees Jan van Eck and Ludo Waltman, Leiden University, The Netherlands) and CiteSpace 5.7R1 (Chaomei Chen, Drexel University, US) were used for bibliometric and visual analyses. This study utilised these tools for country or region, institution, and author network analysis as well as for the co-occurrence and emergent analysis of major keywords.

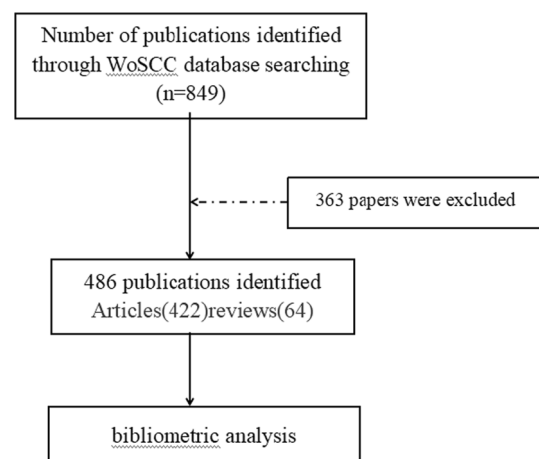
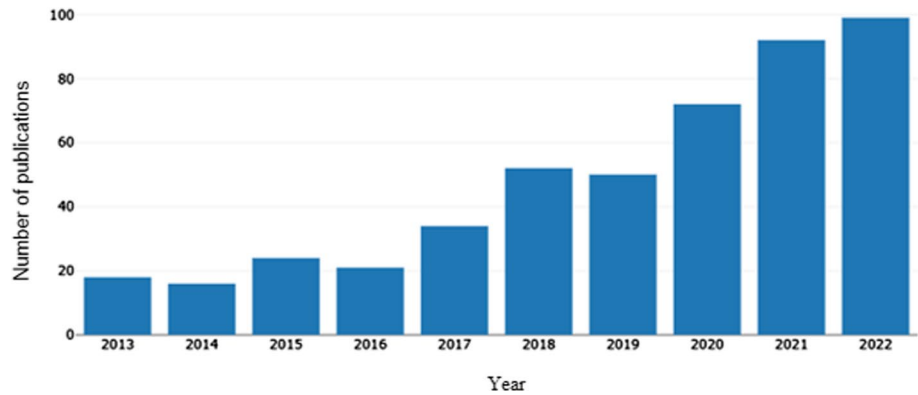


Fig. 1 Flow diagram of literature identification

**Fig. 2** Number of annual research publications



**Table 1** Top ten countries contributing to the research field

Rank	Country	Documents	Citations	Strength
1	China	75	1491	47
2	USA	70	2235	42
3	Spain	46	1248	45
4	Canada	37	2127	25
5	South Korea	37	391	20
6	India	36	478	33
7	England	35	762	49
8	Italy	29	675	34
9	France	25	655	25
10	Australia	21	423	15

database from the last decade (2013–2022), with a total citation frequency of 11,043. Among these 486 publications, there are 422 articles and 64 reviews. Articles are the most important publication type (86.8%, 422/486; Fig. 1). As shown in Fig. 2, the number of publications in the field of smart healthcare systems research for the elderly has been increasing every year since 2013.

