

# Bibliometric Analysis of Post-Stroke Pain Research Published from 2012 to 2021

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**Background and Purpose:** Pain is one of the most common symptoms in patients after stroke. It is a distressing experience that affects patients' quality of life, and it is highly prevalent in clinical practice. The pathogenesis mechanisms of PSP are not so clear, and there is currently a lack of effective medical treatments, hence it is necessary to establish a sufficient understanding of this disease. Limited number of studies have applied bibliometric methods to systematically analyze studies on post-stroke pain. This study aimed to systematically analyze scientific studies conducted worldwide on post-stroke pain from 2012 to 2021 to evaluate global trends in this field using a bibliometric analysis.

**Methods:** Publications related to post-stroke pain from 2012 to 2021 were obtained from the Web of Science Core Collection database. Bibliometrics Biblioshiny R-package software was used to analyze the relationship of publication year with country, institution, journals, authors, and keywords and to generate variant visual maps to show annual publications, most relevant countries, authors, sources, keywords, and top-cited articles.

**Results:** In this study, 5484 papers met the inclusion criteria. The annual growth rate of publications was 5.13%. The USA had the highest number of publications (1381, 25.2%) and citations (36,395), and the University of Toronto had the highest number of papers (156, 2.8%). "Stroke", "management", "pain", "risk", "prevalence", "ischemic stroke", "risk factors", "disease", "diagnosis" and "therapy" are the top 10 keywords.

**Conclusion:** The global research interest regarding PSP has maintained growing over the past ten years. Both central post stroke pain and hemiplegic shoulder pain are the hottest research subjects. Further investigations are needed in order to reveal the mystery of the pathophysiologic mechanisms of CPSP, and high-quality well-designed trials of potential treatments of CPSP and HSP are also needed.

**Keywords:** post-stroke pain, publication trends, bibliometric analysis, research interest

## Introduction

Post-stroke pain (PSP) is a common and refractory disabling complication in stroke survivors. The mean prevalence of the various types of post-stroke pain was 29.56%, which was higher in the subacute and chronic stages than in the acute post-stroke stage (14.06% in the acute, 42.73% in the subacute, and 31.90% in the chronic post-stroke stage).<sup>1-3</sup> The most common types of PSP include central post-stroke pain (CPSP), complex regional pain syndrome (CRPS), pain secondary to spasticity, shoulder pain, and headache.<sup>3-5</sup> Currently, the diagnosis of definite neuropathic pain should be based on the sensory findings, relevant lesion, and specific findings on clinical examination, as there are no pathognomonic features of PSP.<sup>6-8</sup> Patients who experience PSP seem to be more likely to have a lower quality of life, poorer cognitive and functional performance, higher fatigue perception, and higher incidence of depression, anxiety symptoms,

sleep disorders, and suicidality, facing the dual challenges of physical and mental suffering.<sup>9–15</sup> Both pharmacological and non-pharmacological interventions can be used to relieve PSP.<sup>16</sup> Besides, a multimodal strategy incorporating lifestyle-related interventions have been studied to optimize prognosis with improved quality of life and social participation after stroke, considering the complex interrelation between medical and psychosocial aspects of post-stroke pain and other post-stroke complications.<sup>16</sup>

Bibliometrics is a comprehensive science mapping analysis tool for analyzing and processing massive literature information, improve the efficiency of scientific research.<sup>17</sup> It is extensively used to visualize the citation, cooperation, co-occurrence and other relationships within the literatures, and construct various types of knowledge maps,<sup>17–19</sup> and explore the critical paths, research hotspots, and frontiers of the evolution of this discipline or field.<sup>20</sup> In the past 10 years, bibliometric analyses have been conducted on other stroke-related research hotspots, such as inflammasomes,<sup>21</sup> traditional medicine,<sup>22</sup> and rehabilitation treatment.<sup>23</sup> They used bibliometric methods to objectively present the global trend of pathogenesis, treatments of stroke and to provide important information for relevant researchers.

The pathogenesis mechanisms of PSP are not so clear, and there is currently a lack of effective medical treatments, hence it is necessary to establish a sufficient understanding of this disease.<sup>5,24</sup> Limited number of studies have used bibliometric methods to analyze the overall aspects pertaining to PSP currently. Therefore, this study aimed to methodically offer a comprehensive scientific analysis of published research within the past 10 years using a bibliometric analysis. The results of the present study would provide valuable reference information for researchers about identification of the current focus and challenges in the research evidence of post-stroke pain.

