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Publications on the Association Between Cognitive Function and Pain from 2000 to 2018: A Bibliometric Analysis Using CiteSpace

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: This study aimed to use CiteSpace software to conduct a bibliometric analysis of published studies on the association between pain and cognitive function from 2000 to 2018. The study also aimed to determine publication patterns and authorship and to identify recent trends for research in this field.

Material/Methods: Publications on the association between cognitive function and pain between 2000 and 2018 were identified from the Web of Science database. Bibliographic information, including authorship, country, citation frequency, changes in citation, and interactive visualization were generated using CiteSpace software. Co-citation, or frequency of two publications cited together by another publication, was also studied.

Results: On 8th January 2019, 4,889 publications were identified. The United States (1132 publications) and the University of Washington (87 publications) were the most productive country and institution, respectively. The journal, *Pain* (182 publications) had the largest number of publications and was the most frequently cited journal (citation counts, 1569) with the highest centrality (0.62). Author A had the largest number of publications (21). Author B had the greatest co-citation count (223). Author C tied with Author D as the first co-cited author in terms of centrality (0.18). Author E in 2011 (co-citation count, 96) and Author F in 2008 (centrality: 0.11) had the highest co-citation counts and centrality, respectively. The keyword 'empathy' ranked first for research developments with the highest citation burst (10.045).

Conclusions: Bibliometric analysis of the association between pain and cognitive function might identify new directions for future research.

MeSH Keywords: Association • Bibliometrics • Cognition • Pain

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Background

Pain is perceived as an unpleasant sensation associated with actual or potential tissue damage and is associated not only with sensation, but also has emotional, cognitive, and social components [1]. Pain has a high prevalence in daily life. During severe or chronic pain, most individuals have a poor quality of life and are limited in terms of daily activity and work capacity [2]. Most patients will seek medical treatment to help manage their pain, and this condition results in increased time and healthcare costs to individuals, families, society, and healthcare providers [3].

Pain-associated cognition has been extensively studied and is defined as the psychological processes associated with attention, memory, reasoning, and executive functions [4–6]. Cognition and pain are closely related, and cognitive dysfunction is regarded as a comorbidity of the experience of pain [2]. Studies that have included patients attending pain clinics and people with pain in the community have estimated that at least 50% of patients with pain report cognitive problems, and during objective cognitive tests, a similar proportion of patients show cognitive impairment [7]. The main impairments to cognitive function include reduced attention, impaired learning and memory, reduced speed of information processing, impaired psychomotor performance, as well as reduced execution capacity [2,7]. Several mechanisms may explain the association between pain and impaired cognitive function. Pain competes for attentional resources and disturbs the neurochemistry and neuroplasticity of areas in the brain. Some studies have shown that chronic pain is more common in the elderly where it can also be associated with other geriatric syndromes that may also affect cognitive function, sometimes reducing the subjective awareness of pain [2,8–12]. In the elderly, cerebral atrophy in the elderly may involve areas of the brain that are involved in both cognition and the experience of pain [2,8–12].

Bibliometrics is a quantitative method that uses mathematical and statistical methods to analyze the scientific publications, allowing researchers to identify the status and trends of a specific field, and make academic decisions [13–15]. The number of research publications continues to increase in all research fields. However, there has been limited bibliometric analysis of published research on the association between cognitive function and pain.

CiteSpace was developed in 2004 by Professor Chaomei Chen. Citespace V (Drexel University, Philadelphia, United States), a Java application, is a visualization tool for exploring the trends and patterns in a knowledge domain. CiteSpace can conceptualize knowledge domains as mapping functions between research fronts and intellectual bases, identifying the highly cited and pivotal points, identifying specialty areas, and detecting emerging trends [16]. CiteSpace V permits users to generate and analyze co-occurrence network maps of authors, countries, institutions, and keywords, and co-citation networks of cited authors, cited journals, and cited references, based on bibliographical records collected from the Web of Science [17].

Therefore, this study aimed to use CiteSpace V software to conduct a bibliometric analysis of published studies on the association between pain and cognitive function from 2000 to 2018. The study also aimed to determine publication patterns and authorship and to identify recent trends for research in this field.

Material and Methods

Data collection

Data were collected from the Science Citation Index Expanded (SCI-E) of the Web of Science Core Collection (WoSCC). The data retrieval strategy included the topic (cognition or cognitive function) AND the topic (pain), with the publications identified between 2000–2018. In this study, publication type and language had no restriction. The expanded dataset included 4,889 publications, which were reviewed on 8th January 2019.