### 3 Results

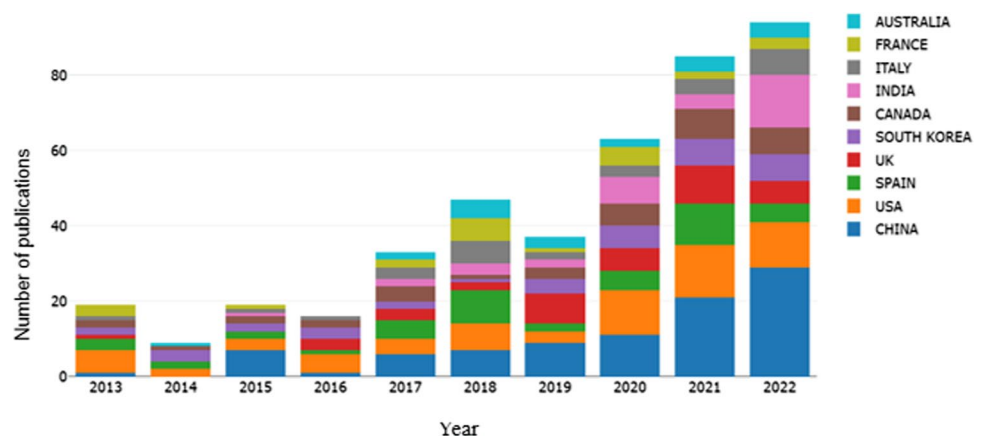
#### 3.1 Annual Publications and Trends

Based on the aforementioned search criteria, 486 eligible publications on smart healthcare for older people were collected from the Web of Science Core Collection (WoSCC)

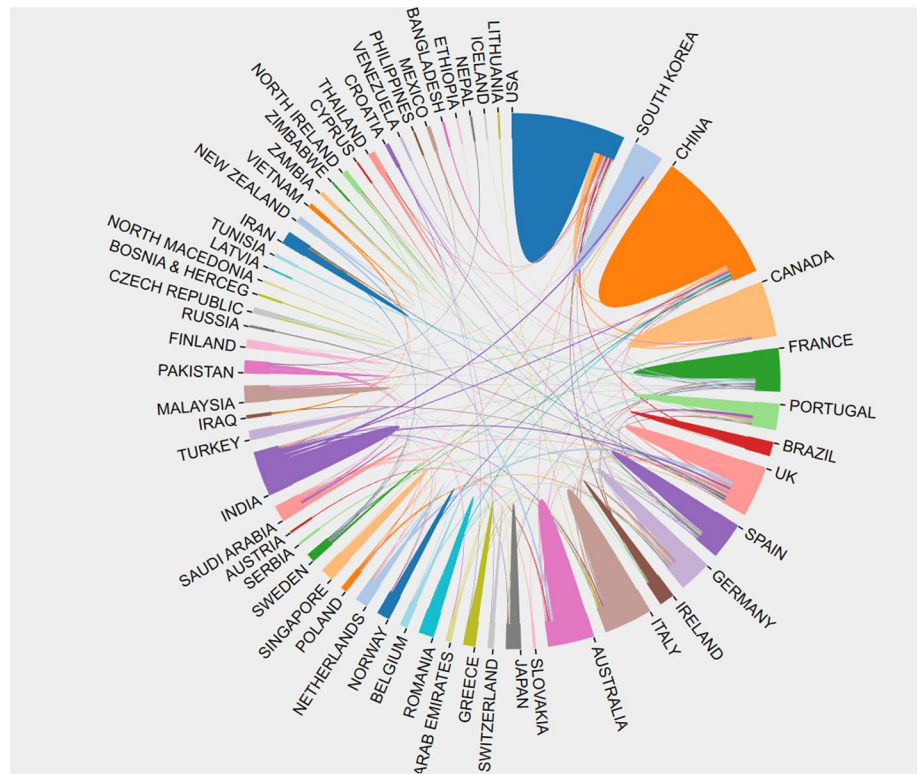
#### 3.2 Contribution of Countries or Regions

In total, 75 countries/regions have published studies related to smart healthcare for older people, of which 34 have submitted more than five papers. The most active countries/regions are listed in Table 1. The results show that China was the most prolific country, with 75 papers published, followed by the US and Spain, with 70 and 46 papers published, respectively. The most influential countries were the US, Canada, and China with 2235, 2127, and 1491 citations, respectively. Figure 3 shows the annual trend of the number of publications in these ten countries. Figure 4 shows the publication status and collaboration of each country.

