

Knowledge mapping of medication literacy study: A visualized analysis using CiteSpace

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Chaocong Liang^{1,2,3}, Aijing Luo^{1,3}  and Zhuqing Zhong^{1,3}

Abstract

Objective: The objective of this study was to analyze knowledge mapping and demonstrate the status quo, intellectual base, and hotspots in the field of medication literacy.

Methods: Using the data from Web of Science Core database, we constructed a knowledge map to visualize medication literacy using CiteSpace, which revealed the power of the studies, core authors and journals, intellectual base, and hotspots in this field.

Results: According to an analysis of 2025 literature reports, the stronger studies were mainly conducted at research institutions of higher education in the United States. Core author groups with a higher influence were not identified. The core journals included *Patient Educ Couns* and *Fam Med*. The health literacy studies served as the foundation for the medication literacy studies. The keywords formed 13 clusters including 5 major clusters.

Conclusion: The topics in medication literacy study focused on instruments assessing medication literacy, measurement and assessment of medication literacy, medication literacy for the prevention of chronic disease and medication treatment adherence, medication literacy education, and family practice. This study provides an insight into medication literacy and valuable information for medication literacy researchers to identify new perspectives on potential collaborators and cooperative institutions and hotspots.

Keywords

Medication literacy, literacy, knowledge map, visualized analysis, CiteSpace

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Introduction

Medication literacy refers to the ability of individuals to safely and appropriately acquire, understand, and act upon basic medication information.¹ Most patients lack understanding of medication knowledge, do not follow the prescribed dosage and frequency of prescription drugs, and lack understanding of prescription drug labels, indicating their lower level of medication literacy. For instance, Kripalani et al.² performed telephone follow-up interviews with inner-city patients after discharge and found that 22% of the patients had not filled their prescriptions, 21% of the patients found it difficult to understand the reason they were prescribed the medications, and literacy was limited in the patient population. Custodis et al. conducted a cohort study to assess medication knowledge in patients hospitalized with heart failure. Most patients did not know the number of drugs they were taking, and 3 months after discharge, only 18% of the patients correctly stated the number of drugs they were taking compared to 37% at baseline.³ Professor Maniaci

developed the Medication Literacy Questionnaire, which was specifically designed to assess medication literacy in inpatients. This tool is simple and convenient, and has good reliability and validity.^{4,5}

Knowledge mapping is a novel analysis tool that combines theories and methods from mathematics, graphics, and other disciplines with citation analyses, co-occurrence analyses, and other bibliometric methods to reveal the core structure, developmental history, hotspots, and integral knowledge architecture of a discipline.⁶ A variety of tools, such as Pajek,

¹The Third Xiangya Hospital, Central South University, Changsha, China

²Information Security and Big Data Research Institute, Central South University, Changsha, China

³Key Laboratory of Medical Information Research, Central South University, College of Hunan Province, Changsha, China

Corresponding author:

Aijing Luo, The Third Xiangya Hospital, Central South University, 138 Tongzipo Road, Yuelu District, Changsha 410013, China.
Email: luoaijing@163.com



UCINET, CiteSpace, and VOSviewer, can be used to visualize knowledge maps. CiteSpace, which is among the most popular analysis tools, can generate co-citation networks based on reference citations to reveal the structure of a particular research field.^{7,8} Knowledge mapping has been applied in many research fields. Liang et al. performed a bibliometric analysis of studies investigating acupuncture for low back pain using recent studies published within the previous 20 years via CiteSpace. Liu et al. and Chen et al. separately conducted knowledge mapping to reveal the research fronts and development trends in sciatic nerve injury repair and regenerative medicine.^{9–11}

To date, a knowledge mapping analysis of medication literacy has not been performed. In this study, we generated visualized knowledge maps of medication literacy and analyzed the research study practices and intellectual base, which we hope to provide a reference for study in the field of medication literacy.

Methods

Data sources

In this study, the literature was retrieved from Web of Science. The data retrieval strategy included the following—topic: (medication literacy) OR topic: (medicine literacy) OR topic: (drug literacy); index: (SCI-EXPANDED, SSCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH); document type: “Article” and “Proceeding Paper”; and time span: 1900–2016 (retrieved date: 30 May 2017). No language restrictions were applied. In total, 2025 articles on medication literacy were obtained. Of the retrieved studies, the oldest article was published in 1985.¹²