Method of analysis using CiteSpace version V

CiteSpace was the method chosen to perform the bibliometric analysis, including the analysis of the trends and patterns in the identified publications [16]. The visualization knowledge network created by CiteSpace consisted of nodes and lines. The nodes in the network stood for items, such as authors, countries, institutions, and cited references, and lines between the nodes represented cooperation or co-occurrence or co-citation relationships. The size of each node indicated the count. Each node was represented by a series of citation rings that represented different years, and the thickness of the ring was proportional to the citation count in the corresponding time zone. The purple ring represented centrality, which identified and measured the importance of the publication, and a node with high centrality was considered to be a pivotal point in the publication [17–20].

Results

Distribution of publication output

A total of 4,889 publications were included in the study. The distribution of annual publications varied at different times (Figure 1). In general, research interest on cognitive function and pain has increased significantly in recent years, as the number of publications increased from 76 in 2000, to 509 in 2018.

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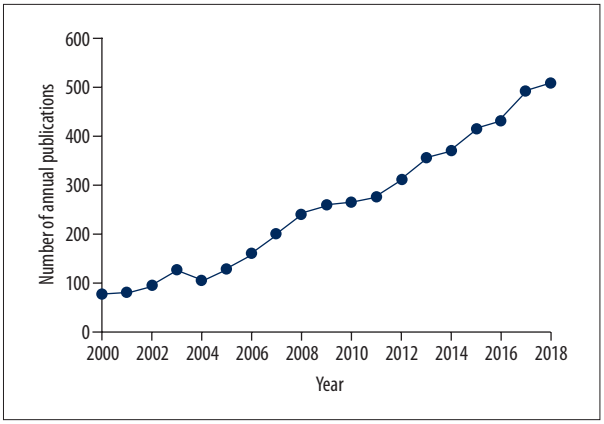

Figure 1. The number of annual publications on cognitive function and pain research between 2000–2018. The horizontal coordinates represent the year of publication. The vertical coordinates represent the number of publications.

Table 1. Types of publications on the association between cognitive function and pain between 2000–2018.

Ranking	Type of publication	Counts (%)	
1	Article	3,976	(81.325)
2	Review	810	(16.568)
3	Proceedings paper	120	(2.454)
4	Meeting abstract	49	(1.002)
5	Editorial material	47	(0.961)
6	Book chapter	26	(0.532)
7	Letter	3	(0.061)
8	Retracted publication	3	(0.061)
9	Correction	2	(0.041)
10	Early-access	2	(0.041)
11	Reprint	2	(0.041)

The data were taken from Web of Science on 8 January 2019.

Distribution of publication type

Eleven publication types were identified from a total of 4,889 publications (Table 1). Journal articles (3,976, 81.325%) were the most common publication type, followed by review articles (810, 16.568%) and proceedings or meetings abstracts (120, 2.454%).

Distribution of country and institution

The generation of a country network with CiteSpace V identified 50 nodes (Figure 2). The 4,889 references were published in 50 countries or regions. As shown in Table 2, the country

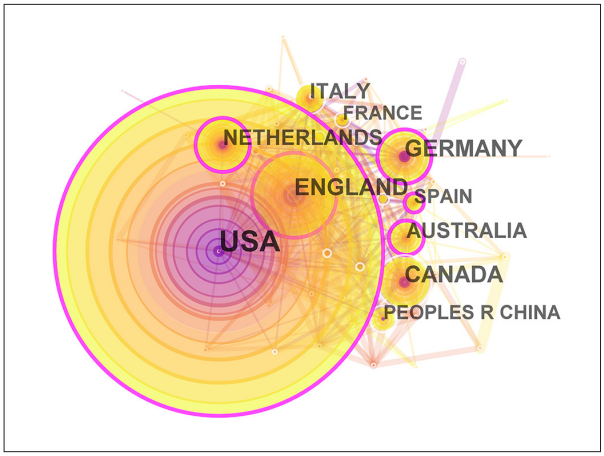

Figure 2. Map of the main countries that published on cognitive function and pain research between 2000–2018. The nodes in the map represent countries/territories. The lines between the nodes represent cooperation relationships. The larger the area of the node, the larger the number of publications. The purple ring represents centrality, and nodes with high centrality are considered as pivotal points in the literature. USA, United States of America; PEOPLES R CHINA, the People's Republic of China.

with the most publications was the US (1132 publications), followed by England (347 publications), Canada (258 publications), Germany (256 publications), and the Netherlands (241 publications). The first country in terms of centrality (round, purple node) was England (0.19), followed by Spain (0.15), Australia (0.13), the Netherlands (0.12), and Germany (0.11).

Generating an institutional network with CiteSpace contributed to 331 nodes (Figure 3), that is, 331 institutions published a total of 4,889 publications on the association between cognitive function published between 2000 to 2018. As shown in Table 3, the institution with the most publications was the University of Washington (87 publications), followed by the University of Toronto (73 publications), Harvard University (71 publications), the University of Sydney (50 publications), and King's College, London (49 publications). The lead institution in terms of centrality was Duke University (0.15), followed by the University of Washington (0.13), the University of Toronto (0.13), the Karolinska Institute (0.12), and King's College, London (0.10).