**Fig. 3** Annual trends in the number of publications in the top ten countries



**Fig. 4** Publication and cooperation by country



**Table 2** Top ten most productive institutions

Rank	Organisation	Documents	Citations
1	King Saud University	8	599
2	Universidad Politecnica de Madrid	7	195
3	University of Toronto	7	675
4	University of Waterloo	7	149
5	Hanyang University	6	109
6	McMaster University	6	1030
7	University of Washington	6	85
8	Oregon Health & Science University	5	159
9	University of Auckland	5	176
10	University Health Network	5	44

### 3.3 Institutional Contributions

The published studies belonged to 932 different institutions. In Table 2, the top ten most productive institutions are listed, with four institutions located in Canada and two in the US. Twelve institutions published at least five papers each. King Saud University (Saudi Arabia) was considered the most prolific institution, with eight papers published, followed by the Universidad Politecnica de Madrid (Spain) and the University of Toronto (Canada), with seven papers each. Although McMaster University (Canada) published only six papers, its papers were cited 1030 times, which was much higher than that of the other

institutions. Figure 5 shows the collaboration among different institutions.

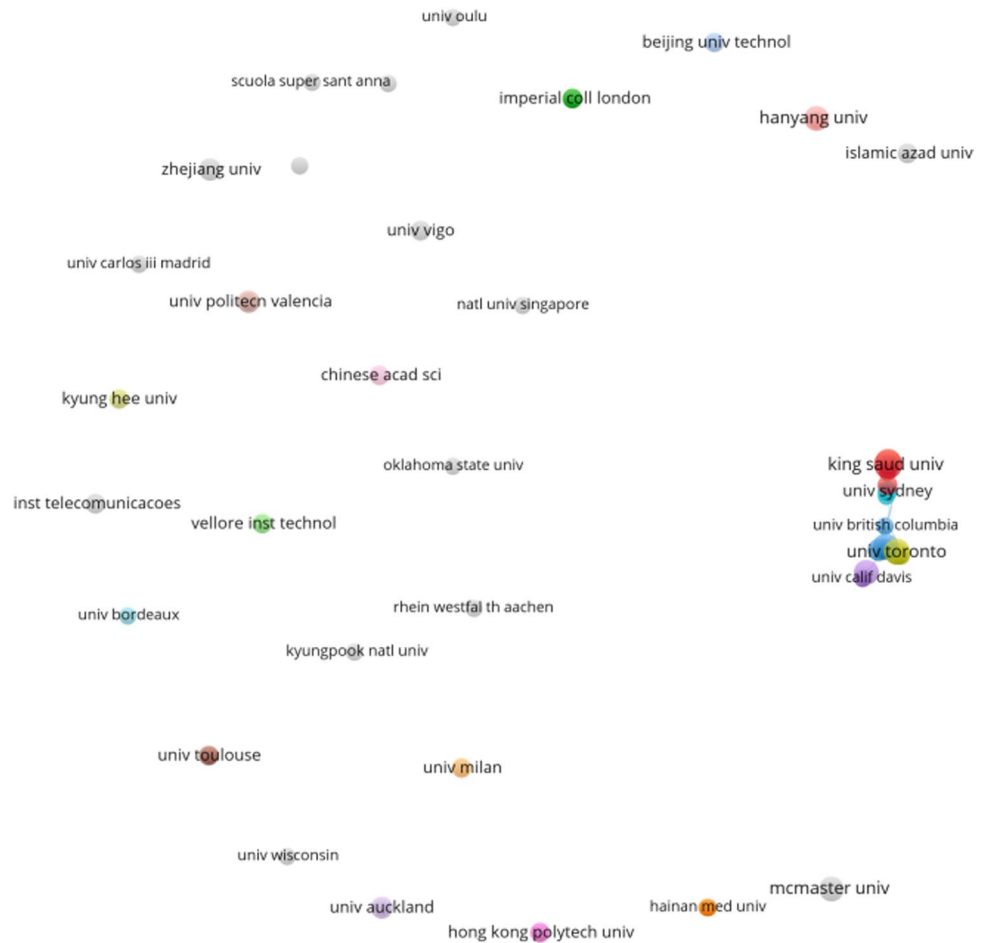
### 3.4 Author Contributions

In total, 2127 authors have contributed to the research on smart healthcare for older people; 23 of whom have published at least three articles. The prolific and influential authors are listed in Table 3 (Fig. 6). The results show that Deen, Demiris, and Muhammad were the most prolific authors, with six, five, and five papers, respectively. Moreover, Deen, Majumder, and Muhammad were the most influential authors, with 1030, 766, and 530 citations, respectively, for their studies.