Analysis tool

Visualization software was used to visualize and bibliometric analysis in the field of medication literacy. Using analysis methods, such as bibliometric analyses, co-occurrence analyses, cluster analyses, centrality analyses, and so on, visualization software can produce node-link maps, citation network maps, and other visualized results. These results allow one to intuitively observe the development track, intellectual base, research hotspots, and other aspects of a discipline.¹³ The analysis tool used in this study is based on the visualization analysis software CiteSpace (3.8.R5, 64 bit). In the knowledge maps generated by CiteSpace, the nodes represent the analysis elements, such as country, organization, author, co-citation literature, and keywords. The size of the nodes reflects the number of publications or frequency (i.e. citation count); the larger the node, the higher the number of publications or frequency (i.e. citation count). The different colors within the nodes represent different times, the connection lines between the nodes reflect the relationship between the co-operation or

co-citation, and the color of the line reflects the years when the co-operation or co-citation first appeared. In addition, the centrality reflects the role of the nodes in the knowledge network and indicates the influence of a node on the other nodes. Nodes with a larger centrality are more likely to become the key nodes in the network and are represented by purple on the node ring in the knowledge network map.^{6,7} In this study, an analysis of countries, organizations, author co-citations, journal co-citations, references, and co-occurrence of keywords was performed to explore the core strengths, core authors, core journals, intellectual base, and hotspots in the field of medication literacy.

Results

Analysis of core strengths

In CiteSpace, the node type was set to “Country and Institution,” the threshold was set to top 30, and the labeling was set to (15, 8, 16), which generated a knowledge map of the core strengths (Figure 1). Table 1 shows the top 5 countries according to centrality related to medication literacy.

Table 2 shows the top 5 institutions according to the number of publications, and Table 3 shows the top 5 institutions according to the centrality.

Analysis of authors and co-cited authors

Table 4 shows the top 10 authors according to the number of publications related to medication literacy. Generating a co-author map using CiteSpace resulted in 576 nodes and 410 links (Figure 2). Several collaborations among Bailey, Wolf, Davis, Parker, and Federman, and among Kripalani, Osborn, Rothman, and Wallston were observed. The other collaborations included two-author links that did not form larger co-operation networks.

For the analysis of author co-citations, the node type was set to “Cited Author,” the threshold was set to top 25, and the labeling was set to (2, 5, 100), which generated a map of author co-citations related to medication literacy publications (Figure 3). The author with the highest co-citation count was Davis TC (563 citations), followed by Ker DW (461 citations), Parker RM (344 citations), and Wolf MS (307 citations). Table 5 shows the top 5 co-cited authors according to centrality related to medication literacy.

Analysis of journals and co-cited journals

In CiteSpace, the node type was set to “Cited Journal,” the threshold was set to top 30, and the labeling was set to (200, 2, 2), which generated a map of journal co-citations related to medication literacy (Figure 4). Table 6 shows the top 10 co-cited journals according to centrality. The journal with the highest centrality was *Am J Public Health* (impact factor (IF) 2016, 3.858), followed by *Soc Sci Med* (IF 2016, 2.797).

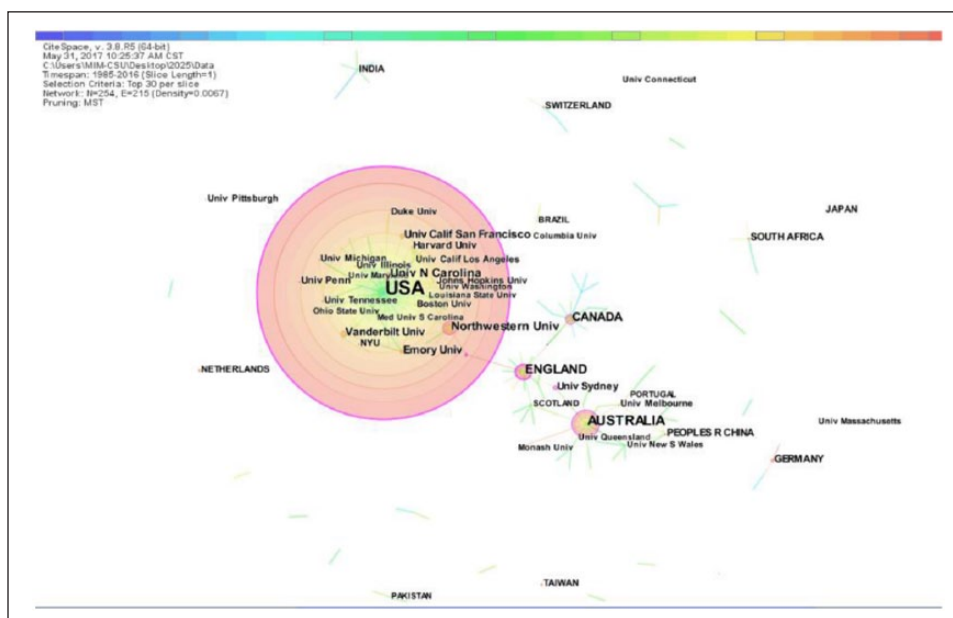


Figure 1. Knowledge map of countries and institutions performing medication literacy.

Table 1. Top 5 countries according to centrality related to medication literacy.