Distribution of journals and co-cited journals

The top ten journals that published manuscripts on cognitive function and pain research are shown in Table 4. Among them, *Pain* was the most productive journal in terms of studies on cognitive function and pain research (182 publications). Figure 4 and Table 5 show co-citation combined with centrality. The journals, *Pain*, *Journal of Neuroscience*, *Science*, and the

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Table 2. The top 11 countries publishing on the association between cognitive function and pain between 2000–2018.

Rank	Publications	Country	Centrality	Country
1	1132	United States	0.19	England
2	347	England	0.15	Spain
3	258	Canada	0.13	Australia
4	256	Germany	0.12	Netherlands
5	241	Netherlands	0.11	Germany
6	179	Australia	0.10	United States
7	162	Italy	0.09	Israel
8	145	China	0.08	France
9	119	France	0.07	Belgium
10	118	Spain	0.06	Canada
11	112	Sweden	0.06	Denmark

The data were derived from analysis using CiteSpace V, of the 4,889 publications retrieved on 8 January 2019.

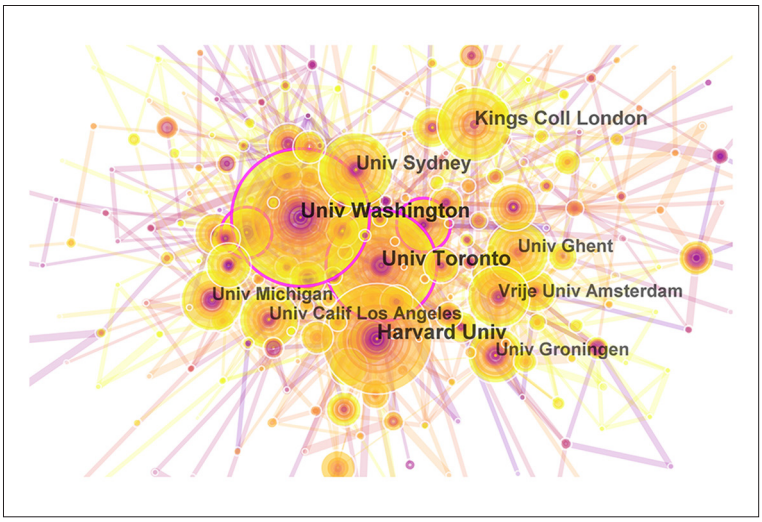

Figure 3. Map of the institutions that published on cognitive function and pain research between 2000–2018. The nodes in the map represent institutions, and lines between the nodes represent collaborative relationships. The larger the node area, the larger the number of publications. The purple ring represents centrality, and nodes with high centrality are considered as pivotal points in the literature. Univ Washington, University of Washington; Univ Toronto, University of Toronto; Harvard Univ, Harvard University; Univ Sydney, University of Sydney; Kings Coll London, King's College London; University of Michigan, Univ Michigan; Vrije Univ Amsterdam, Vrije Universiteit Amsterdam; Univ Calif Los Angeles, University of California, Los Angeles; Univ Ghent, Ghent State University; Univ Groningen, University of Groningen.

Lancet were the most influential in terms of research publications on the association between cognitive function and pain.

Distribution of author and co-cited author

There were 503 authors who contributed to a total of 4,889 publications. The top ten most prolific authors who published on cognitive function and pain are shown in Table 6. Six authors made the greatest published research contributions in the field. Author A (Jensen MP) had the highest number of publications (21). Author B (Ware JE) had the highest co-citation count (223). Author C (Apkarian AV) tied with Author D (Eccleston C) as the first co-cited author concerning centrality (0.18). Landmark publications were by Author E (Moriarty O) in 2011 (co-citation count, 96) [2], and Author F (Baliki MN) in 2008 (centrality: 0.11) [38], who had the highest co-citation counts and centrality, respectively (Figure 5, Table 7). Other key authors were Meeus M (16 publications) and McCracken LM (15 publications), and key co-cited authors were Sullivan MJL, Beck AT, Turk DC, and Folstein MF.

Distribution of co-cited references

Citation analysis is an important indicator in bibliometrics. Figure 6 shows a cited reference co-citation map generated by CiteSpace V, which indicated the scientific relevance in terms of citations. Tables 8 and 9 present the top six co-cited references in relation to co-citation counts and centrality during

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Table 3. The top ten most prolific academic institutions publishing on the association between cognitive function and pain between 2000–2018.