## Materials and Methods

### Source of Data and Search Strategy

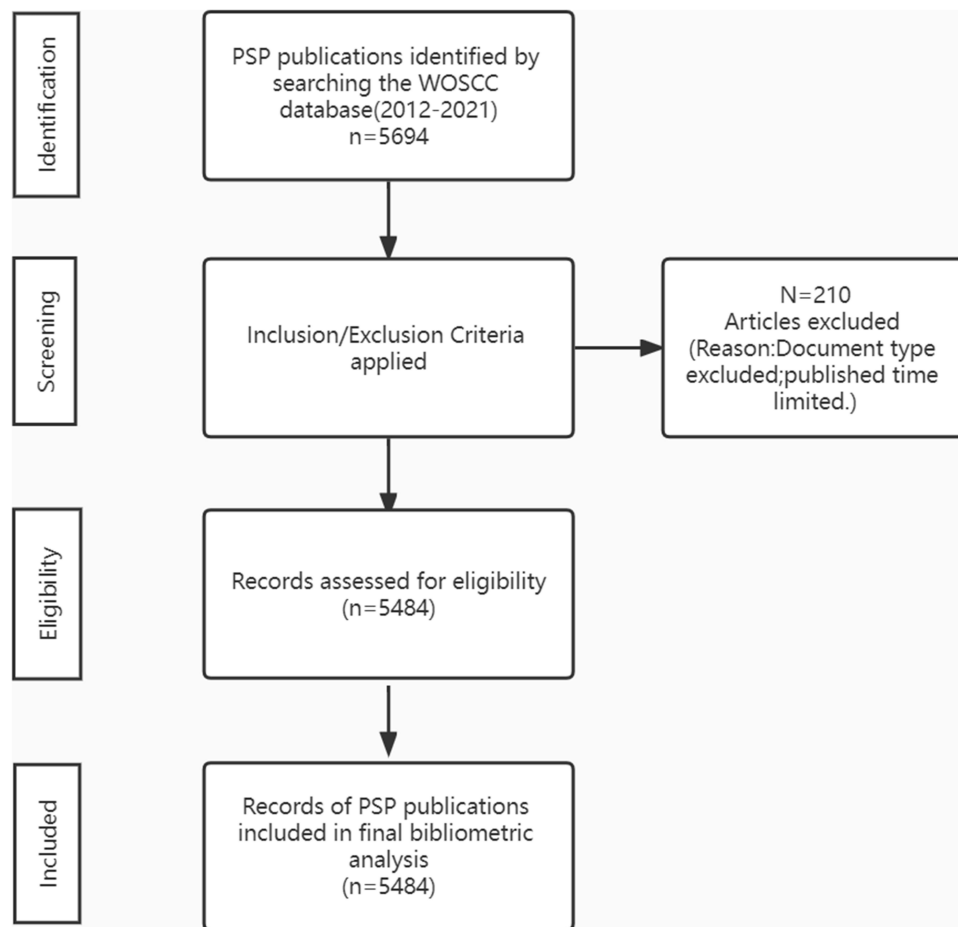
We chose the WoSCC database as the source of data. The WoS was chosen because it consists of a wide conglomerate of quality and high-impact scientific studies, which is the most frequent database used for bibliometric study.<sup>25–27</sup> A combination of controlled vocabulary (MeSH) and free text terms was used to search the database. The search strategy was as follows: TS = (apoplexy\* OR “stroke”, OR “hemiplegia”, OR “cerebrovascular accident”) AND TS = (“pain”, OR pain\* OR “ache”, OR ache\*OR \*ache). The publishing year was set from January 1, 2012 to December 31, 2021. We can analyze the development and changes in a field through ten years, which is the most frequent time span used for bibliometric study.<sup>27</sup>

### Inclusion and Exclusion Criteria

Papers published between 2012 and 2021 were retrieved. Articles and reviews related to stroke and pain in different academic journals were included. We excluded proceedings papers, meeting abstracts, editorial materials, early access, letters, notes, book chapters, corrections, reprints, discussions, news items, retracted publications, biographical articles, retractions, and duplicate papers. The language was unrestricted, and species-specific restrictions were not specified. We identified 5694 documents from the WoSCC database. After excluding 210 articles, 5484 papers were included. The papers were filtered using the Web of Science (WoS) website and Bibliometrix Biblioshiny R-package software.