Ranking	Country	Centrality	Publications
1	The United States	0.45	1274
2	England	0.41	96
3	Australia	0.24	150
4	Canada	0.11	77
5	People's Republic of China	0.05	31

Table 2. Top 5 institutions according to the number of publications related to medication literacy.

Ranking	Research institute	Publication	Country
1	Northwestern University	86	The United States
2	University of North Carolina	67	The United States
3	Vanderbilt University	58	The United States
4	University of California, San Francisco	49	The United States
5	Emory University	43	The United States

Analysis of the intellectual base

In CiteSpace, the node type was set to “Cited Reference”, the threshold was set to top 45, the time slice was set to 5 years, and Pathfinder was selected for the pruning, which generated a map of reference co-citations (Figure 5). Tables 7 and 8, respectively, list the top 5 co-cited references according to the number of citations related to medication literacy and top 5 co-cited references according to centrality related to medication literacy.

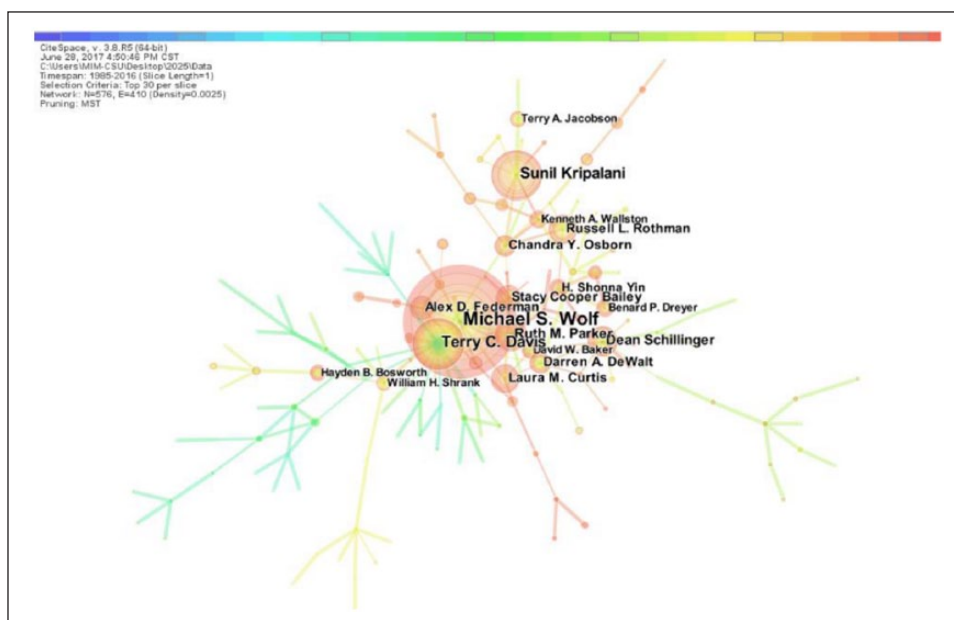
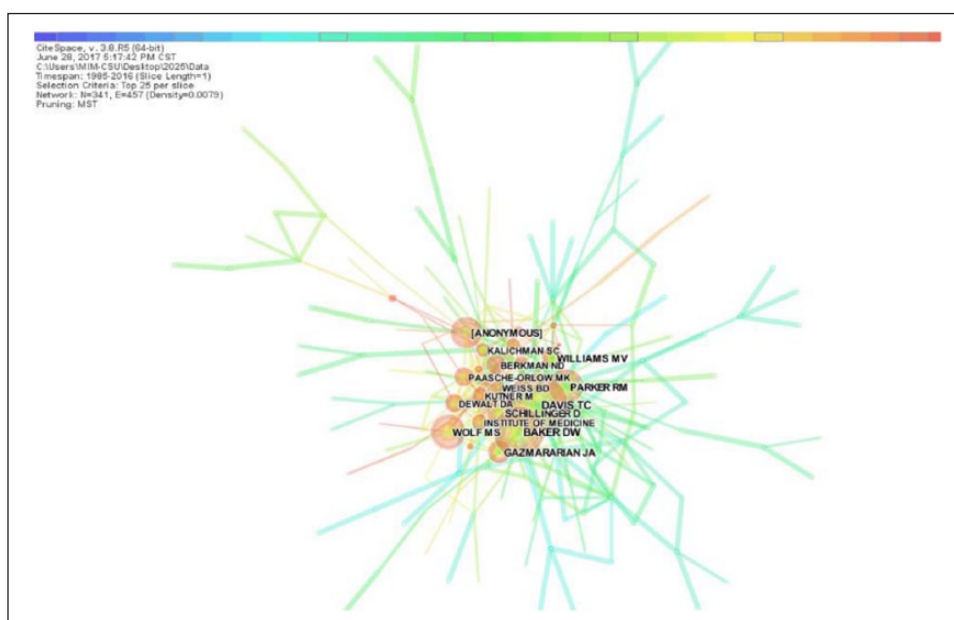
Table 3. Top 5 institutions according to centrality related to medication literacy.