Rank	Publications	Institution	Centrality	Institution
1	87	University of Washington	0.15	Duke University
2	73	University of Toronto	0.13	University of Washington
3	71	Harvard University	0.13	University of Toronto
4	50	University of Sydney	0.12	Karolinska Institute
5	49	King's College, London	0.10	King's College, London
6	46	University of Michigan	0.09	Stanford University
7	42	Vrije Universiteit, Amsterdam	0.08	University of Sydney
8	40	University of California, Los Angeles	0.08	Vrije Universiteit, Amsterdam
9	40	Ghent State University	0.08	Maastricht university
10	38	University of Groningen	0.08	Boston University

The data were derived from analysis using CiteSpace V, of the 4,889 publications retrieved on 8 January 2019.

Table 4. The top ten academic journals publishing on the association between cognitive function and pain between 2000–2018*.

Rank	Publications*	Journal	IF** (2017)
1	182	*Pain*	5.559
2	87	*Clinical Journal of Pain*	3.209
3	85	*PLoS One*	2.766
4	81	*Journal of Pain*	4.859
5	74	*European Journal of Pain*	2.991
6	71	*Pain Medicine*	2.782
7	54	*Journal of Pain and Symptom Management*	3.249
8	50	*Cochrane Database of Systematic Reviews*	6.754
9	43	*Journal of the American Geriatrics Society*	4.155
10	43	*Quality of Life Research*	2.392

* The data were taken from Web of Science on 8 January 2019. ** The data were taken from *https://www.geenmedical.com/* on 12 January 2019. IF – impact factor.

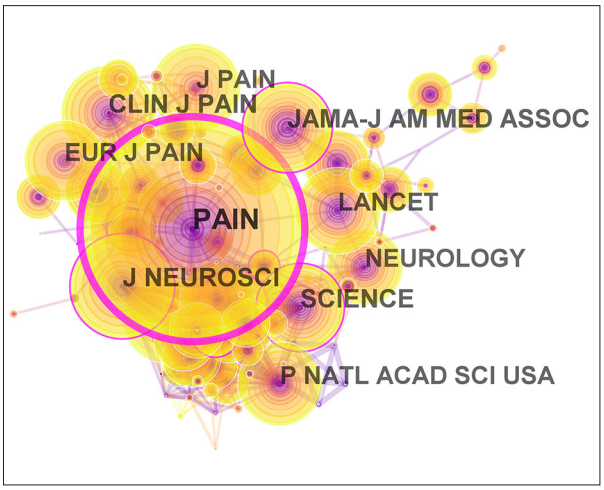

Figure 4. Journal co-citation map associated with publications on cognitive function and pain research between 2000–2018. The nodes in the map stand represent journals, and lines between the nodes represent co-citation relationships. The larger the node area, the greater the number of co-citations. The purple ring represents centrality, and nodes with high centrality are considered as pivotal points in the literature. J NEUROSCI, *Journal of Neuroscience*; CLIN J PAIN, *Clinical Journal of Pain*; JAMA-J AM MED ASSOC, *JAMA, Journal of The American Medical Association*; J PAIN, *Journal of Pain*; P NATL ACAD SCI USA, *Proceedings of The National Academy of Sciences of The United States of America*; EUR J PAIN, *European Journal of Pain*.

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Table 5. Top ten co-cited journals and centrality on the association between cognitive function and pain between 2000–2018.

Rank	Co-citation counts	Cited journal	Centrality	Cited journal
1	1569	*Pain*	0.62	*Pain*
2	797	*Journal of Neuroscience*	0.21	*Brain*
3	721	*Clinical Journal of Pain*	0.17	*JAMA. Journal of The American Medical Association*
4	705	*JAMA. Journal of The American Medical Association*	0.13	*Journal of Neurology Neurosurgery and Psychiatry*
5	684	*Science*	0.12	*Journal of Neuroscience*
6	660	*Lancet*	0.12	*Science*
7	654	*Journal of Pain*	0.10	*Neuroscience Letters*
8	646	*Proceedings of The National Academy of Sciences of The United States of America*	0.10	*American Journal of Psychiatry*
9	634	*European Journal of Pain*	0.10	*Biological Psychiatry*
10	611	*Neurology*	0.09	*Lancet*

The data were derived from analysis using CiteSpace V, of the 4,889 publications retrieved on 8 January 2019.

Table 6. Top 11 authors who published on the association between cognitive function and pain between 2000–2018.

Rank	Publications	Author
1	21	Jensen MP
2	16	Meeus M
3	15	Mccracken LM
4	10	Borsook D
5	10	Nijs J
6	10	Eccleston C
7	9	Davis KD
8	9	Edwards RR
9	8	Koyanagi A
10	8	Kurita GP
11	8	Cagnie B

The data were derived from analysis using CiteSpace V, of the 4,889 publications retrieved on 8 January 2019.