### Bibliometric Analysis

We followed a previously defined search strategy to search through the WoSCC database and then imported these results to the Bibliometrix Biblioshiny R-package software (<https://bibliometrix.org/Biblioshiny.html>) for analysis.<sup>27,28</sup> We analyzed the following: (1) distribution of countries, institutions, authors, and journals, (2) number of papers and H-index in the top 20 journals, (3) collaborations among countries/institutions/authors, and (4) keywords and the top 20 papers cited most frequently. Additionally, we visualized the structure, regular patterns, and distribution of scientific knowledge using Biblioshiny. The complete data acquisition process is illustrated in [Figure 1](#).



**Figure 1** Flow chart for publications selection.

## Results

### General Information on the Retrieved Documents

There were 4395 articles and 1089 review papers. All these documents use 10,223 keywords plus. Keywords plus are words or phrases that frequently appear in article reference titles and are generated automatically by a computer. There is a high collaboration in PSP publications that is shown by the collaboration index. Authors per document ratio is 5.26, which means, on average, almost five authors have written one document. [Table 1](#) summarizes the preliminary information on the collected bibliometric data.

### Countries and Institution Distribution

The 5484 papers on PSP were contributed by 88 countries/regions between 2012 and 2021 ([Supplementary Table 1](#)). The USA made the highest contribution to PSP research, having produced the highest number of papers (1381), followed by China (716), Italy (276), and Korea (265). [Figure 2](#) gives a complete picture of the number of authors affiliated with the country of publication. The blue color intensity, in the figure, is proportional to the number of affiliated authors with each country. The USA, China, and Italy made the darkest blue. The top 20 countries or regions according to the number of citations are listed in [Figure 3A](#), with the USA having the most significant number of citations (36,395), followed by the UK (7105), China (7026), and France (5914). Among 6903 institutions ([Supplementary Table 2](#)), the top 20 were listed according to number of publications, as shown in [Figure 3B](#). The University of Toronto had the highest number of papers (156), followed by Harvard University (139), Mayo Clinic (118), and Harvard Medical School (104). The extensive cooperation among the countries is shown in [Figures 4 and 5A](#). The link thickness was proportional to the number of

**Table 1** Summary of the Main Information of Collected Bibliometric Data

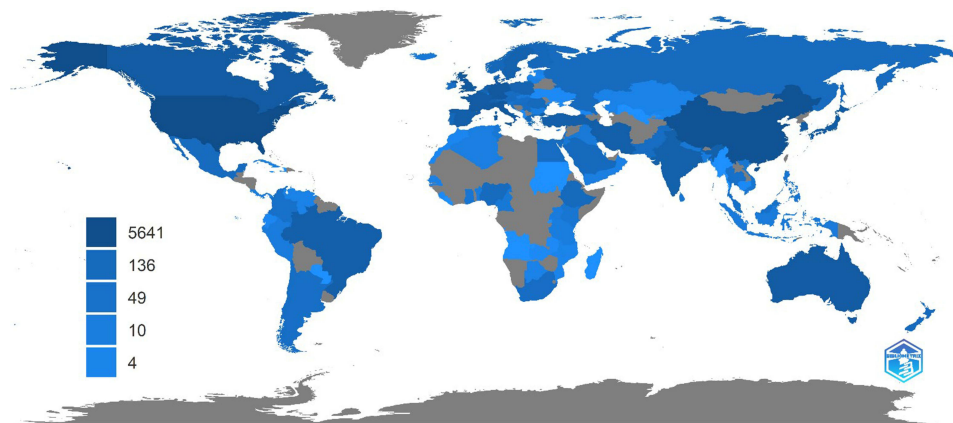
Description	Results
Documents	5484
Articles	4395
Review	1089
Period	2012–2021
Countries/regions	88
Institutions	6903
Authors	28,844
Sources (Journals)	1551
Keywords Plus	10,223
The annual production growth rate	5.13%
Authors per document	5.26
Collaboration index	5.41

joint publications within each country. Overall, the USA seemed to be the hub for any published document, as there were many scientific links between the USA and other countries.