### 3.5 Journal Analysis

Overall, 242 journals have published research related to smart healthcare systems for older adults. Among them, 17 journals published at least five articles. *Sensors* was the most prolific journal, publishing 57 papers on smart healthcare for older people, and it was also the most cited journal. This was followed by the *IEEE Access* and *Applied Sciences-Basel*, with 22 and 13 publications, respectively (Table 4).

**Fig. 5** Institutional contributions in the research field



**Table 3** Top ten authors in the research field of smart healthcare for older people

Rank	Author	Documents	Citations	Strength
1	Deen, M. Jamal	6	1030	7
2	Demiris, George	5	45	4
3	Muhammad, Ghulam	5	530	3
4	Campo, Eric	4	23	3
5	Hossain, M. Shamim	4	485	3
6	Majumder, Sumit	4	766	7
7	Thompson, Hilaire J	4	30	4
8	Baig, Mirza Mansoor	3	172	6
9	Cavallo, Filippo	3	84	0
10	Charlon, Yoann	3	23	3

### 3.6 Keywords Analysis

We conducted a keyword co-occurrence analysis to trace the trends and popular topics in the research field of smart healthcare systems for the elderly (Fig. 7). The results showed that there were 2410 keywords in 486 papers, and the top 10 keywords that appeared most frequently included

system, health, smart home, smart homes, Internet of Things, care, older adults, technology, healthcare, and people (Table 5). ‘Smart home’ or ‘smart homes’ was the most frequent keyword (119 occurrences), followed by ‘system’ and ‘health’ (83 and 68 occurrences, respectively), which is consistent with our research theme. Figure 8 shows the top 14 keywords with the strongest emergence. The keyword with the strongest emergence was ‘telemedicine’, while the most recent keyword to gather attention was ‘artificial intelligence’.

### 4 Discussion

For a long time, the flaws of the healthcare system, such as the high cost of healthcare, lack of healthcare access, and limited coverage, have been concerning issues. Notably, as the elderly population faces more medical problems due to ageing, they usually need more healthcare resources on an urgent basis [15]. The emergence of smart healthcare systems can help older people access convenient and quality healthcare services. Smart healthcare systems originated from the ‘smart planet’ and include three types of integrated