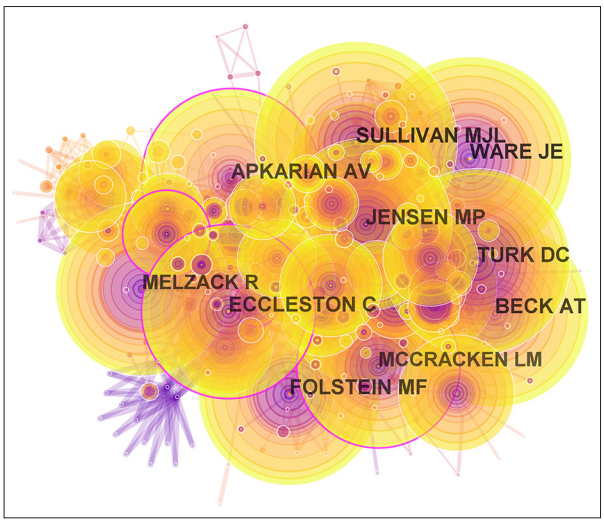

Figure 5. Map of co-cited authors that contributed to publications on cognitive function and pain research between 2000–2018. The nodes in the map represent co-cited authors, and lines between the nodes represent co-citation relationships. The larger the node area, the greater the number of co-citations. The purple ring represents centrality, and nodes with high centrality are considered to be pivotal points in the literature.

19 years, respectively. These cited studies are landmark publications in this field, providing the foundation for future studies.

Distribution of keywords

Over time, the keyword co-occurrence knowledge map reflects topicality. A total of 177 co-occurring keywords appeared from 2000 to 2018, reflecting the range of research topics on the association between pain and cognitive function (Figure 7). As shown in Table 10, the most common keywords were 'pain,' 'quality of life,' 'depression,' 'cognition,' 'low back pain,' and 'disability.' The keywords associated with an increased burst

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Table 7. Top ten co-cited authors in terms of co-citation counts and centrality who published on the association between cognitive function and pain between 2000–2018.

Ranking	Co-citation counts	Cited author	Centrality	Cited author
1	223	Ware J.E.	0.18	Apkarian A.V.
2	221	Sullivan M.J.L.	0.18	Eccleston C.
3	206	Beck A.T.	0.14	Craig A.D.
4	204	Turk D.C.	0.13	McCracken L.M.
5	196	Folstein M.F.	0.12	Lorenz J.
6	193	Apkarian A.V.	0.1	Turk D.C.
7	191	Jensen M.P.	0.1	Singer T.
8	191	Eccleston C.	0.09	Wolfe F.
9	190	Melzack R.	0.07	Folstein M.F.
10	187	Anonymous	0.07	Crombez G.

The data were derived from analysis using CiteSpace V, of the 4,889 publications retrieved on 8 January 2019.

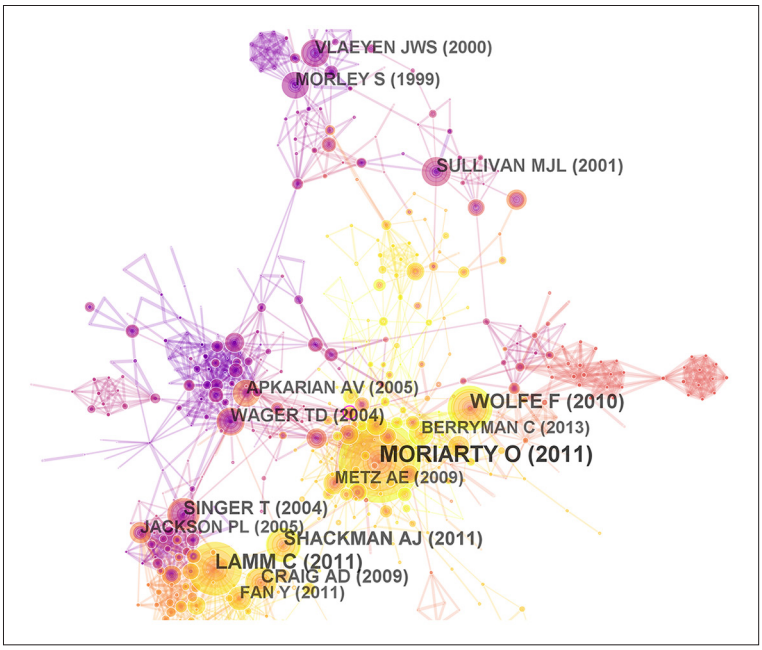

Figure 6. Reference co-citation map related to publications in cognitive function and pain research between 2000–2018. The nodes in the map represent co-cited references, and lines between the nodes represent co-citation relationships. The larger the node area, the greater the number of co-citations. The purple ring represents centrality, and nodes with high centrality are considered as pivotal points in the literature.

in citation, which frequently appeared within a certain period, were considered to be indicators of frontier topics or emerging trends [19,20]. CiteSpace was used to detect the citation burst keywords [21]. Figure 8 shows the top 32 keywords with the strongest citation bursts between 2010 and 2018. The most recent burst keywords were 'empathy,' 'outcome,' 'physical activity,' 'older adult,' 'impact,' 'meta-analysis,' 'cognitive behavioral therapy,' 'performance,' 'fatigue,' and 'primary care.' The keyword 'empathy,' which emerged from 2012, showed the strongest citation burst (10.045).