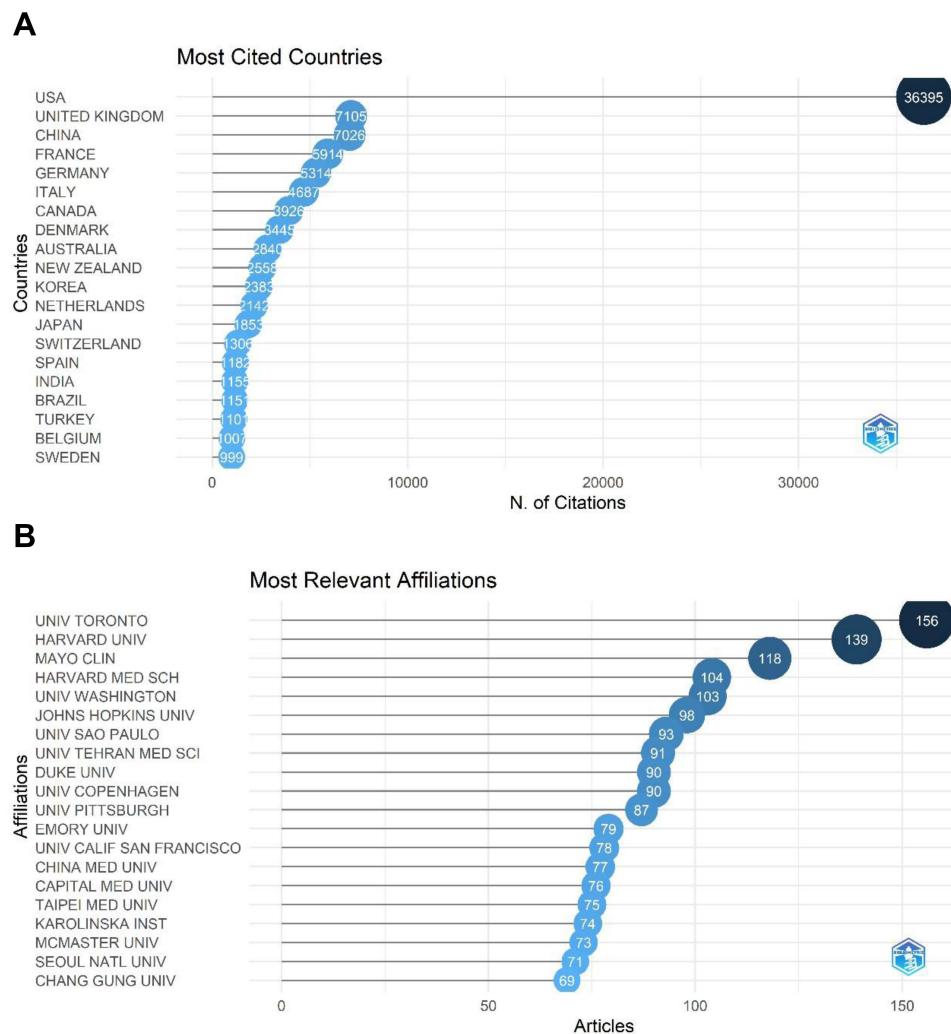
The extensive cooperation among the institutions is shown in [Figure 5B](#). The University of Toronto and Harvard University are the two leading scientific centers; they have extensive cooperation with other institutions.

## Authors

The 5484 papers were contributed by 28,844 authors ([Supplementary Table 3](#)). The top 20 authors were ranked according to the number of publications ([Figure 6A](#)). [Figure 6B](#) shows the top 20 authors ranked by H-index. Zhang Y had the highest number of publications (25). Kurth T had the highest H-index value (12). In [Figure 7](#), the top 20 countries are ranked according to the number of scientific publications. Red lines indicate the publication rate by the corresponding author's country, wherein at least one foreign co-author exists, while blue lines represent the number of publications by



**Figure 2** Country's scientific production world map of post stroke pain research field (blue color intensity: the number of authors affiliated with each country, grey color: non-related country).