Ranking	Research institute	Centrality	Country
1	Northwestern University	0.37	The United States
2	Queen Mary University of London	0.34	England
3	The University of Sydney	0.21	Australia
4	University of Toronto	0.13	Canada
5	The University of Melbourne	0.05	Australia

The clustering of similar references resulted in co-citation clusters that can provide insight into the main research topics in the intellectual base. The Modularity Q reflects the relationships and connections among the clusters. Generally, Modularity Q values between 0.4 and 0.8 are acceptable, and a Mean Silhouette value close to 1 indicates that references within a cluster contain highly consistent or similar content. Figure 6 shows the details of the co-citation reference clusters. The Modularity Q value was 0.729, and the Mean Silhouette value was 0.7077. In total, nine clusters were identified, including two major clusters (Table 9). Cluster #0, which was mainly labeled health and health literacy (locally linear regression (LLR) algorithm), ranked first and contained 33 references with a Mean Silhouette value of 0.754, followed by cluster #1, which was labeled brief test and health (LLR algorithm) and contained 27 references with a Mean Silhouette value of 0.841.

Table 4. Top 10 authors according to the number of publications related to medication literacy.

Ranking	Author	Publications	Ranking	Author	Publications
1	Wolf MS	87	6	Curtis LM	23
2	Davis TC	41	7	Rothman RL	23
3	Kripalani S	40	8	Bailey SC	20
4	Parker RM	26	9	Federman AD	19
5	Schillinger D	24	10	DeWalt DA	17

**Figure 2.** Map of co-authors performing studies related to medication literacy.**Figure 3.** Map of author co-citations related to medication literacy.

Analysis of hotspots

In CiteSpace, the node type was set to “Keyword,” the threshold was set to top 35, and Pathfinder was selected for the pruning, which generated a map of keyword co-occurrence related to medication literacy (Figure 7).

Table 5. Top 5 co-cited authors according to centrality related to medication literacy.

Ranking	Centrality	Co-citation counts	Start year	Cited author
1	0.10	141	1985	Doak CC
2	0.09	189	1999	Kalichman SC
3	0.07	563	1993	Davis TC
4	0.06	344	1995	Parker RM
5	0.05	254	1999	Gazmararian JA

Table 10 shows the top 10 keywords according to their frequency in the medication literacy literature. As shown in Table 10 and Figure 7, the keyword with the highest frequency was health literacy (659), followed by care (374), literacy (338), knowledge (254), adherence (254), and so on. In total, 13 keyword clusters, including 5 major clusters, were identified (Figure 8).

The largest cluster (cluster #0) included 47 keywords and a Mean Silhouette value of 0.682. This cluster was labeled reading ability by LLR algorithm, consent form by TFIDF algorithm, and clinical practice, identification of patients, adult literacy, care, skills, trust, communication, association, physicians, and providers by MI algorithm. This hotspot focused on instruments to assess medication literacy.

The second largest cluster (cluster #1) included 34 keywords and a Mean Silhouette value of 0.869. This cluster was labeled adolescents by LLR algorithm, school by TFIDF

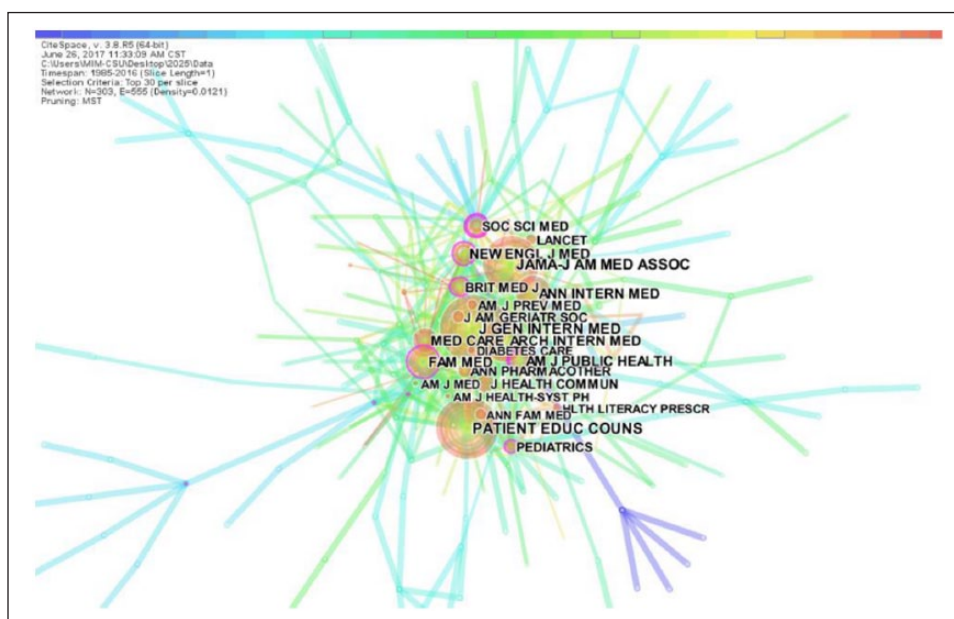


Figure 4. Map of journal co-citations related to medication literacy.