Discussion

This study used CiteSpace V software to conduct a bibliometric analysis of published studies on the association between pain and cognitive function and included the period from 20004018. The study evaluated all types of publication and identified 4,889 publications that included journal articles (3,976, 81.325%), review articles (810, 16.568%), and proceedings or meetings abstracts (120, 2.454%). According to the annual publications, the overall trend in publications in this field showed a pattern from 2000–2003, where annual publications increased slowly, and from 2004–2018, where annual publications in this field increased rapidly.

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Table 8. Top six co-cited references related to the association between cognitive function and pain between 2000–2018.

Rank	Co-citation counts	Co-cited reference	First author (year)
1	96	The effect of pain on cognitive function: A review of clinical and preclinical research	Moriarty O. (2011) [2]
2	63	Meta-analytic evidence for common and distinct neural networks associated with directly experienced pain and empathy for pain	Lamm C. (2011) [37]
3	55	The American College of Rheumatology Preliminary Diagnostic Criteria for Fibromyalgia and Measurement of Symptom Severity	Wolfe F. (2010)
4	43	The integration of negative affect, pain and cognitive control in the cingulate cortex	Shackman A.J. (2011)
5	40	Empathy for pain involves the affective but not sensory components of pain	Singer T. (2004) [39]
6	39	How do you feel – now? The anterior insula and human awareness	Craig A.D. (2009)

The data were derived from analysis using CiteSpace V, of the 4,889 publications retrieved on 8 January 2019.

Table 9. Top six co-cited references in terms of centrality for publications on the association between cognitive function and pain between 2000–2018.

Rank	Centrality	Co-cited reference	First author (year)
1	0.11	Beyond feeling: Chronic pain hurts the brain, disrupting the default-mode network dynamics	Baliki M.N. (2008) [38]
2	0.09	The integration of negative affect, pain and cognitive control in the cingulate cortex	Shackman A.J. (2011)
3	0.09	Coping or acceptance: what to do about chronic pain?	McCracken L.A. (2003)
4	0.08	Imaging how attention modulates pain in humans using functional MRI	Bantick S.J. (2002)
5	0.07	Empathy for pain involves the affective but not sensory components of pain	Singer T. (2004)
6	0.07	Human brain mechanisms of pain perception and regulation in health and disease	Apkarian A.V. (2005)

The data were derived from analysis using CiteSpace V, of the 4,889 publications retrieved on 8 January 2019. MRI – magnetic resonance imaging.

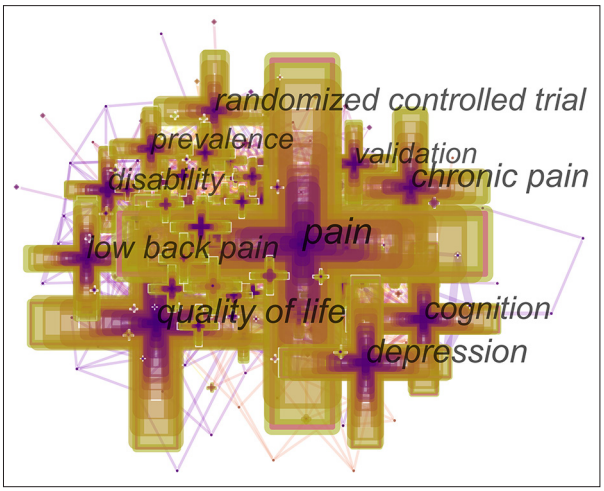

Figure 7. Map of the occurrence of keywords in publications on cognitive function and pain research between 2000–2018. The nodes in the map represent keywords. The lines between the nodes represent co-occurrence relationships. The larger the node area, the higher the frequency. The purple ring represents centrality, and nodes with high centrality are considered as pivotal points in the literature.

Most publications were in the form of journal articles, which were mainly original research articles. The most cited original research article was by published by Vos et al. in 2012 [22]. In this published study, the authors reported that the main causes of years lived with disability (YLDs) were low back pain and neck pain, with anxiety disorders and migraine [22].

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Table 10. Top ten keywords in terms of frequency and centrality for publications on the association between cognitive function and pain between 2000–2018.