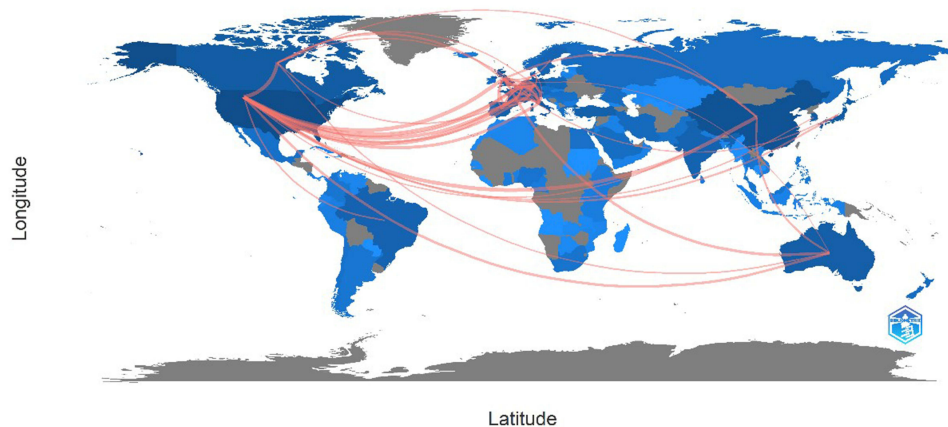
**Figure 3 (A)** Top 20 most cited countries based on the number of citations. **(B)** Top 20 most relevant affiliations based on the number of articles. The number of citations or articles determines the intensity of the colour of the ball and its size; deeper colour and bigger size indicate a higher number of citations or articles.

authors from the same country. These are called multiple countries publication (MCP) and single country publication, respectively. The percentage of MCP indicated the status of international cooperation among the authors. The USA had the highest number of international collaboration, followed by China and the UK. Figure 8 shows the collaboration between the authors. Amongst the authors, Zhang Y not only has many cooperative relations with Wang Y but also has close cooperation with Li Y. There is also close cooperation between Ferrari MD, who ranks second in H-index, and Terwindt GM, who ranks third in H-index.

## Publication Outputs

In total, 5484 papers were included in the analysis. As shown in Figure 9A, the number of publications has been growing steadily over the last 10 years. The number of publications increased from 436 in 2012 to 717 in 2021. The annual growth rate was 5.13% as computed by Biblioshiny. The highest number of papers (717) was published in 2020. Figure 9B shows that the average number of article citations had a steady growth from 2013 to 2016, but started to fluctuate from 2017 to 2021, and tended to decline sharply from 2020 to 2021.