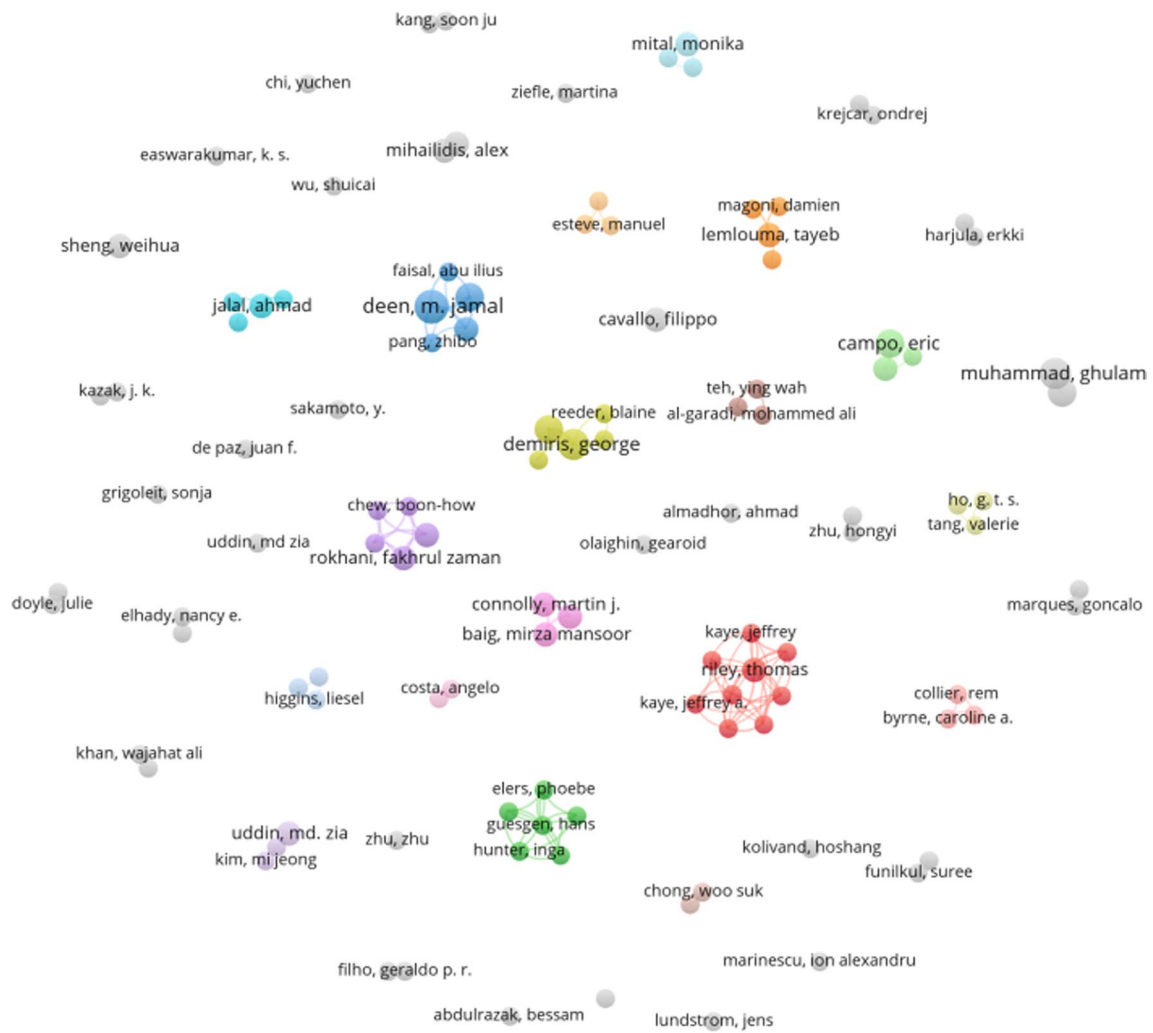


Fig. 6 Collaborative network of authors in the research field of smart healthcare for older people

Table 4 Top ten journals in the research field of smart healthcare for older people

Rank	Source	Documents	Citations	IF(2021)	JCR
1	Sensors	57	1919	3.847	Q2
2	IEEE Access	22	599	3.476	Q2
3	Applied Sciences-Basel	13	107	2.838	Q2
4	Electronics	9	96	2.69	Q3
5	JMIR mhealth and uhealth	9	145	4.948	Q1
6	Journal of Ambient Intelligence and Humanized Computing	9	69	3.662	Q2
7	Journal of Ambient Intelligence and Smart Environments	8	52	2.759	Q3
8	JMIR Aging	7	35	–	–
9	Future Generation Computer Systems-The International Journal of Escience	5	111	7.307	Q1
10	Healthcare	5	19	3.16	Q2