Table 6. Top 10 co-cited journals according to centrality related to medication literacy.

Ranking	Citation frequency	Centrality	Journal	Impact factor (2016)	5-year impact factor	Citation half-life
1	434	0.25	<i>Am J Public Health</i>	3.858	4.877	9.9
2	377	0.22	<i>Soc Sci Med</i>	2.797	3.505	>10.0
3	402	0.20	<i>Brit Med J</i>	20.785	19.355	>10.0
4	110	0.17	<i>Ann Emerg Med</i>	4.728	5.195	9.8
5	481	0.16	<i>New Engl J Med</i>	72.406	64.201	8.3
6	87	0.16	<i>J Reading</i>	–	–	–
7	515	0.12	<i>Fam Med</i>	1.203	1.363	>10.0
8	317	0.12	<i>Pediatrics</i>	5.705	6.476	8.9
9	1	0.11	<i>Reading Res Instruct</i>	–	–	–
10	880	0.10	<i>Patient Educ Couns</i>	2.429	3.042	7.5

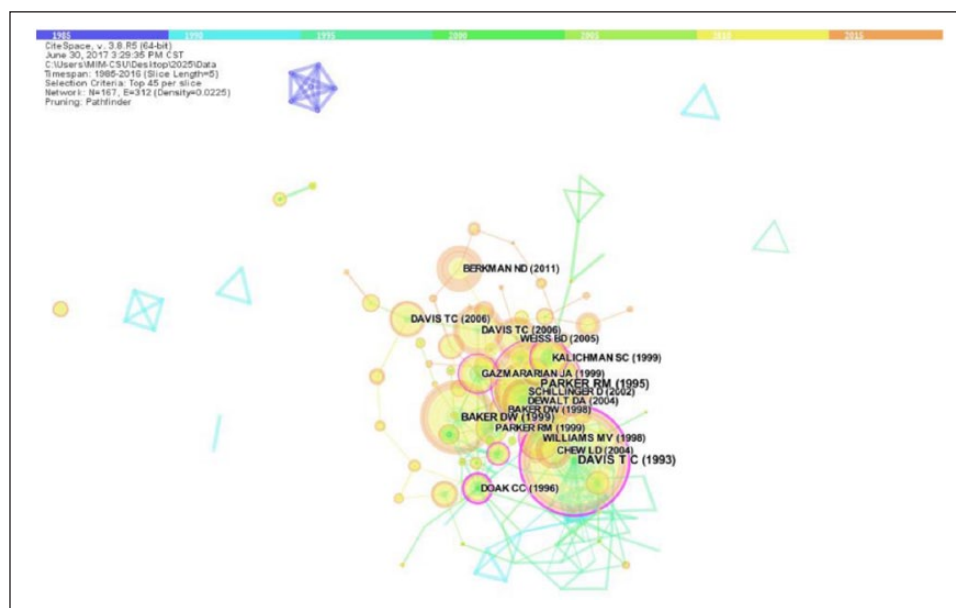


Figure 5. Map of reference co-citations related to medication literacy.

Table 7. Top 5 co-cited references according to the number of citations related to medication literacy.

Ranking	Co-citation counts	Cited reference	Representative author and publication year
1	283	REALM: a shortened screening instrument	Davis TC, 1993
2	245	The TOFHLA: a new instrument for measuring patients' literacy skills	Parker RM, 1995
3	201	Development of a brief test to measure functional health literacy	Baker DW, 1999
4	163	Association of health literacy with diabetes outcomes	Schillinger D, 2002
5	140	Literacy and misunderstanding prescription drug labels	Davis TC, 2006

REALM: rapid estimate of adult literacy in medicine; TOFHLA: test of functional health literacy in adults.

Table 8. Top 5 co-cited references according to centrality related to medication literacy.

Ranking	Centrality	Cited reference	Representative author and publication year
1	0.21	REALM: a shortened screening instrument	Davis TC, 1993
2	0.20	Strategies to improve cancer education materials	Doak CC, 1996
3	0.19	Adherence to combination antiretroviral therapies in HIV patients of low health literacy	Kalichman SC, 1999
4	0.15	Health literacy among Medicare enrollees in a managed care organization	Gazmararian JA, 1999
5	0.14	The TOFHLA: a new instrument for measuring patients' literacy skills	Parker RM, 1995

REALM: rapid estimate of adult literacy in medicine; TOFHLA: test of functional health literacy in adults.

algorithm, and reading, parents, disabilities, assessment, education materials, elderly people, literacy, children, discipline, prevention, emergency, knowledge, injuries, and mothers by MI algorithm. This hotspot focused on the measurement and assessment of medication literacy in various ages and groups.