## Country Collaboration Map



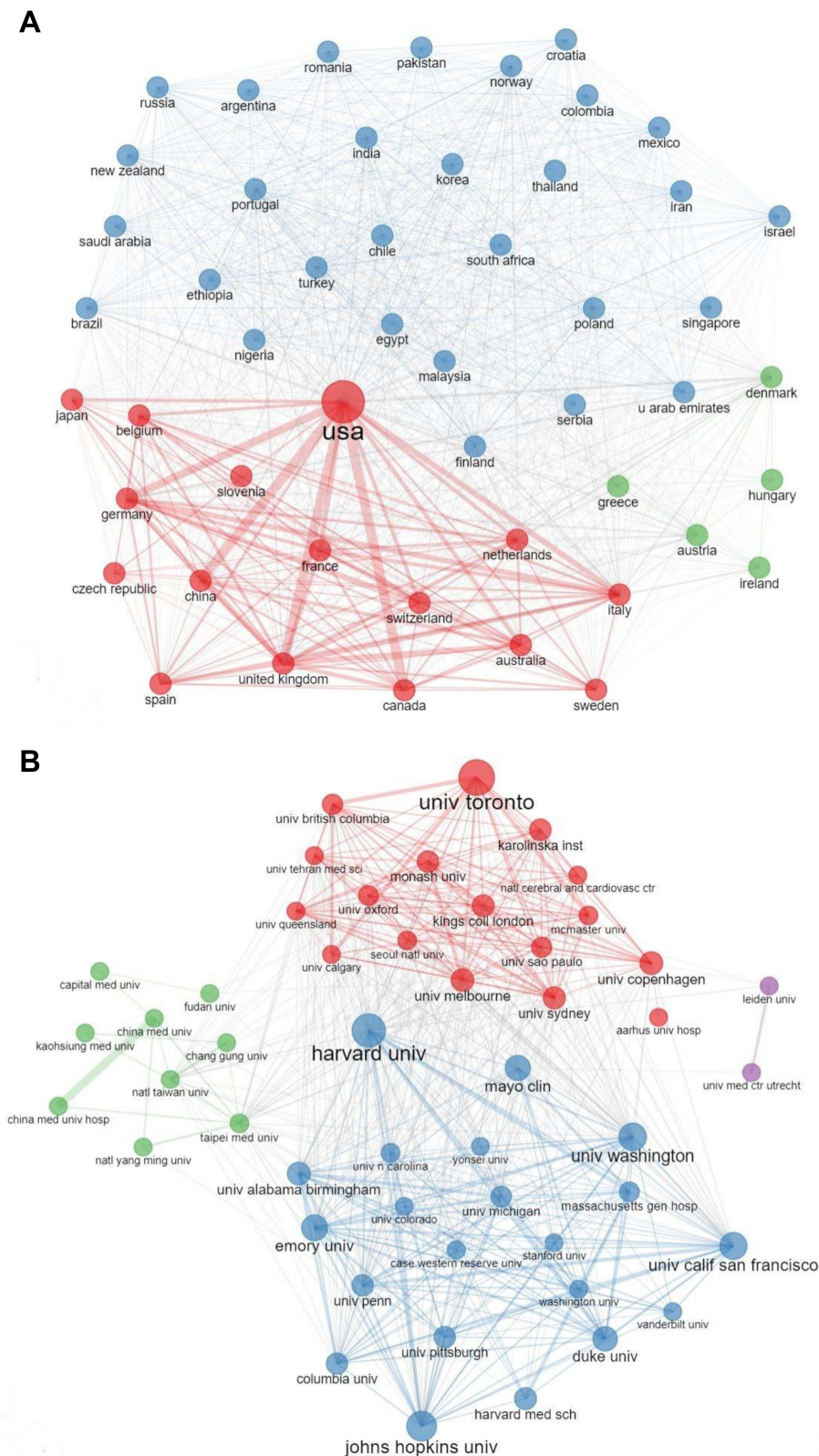
**Figure 4** Social structure: Countries collaboration map. The thickness of connecting lines indicates the frequency of collaboration.

### Journals

The 5484 papers were published in 1551 academic journals, as shown in [Supplementary Table 4](#). The top 20 journals were selected and recorded according to the number of papers, as shown in [Figure 10A](#). The total number of published articles in the top 20 journals was approximately 20.3% of the total articles. The Journal of Stroke & Cerebrovascular Diseases, an academic journal with an impact factor (IF) and Quartile 2021 of 2.136/Q4, had the highest number of papers on PSP (150 publications, 2.7%), followed by Medicine (IF/Quartile 2021, 1.89/Q2; 78 publications; 1.4%), PLoS One (IF/Quartile 2021, 3.240/Q2; 72 publications; 1.3%), and Stroke (IF/Quartile 2021, 7.914/Q1; 66 publications; 1.2%). The academic journals Stroke and Neurology tied for the first place, as they had the highest H-index value, which reached 28, as shown in [Figure 10B](#). Among the top 20 journals with the highest number of papers, 25% of them were in the first quartile (Q1) and 40% were in the second quartile (Q2), under the journal IF quartile of WoS.

### Keywords

As shown in [Figure 11](#), the top 10 keywords from the start of 2012 were analyzed using keywords plus. The most frequent keywords were “stroke” (n = 1044), “management” (n = 439), “pain” (n = 424), “risk” (n = 403), “prevalence” (n = 352), “ischemic stroke” (n = 290), “risk factors” (n = 290), “disease” (n = 286), “diagnosis” (n = 226), and “therapy” (n = 223). [Figure 12](#) shows the top keywords used in the PSP field over the last 10 years. The font size or color of these words shows their importance. [Figure 13](#) shows the themes in the PSP field on a thematic map. A thematic map helps to identify the important concepts within a field. It presents a visualization of the semantic strength of the themes’ internal (correlation between concepts) and external (cohesiveness of nodes) association, which are measured as density and centrality, respectively (Examining the developments in scheduling algorithms research: A bibliometric approach). In [Figure 13](#), each bubble represents a keyword network cluster. The cluster name is the word with the highest existence rate. The bubble size is related to the cluster word occurrences, and its position depends on cluster centrality and density. The upper-right quadrant shows the motor themes, the lower-right quadrant shows the basic themes, the lower-left quadrant shows the emerging or disappearing themes, and the upper-left quadrant shows the developed themes less used and possibly understudied. Keywords, such as pain, therapy and quality-of-life, are called motor themes because of their high level of importance and improvement. Keywords, such as double-blind, brain, neuropathic pain are called niche themes because of their low level of importance and high level of improvement. Keywords, such as stroke, risk, and prevalence, are called basic and transversal themes because of their high level of importance and low level of improvement. Keywords, such as management, diagnosis, and outcomes, are called emerging or clinging themes because of their low level of importance and improvement. It is expected that the outcomes of this study will provide a better vision of future research directions.