Ranking	Counts	Keyword	Centrality	Keyword
1	726	Pain	0.27	Pain
2	495	Quality of life	0.11	Depression
3	342	Depression	0.11	Cognition
4	322	Chronic pain	0.10	Quality of life
5	310	Cognition	0.09	Low back pain
6	259	Low back pain	0.09	Brain
7	254	Randomized controlled trial	0.09	Anxiety
8	193	Disability	0.08	Disability
9	184	Validation	0.08	Fibromyalgia
10	177	Prevalence	0.08	Management

The data were derived from analysis using CiteSpace V, of the 4,889 publications retrieved on 8 January 2019.

Low back pain and neck pain comprised up to two-thirds of YLDs from musculoskeletal disease, which is the second largest contributor to YLDs globally [22]. This highly cited publication clearly had international relevance and generated global interest, which explained its high citation.

In this bibliometric analysis of publications on the association between pain and cognitive function, analysis by country and institution identified that four of the top ten most prolific institutions were from the US. This finding was also reflected by the centrality of the country of origin of the top ten academic institutions, indicating the US academic institutions were research leaders in this field. The top ten most prolific journals and co-cited journals were professional journals in this field. The United States (1132 publications) and the University of Washington (87 publications) were the most productive country and institution, respectively. Among the top ten most prolific journals, only the *Cochrane Database of Systematic Reviews,* with an impact factor (IF) in 2017 of 6.754, and *Pain,* with an IF in 2017 of 5.559, had an IF >5.000. Four journals, including the *Journal of Pain* (2017 IF, 4.859), the *Journal of the American Geriatrics Society* (2017 IF, 4.155), the *Journal of Pain and Symptom Management* (2017 IF, 3.249), and the *Clinical Journal of Pain* (2017 IF, 3.209), had an IF >3.000. Also, the top ten most prolific journals, with a high IF (>3.000) published 17% of all the publications identified.

In this study, CiteSpace V helped to identify the top authors in terms of numbers of publications and the number of citations, and the information on author citation in the field contributing to establishing potential co-authorships. Six authors made the most significant research contributions in the field. Author A (Jensen MP) had the highest number of publications (21). Author B (Ware JE) had the highest co-citation count (223). Author C (Apkarian AV) tied with Author D (Eccleston C) as the first co-cited author in terms of centrality (0.18). Landmark publications were by Author E (Moriarty O) in 2011 (co-citation count, 96) [2], and Author F (Baliki MN) in 2008 (centrality: 0.11) [38], who had the highest co-citation counts and centrality, respectively. Author A, who was the most productive author, with 21 publications, was based at the University of Washington in the US and studied the relationship between pain and cognition, including measures of the cognitive process, the effect of catastrophizing, pain management, and cognitive and behavioral models of chronic pain [23–28]. Author B, who was the top co-cited author according to the co-citation counts, was a professor at the University of Massachusetts in the US. In one of his studies, he recommended that aged patients suffering from several chronic diseases should complete a brief initial composite measure that includes measurement of pain and the assessment of cognitive function [29]. Author C worked with author D for the first co-cited author in terms of centrality. Author C was based at Northwestern University, and mainly studied the neurochemical and morphological mechanisms of pain-associated cognitive impairment and the mechanisms that drove pain chronicity. For example, author C found that the reorganization of the medial prefrontal cortex, which is critical to the perception of chronic pain, was associated with neuropathic pain [30]. Author D, based at the University of Bath in England, has several publications on the management of pain in children, adolescents, and older adults and the effect of pain on attention, execution, and reasoning [31–36].

In bibliometric studies, CiteSpace can also identify landmark publications that are highly cited by scientists and that reflect active frontiers and developments in research [16]. The top six co-cited references, shown in Tables 8 and 9, had high

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Keywords	Year	Strenght	Begin	End	2010–2018
Working memory	2000	13.5958	2010	2015	
Emotion	2000	11.0867	2010	2013	
Fibromyalgia	2000	5.1527	2010	2011	
Long termpotentiation	2000	4.8815	2010	2012	
Sleep	2000	4.5251	2010	2011	
Efficacy	2000	3.6905	2010	2011	
Parkinson's disease	2000	3.4087	2010	2011	
Anterior cingulate cortex	2000	3.3531	2010	2012	
Human	2000	9.5349	2011	2013	
Empathy	2000	10.045	2012	2018	
System	2000	8.0768	2012	2013	
Disorder	2000	5.0413	2012	2015	
Executive function	2000	4.2359	2012	2013	
Irritable bowel syndrome	2000	7.4004	2013	2014	
Social cognition	2000	7.1505	2013	2015	
Behavior	2000	3.5823	2013	2014	
Perception	2000	3.573	2013	2015	
Dementia	2000	6.0861	2014	2016	
Risk factor	2000	5.2074	2014	2016	
Disease	2000	4.9281	2014	2016	
Women	2000	4.779	2014	2015	
Alzheimers disease	2000	3.0719	2014	2015	
Outcome	2000	7.9872	2015	2018	
fMRI	2000	4.1826	2015	2016	
Physical activity	2000	9.7646	2016	2018	
Older adult	2000	8.3627	2016	2018	
impact	2000	6.2299	2016	2018	
Meta-analysis	2000	5.8666	2016	2018	
Cognitive behavioral therapy	2000	4.9014	2016	2018	
Permormance	2000	4.7215	2016	2018	
Fatigue	2000	3.9235	2016	2018	
Primary care	2000	3.438	2016	2018	