The third largest cluster (cluster #2) included 34 keywords but a low Mean Silhouette value of 0.497. The fourth largest cluster (cluster #3) included 29 keywords and a

Mean Silhouette value of 0.798. This cluster was labeled obstructive pulmonary disease by LLR algorithm, ability by TFIDF algorithm, and diabetes mellitus, literacy, self-care, chronic illness care, functional health literacy, improving primary care, blood-glucose control, quality-of-life, outcomes, association, education, program, and system by MI algorithm. This hotspot focused on medication literacy for the prevention of chronic disease and the improvement of clinical outcomes and life.

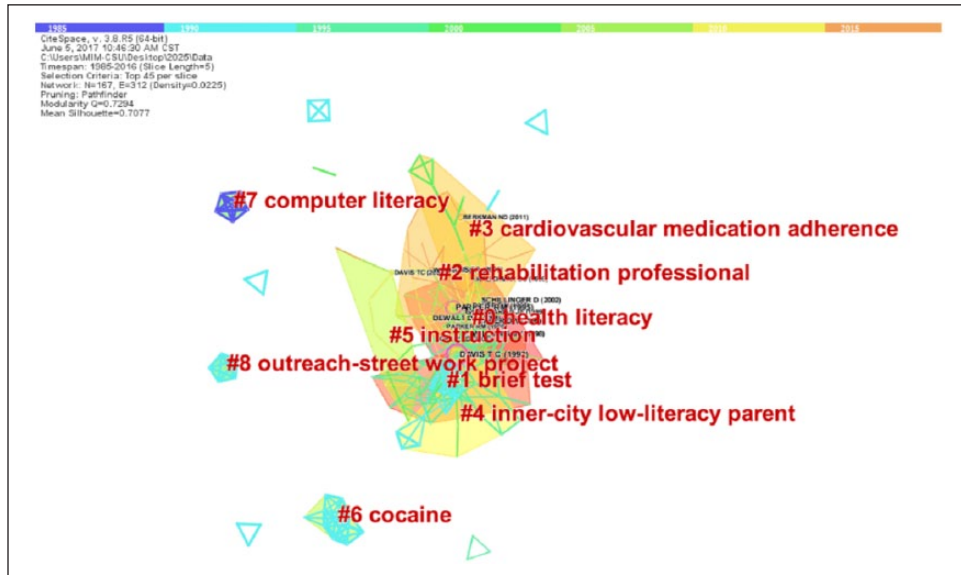


Figure 6. Map of reference co-citation clusters.

Table 9. Two major reference co-citation clusters.

ID	Size	Mean Silhouette	Mean year	Label (LLR algorithm)	Label (TFIDF algorithm)	Label (MI algorithm)
0	33	0.754	1998	Health (11.54), health literacy (11.2)	Health literacy (29.39, 1.0E-4)	Attitude
1	27	0.841	1989	Brief test (11.05), health (8.5)	Brief test (38.54, 1.0E-4)	Knowledge

LLR: locally linear regression; MI: mutual information; TFIDF: term frequency-inverse document frequency.