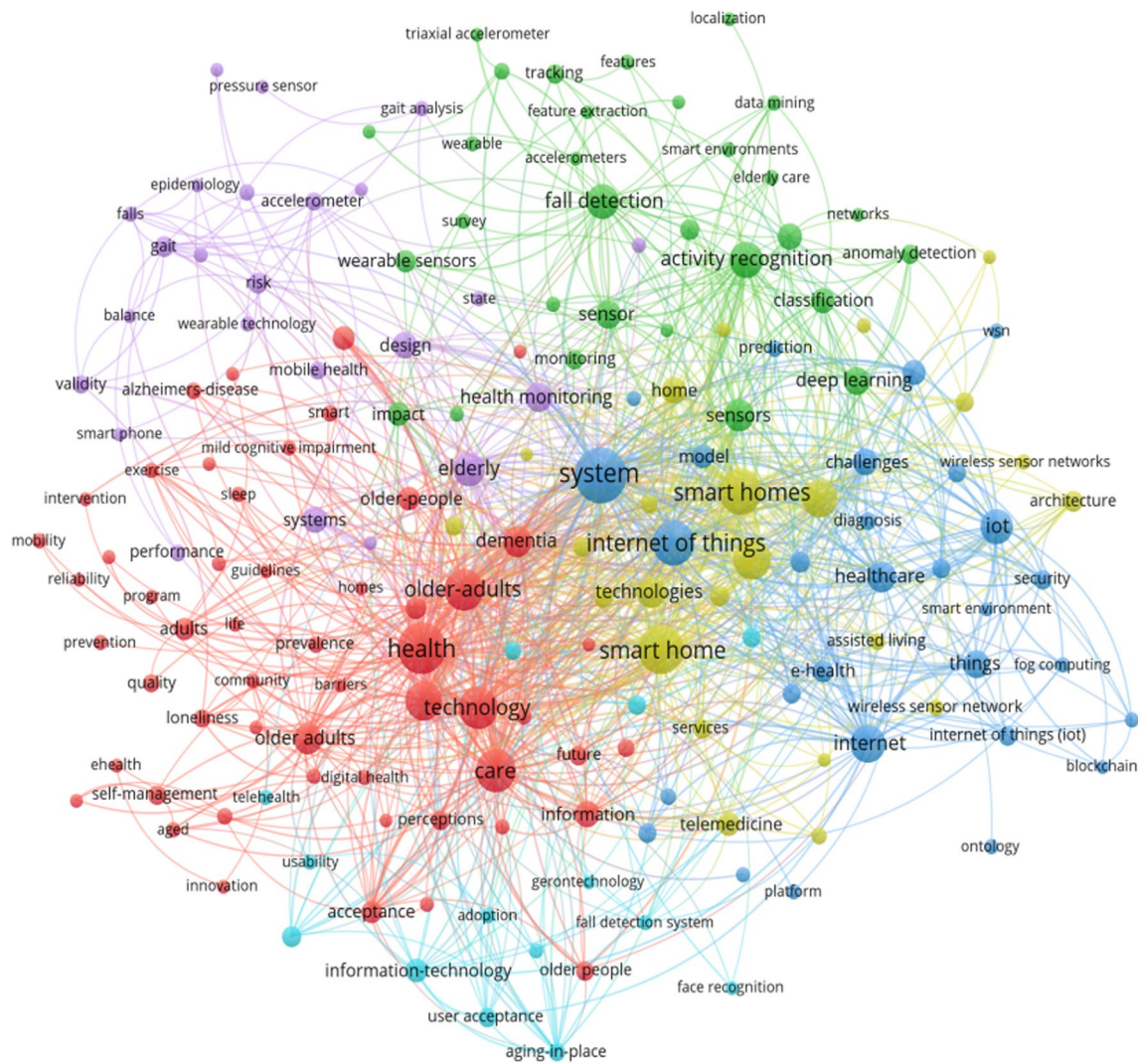


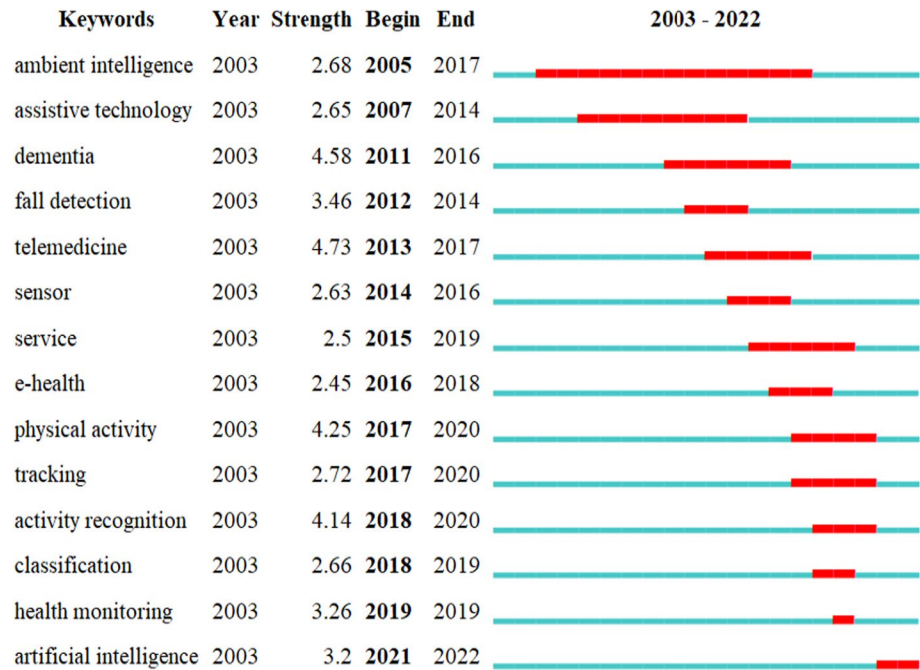
Fig. 7 Keyword co-occurrence network diagram

Table 5 Top ten common keywords for studies

Rank	Keyword	Occurrences	Total link strength
1	System	83	418
2	Health	68	365
3	Smart home	63	359
4	Smart homes	56	317
5	Internet of Things	52	274
6	Care	49	284
7	Older adults	46	271
8	Technology	45	290
9	Healthcare	43	233
10	People	39	280

applications: smart hospital systems, regional health platforms, and home health systems [16, 17]. The core of smart healthcare is ‘patient-centric’, giving patients a comprehensive, professional, and personalised healthcare experience. The smart healthcare system for the elderly is dedicated to helping the elderly in every way, providing humane care and treatment that considers the actual situation of the elderly [18, 19]. From 2013 to the end of 2022, approximately 486 research papers have been published. This study presents an econometric analysis and visualization of all the literature data on smart healthcare systems for older people from an informetrics perspective.

China and the US lead in the number of published papers and total citation frequency, indicating that these two countries are leading the way in research on smart healthcare systems for the elderly. Recently, China has actively approached the ageing population issue as a national strategy and has

**Fig. 8** Keyword emergence analysis**Top 14 Keywords with the Strongest Citation Bursts**

been coordinating research on the ageing causes. China is actively developing elderly care and promoting access to basic elderly care services for all elderly people [20]. The US smart medical industry is conducting strong research and development projects and applies world-leading technology in various medical equipments, such as large imaging diagnostic equipment, surgical robots, and other smart medical equipment. The US is the world's largest smart healthcare market. Many of the world's smart healthcare devices are produced in the US, and the application of smart healthcare in the US elderly