Figure 8. The keywords with the strongest citation bursts for publications on cognitive function and pain research between 2000–2018. The red bars represent frequently cited keywords. The green bars represent infrequently cited keywords. In view of the large study number, only the burst keywords between 2000–2018 are shown. fMRI – functional magnetic resonance imaging.

co-citation counts (≥39) and centrality (≥0.07), respectively. These references were representative and notable, providing an intellectual base in this field. Author E's 2011 publication, a review of clinical and experimental studies, ranks as the first co-cited reference in relation to co-citation counts [2]. The author described the evidence and possible mechanisms for pain-related cognitive difficulty, including impaired attention, execution, and general cognition [2]. Author E proposed a possible mechanism for cognitive impairment as pain competes for limited cognitive resources and disrupts the neuroplasticity and neurochemistry of the brain [2]. The second co-cited reference in relation to co-citation counts was from the publication by Lamm et al. [37], which was published in 2011. The authors performed image-based and coordinate-based analysis and provided evidence that the anterior insula (AI) and the medial/anterior cingulate cortex (MCC/ACC) were also activated during pain, and were involved in the main neural networks associated with empathy [37]. The first co-cited reference in

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terms of centrality was written by author F (Baliki MN) and colleagues, which was published in 2008 [38]. The authors proposed that a series of brain regions known to be active at rest, recognized as the components of the default-mode network (DMN), usually restrain their activity during the performance of tasks, and the DMN is disrupted in some diseases [38]. These authors studied whether cognitive impairment combined with chronic pain were derived from disturbed DMN dynamics by studying functional magnetic resonance imaging (fMRI) of subjects during task performance, which confirmed DMN disruption during pain-related cognitive and behavioral impairment [38].

Burst keywords are considered to be indicators of frontier topics or emerging trends. In this study, the most recent burst keywords included 'empathy,' 'outcome,' 'physical activity,' 'older adult,' 'impact,' 'meta-analysis,' 'cognitive behavioral therapy,' 'performance,' 'fatigue,' and 'primary care.' There were three main research frontiers in terms of burst strength for cognitive function and pain research, 'empathy,' 'physical activity,' and 'older adults.' Empathy is defined as the ability to understand the feelings of others, and in terms of suffering and pain, empathy can be modulated by cognitive and motivational processes. Several studies have shown that the anterior insular cortex and the anterior cingulate cortex are important in the processing of feeling of empathy, and they are commonly activated when individual experience pain or observe others experiencing pain [39–43]. Pain and physical activity are also associated with cognitive function, and cognition can adjust pain-related changes in physical activity. For example, a high level of cognition is linked to increased physical activity and a low pain level [44–49]. Pain is a common problem in older adults that may affect cognitive function [10]. In 2011, half of the older adult population of the US was reported to suffer from pain associated with a decline in physical function, and as the elderly population is expected to double in the US by 2050, older adults suffering from pain is expected to reach 80%, which highlights the importance of studying pain and cognition in the elderly [50–54].

This study had several limitations. Publications were retrieved only from the SCI-E databases of the Web of Science, and limited terms were used in the publication retrieval strategy. The search strategy may not have identified all the relevant studies in the field, including the 'grey literature' that included publications not formally published in indexed journals [55]. Also, the publications retrieved from SCI-E were mainly (96%) in the English language, and publications in the non-English language were limited. The findings from other databases may have resulted in different results, including from Google Scholar, PubMed, and Scopus [56]. It is also possible that not all the highly-cited references contained keywords. More specialized knowledge is needed to use CiteSpace, which might be considered to be a limitation for future studies [16]. However, this study has shown the value of CiteSpace as a tool for objective bibliometric analysis [16].

Conclusions

This study aimed to use CiteSpace V software to conduct a bibliometric analysis of published studies retrieved from Web of Science on the association between pain and cognitive function from 2000 to 2018, to determine publication patterns and authorship, and to identify recent trends for research in this field. The results may help investigators to determine the status of research topics and identify new directions for future research in the field. The findings showed that most publications were from the US, and the most productive institution in terms of the number of publications in this field was the University of Washington, the most productive and co-cited journal was *Pain*. Six authors were identified to have pivotal publications in this field. Analysis of keywords identified 'empathy,' 'physical activity,' and 'older adult' as terms that may represent emerging areas of research in this field.

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Conflict of interests

None.

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