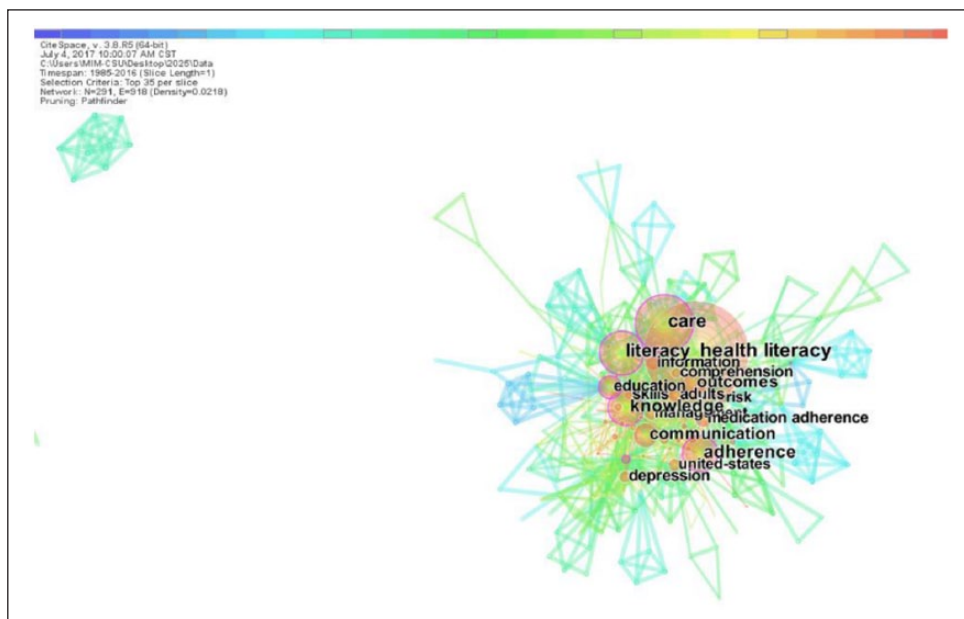


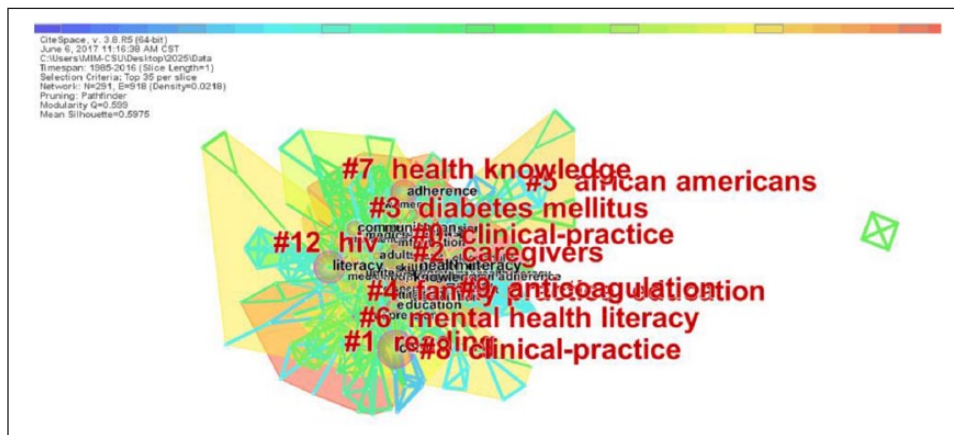
Figure 7. Map of keyword co-occurrence related to medication literacy.

The fifth largest cluster (cluster #4) included 26 keywords and a Mean Silhouette value of 0.894. This cluster was labeled family practice and education by LLR algorithm, epilepsy by TFIDF algorithm, and social support, self-efficacy,

medication adherence, limited literacy, controlled trial, care, knowledge, outcomes, risk, and experience by MI algorithm. This hotspot focused on literacy education and family practice.

Table 10. Top 10 keywords according to frequency related to medication literacy.

Ranking	Keyword	Frequency	Centrality	Ranking	Keyword	Frequency	Centrality
1	Health literacy	659	0.08	6	Outcomes	210	0.05
2	Care	374	0.19	7	Communication	197	0.07
3	Literacy	338	0.15	8	Education	173	0.17
4	Knowledge	254	0.13	9	Information	148	0.03
5	Adherence	254	0.13	10	Medication adherence	147	0.01

**Figure 8.** Map of keyword clusters.

Discussion

Core strengths

In this study, the United States was shown to produce more publications related to medication literacy than other countries. The United States had a strong advantage and an important influence on the field of medication literacy not only because of the number of publications but also due to the high centrality. By examining both the number of publications and centrality, the research strength was found to be mainly concentrated at research institutions of higher education. In the top 5 institutions according to the number of publications, all institutions were all in the United States. The institutions in the United States occupied the top rankings in terms of absolute contribution and influence, which is consistent with the analysis of the impact of the countries in the field of medication literacy. Because the level of health care is closely related with the rate of economic development, distribution tables of institutions provide valuable information and help researchers to identify potential collaborative institutions.

Core authors

By analyzing high-impact authors, the development and research trajectories of scientific studies can be determined, and the authors' academic influence can be determined according to the number of publications and the frequency of citations.¹⁴ Wolf MS et al.^{15–18} ranked first in publications related to medication literacy, which involved a wide range of research

topics on health literacy, medication literacy interventions, the relationship among literacy, medication knowledge, and medication adherence. As shown in Table 4, the top 8 authors published more than 20 papers, and these authors were active professionals in this field. According to the analysis of the cooperative network, several collaborations among Bailey, Wolf, Davis, Parker, and Federman, and among Kripalani, Osborn, Rothman, and Wallston were observed. The other collaborations included two-author links that did not form larger co-operation networks. In addition, the centrality of these collaborations was 0, suggesting that collaboration among authors is insufficient. By combining the citation frequency analysis and the centrality analysis, we found that Davis TC ranked first in citation frequency and that Doak CC (0.1) ranked first in centrality. However, the centrality of the other authors was less than 0.1, indicating that they did not form an influential core author group in the field of medication literacy. This result indicated that researchers should participate actively in studies investigating medication literacy and contribute important scientific input to this field.