population is relatively mature [21]. In addition to the total number of citations, the average number of citations per article is an important indicator of the quality of a publication [22]. Our results show that the ranking of average citations per item is not the same as that based on the number of publications. Canada ranks only fourth in terms of the number of publications but second in terms of total citations and first in the average number of citations per article. This suggests that the relatively high quality of Canadian publications has resulted in a high citation rate for each study. Some positive collaborations were observed between different countries/regions; however, most of them were limited to a few countries, implying that although age-related research of smart healthcare systems has attracted worldwide attention, the collaboration between countries needs strengthening.

The number and influence of research institutions in a given field are somewhat indicative of the level of scholarship in the country where the institution is located. Among

the top ten institutions for research on smart healthcare systems for the elderly, four institutions are from Canada and two are from the US. King Saud University (Saudi Arabia) is the most prolific institution, but it has only published eight papers, indicating fragmented research efforts and a lack of influential institutions in the country. Of the 2970 authors contributing to research on smart healthcare systems for the elderly, Deen from McMaster University, who has published six manuscripts, is the most prolific author in the field and has the highest average number of citations per published article. For journals, the majority of journal sources were computer and telecommunications journals, with a small number of journal sources in healthcare and other categories. Papers on smart healthcare systems for the elderly are mainly published in *Sensors*, *IEEE Access*, and *Applied Sciences-Basel*, highly cited journals contributing to the development of smart healthcare systems research worldwide.