Core journals

By performing a journal co-citation analysis, we identified the core journals related to medication literacy that reflect the utilization and influence of articles published in these journals. The more highly cited journals included *J Gen Intern Med*, *JAMA*, *Patient Educ Couns*, and so on. The journal with a higher centrality included *Am J Public Health*, *Soc Sci Med*,

Brit Med J, and so on. In total, all top 10 journals had a centrality greater than 0.1, indicating that the articles published in these journals had a higher quality and greater influence on medication literacy studies.

By combining the citation frequency analysis and centrality analysis, we found that *Patient Educ Couns* and *Fam Med* were both highly cited and high-centrality journals. *Patient Educ Couns* is an interdisciplinary, international journal for patient education and health promotion researchers, managers, and clinicians who seek to explore and elucidate educational, counseling, and communication models in health care.¹⁹ *Fam Med* particularly focuses on primary care medical education, health workforce policy, and health services studies.²⁰ These two journals publish many high-quality articles and were important literature sources; their academic influence was higher than that of other similar journals and played a strong role in the field of medication literacy.

Intellectual base

In bibliometrics, the frontier in a field of research represents the current developmental state of a discipline, and the references in the frontier article constitute the intellectual base of the field.⁷ By analyzing the references, we identified the intellectual base in the field of medication literacy. This study analyzed the references based on the following two parameters: citation frequency and centrality. The topics discussed in the references with higher citation frequencies focused on the development and application of health literacy assessment tools, such as the rapid estimate of adult literacy in medicine (REALM), the test of functional health literacy in adults (TOFHLA), and the short TOFHLA (S-TOFHLA).^{21–23} The topics discussed in the references with higher centrality focused on cancer education, treatment and medication adherence, and the relationship among the health literacy level, chronic diseases, and treatment knowledge.^{24–27}

In addition, in this study, we conducted a clustering analysis of the references. The clustering of similar references resulted in co-citation clusters, which could be used to explore the main topics in the intellectual base. We identified a total of nine clusters; the largest clusters were labeled health and health literacy. These nine clusters were relatively concentrated, non-dispersed, and overlapping, indicating that the topics in the intellectual base are concentrated. Comprehensively, the intellectual base in the field of medication literacy contained many topics related to health literacy, indicating that the field of medication literacy is closely related to the field of health literacy. Thus, medication literacy can be considered a new research field that originated from the field of health literacy.

Hotspots

A hotspot is a scientific issue or topic discussed in a group of documents that are intrinsically linked to a certain period of

time.²⁸ The keywords are generalizations of the topic in the literature. An analysis of high-frequency keywords can be used to determine the hotspots in the field of medication literacy. In this study, we conducted a statistical analysis of the high-frequency keywords. The keyword with the highest frequency was health literacy, indicating that medication literacy was closely related to health literacy. The other high-frequency keywords such as adherence, outcomes, and education indicated that the topics of medication literacy intervention in medication treatment adherence, clinical outcome, and literacy education were focused in the field of medication literacy.

In addition, the keywords were clustered in this study. The analysis produced a total of 13 clusters, resulting in 4 larger clusters. The topics included in these four clusters mainly focused on instruments assessing medication literacy, measurement and assessment of medication literacy, medication literacy for the prevention of chronic disease, medication literacy education, and family practice. Currently, two assessment tools for medication literacy are available, including the Medication Literacy Questionnaire, which was edited by Maniaci et al., and MedLitRxSE, which was established by Saucedo et al.¹ and Maniaci et al.⁴ No other established or widely recognized assessment tools were identified. Researchers could conduct studies based on the hotspots in this field.

Conclusion

In conclusion, we constructed knowledge maps of the state, organization, author co-citations, journal co-citations, and reference co-citations and keyword clusters. We found that the topics in medication literacy study focused on instruments assessing medication literacy, measurement and assessment of medication literacy, medication literacy for the prevention of chronic disease and medication treatment adherence, medication literacy education, and family practice. This study constructed comprehensive knowledge maps of medication literacy research, which provides an insight into medication literacy and valuable information for medication literacy researchers to identify new perspectives on potential collaborators and cooperative institutions, and hotspots.

Limitation

This study conducted a knowledge map analysis based on scientific literature obtained from the Web of Science Core database. The results were highly credible and showed good reliability. The data of this study are mainly derived from the Web of Science Core database, and other literature databases were not searched. Therefore, we might not have been able to retrieve all papers on this topic, and selection bias may have been present. In addition, the analyses performed in this study were mainly based on frequency and centrality using the visualization software CiteSpace. The centrality was

limited by the choice of the number of nodes, which may affect the accuracy of the conclusions, which is a limitation of this study.

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Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

Not applicable, because this article does not contain any studies with human or animal subjects.

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ORCID iD

Aijing Luo  <https://orcid.org/0000-0001-5890-3470>

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