In bibliometric analysis, keyword co-occurrence analysis helps to estimate the hotspots in the research field. Smart healthcare systems have been shown to benefit the elderly population, and smart home health systems play an important role [23]. The most frequent keyword in our analysis was related to 'smart home', which corroborated our research theme. Many elderly people are reluctant to give up their independence and leave their familiar surroundings to move to a retirement community or institution. Smart homes allow them to live in better conditions at home and to stay in their familiar surroundings for as



long as possible. By equipping the elderly with monitoring devices in fixed places, they are in an all-around, multi-layered protection network [24]. For elderly people with mobility and visual difficulties requiring security, this model can increase their autonomy, comfort, and safety in their homes.

The key terms suddenly increase or decrease in their frequency of use in a certain period. The keyword burst detection function can effectively reflect the changes in the research hotspots in the field of smart medicine around a certain point in time [25, 26]. Our research found that the strongest term in burst detection was 'telemedicine', which indicates that telemedicine is the focus of research in the area of smart healthcare for the elderly. Telemedicine is a medical approach that combines telecommunication technology with healthcare to improve access to timely, efficient, and cost-effective care for the elderly with limited mobility and in remote areas. For the chronically ill elderly patients, telemedicine can reduce the number of hospitalisations and improve the quality of life [27]. The latest keyword to gather attention is 'artificial intelligence', which is seen as the frontier of research in this field and is likely to be studied in depth in the coming years. Artificial intelligence is the theory and application of digital computers or of machines controlled by digital computers to simulate and extend human intelligence, perceive the environment, and learn knowledge, thus obtaining optimal results [28]. Applications of artificial intelligence in medicine include not only intelligent diagnosis and intelligent treatment but also intelligent health and chronic disease management, which is of great importance to the elderly. Artificial intelligence can efficiently collect disease and patient data and build an expert knowledge base, which can be analyzed by artificial intelligence engines to provide guidance on chronic diseases for older adults. It uses machine learning-based methods to uncover individual risk levels and signs from massive amounts of data, identify people in need of intervention, and send targeted interventions, such as health management, healthy recipes, exercise advice, and medication advice, through the user's preferred channels at the precise moment when they are needed [29]. With the help of smart wearable device technology, intelligent medical systems can monitor body conditions in real time, which will open new horizons for the health management of the elderly. With a large amount of data to be mined and analyzed comes the risk of private/personal data leaks; hence, it is vital to strengthen the information security of medical databases and the protection of citizens' health privacy. As an emerging healthcare model, smart healthcare can provide better and more precise healthcare services; however, there are associated problems, such as information flooding and data security

and privacy, which need to be considered and addressed properly in the process of its development [30].

#### 4.1 Restrictions

This study has several limitations. First, we chose a single database source and only obtained data from the WoSCC database; therefore, the publications from other databases were ignored. However, the inconsistent format of different databases may make it difficult to extract and analyse data accurately. Second, the citation of publications is closely related to the time of publication, and newly published publications may have been ignored in our study due to their low citation frequency.

## 5 Conclusion

Our study is the first to use bibliometric and visual analysis to illustrate the current state of research and global trends in the study of smart healthcare systems for the elderly. Overall, the field of research on smart healthcare systems for the elderly is in a rapid development phase, with China and the US maintaining world leadership. The smart home is the current research hotspot in the field of smart healthcare for older people, and artificial intelligence is likely to be the focus of research in the coming years. There is a need for greater collaboration between countries and institutions to help older people benefit from smart healthcare.

**Author Contributions** Study conception and design: YZ; data collection: YZ and QY; analysis and interpretation of results: YZ and QY; draft manuscript preparation: YZ; administration: QY and XFM. All authors reviewed the results and approved the final version of the manuscript.

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**Data Availability** The original contributions presented in the study are included in the article/supplementary material, and further inquiries can be directed to the corresponding author.

#### Declarations

**Conflict of interests** The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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