**Figure 5** Social structure: (A) Country collaboration network in post stroke pain research. (B) Institution collaboration network in post stroke pain research. The connection between nodes indicates countries or institutional collaboration. The thickness of the edges indicates the frequency of collaboration, and a thicker edge means more collaborations between the connected institutions. Different colors represent different clusters and the size of the ball reflects the number of publications.

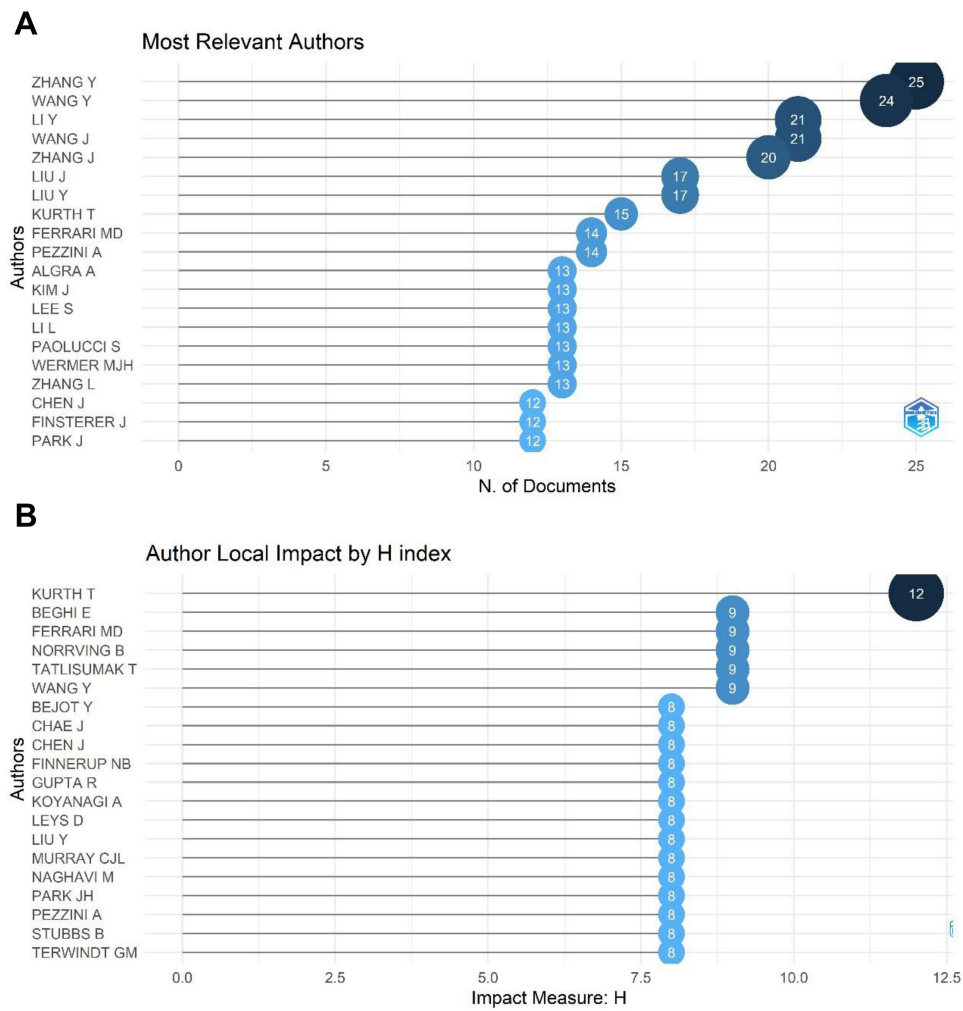


Figure 6 (A) Top 20 authors based on the number of publications. (B) Top 20 authors based on the number of H-index.

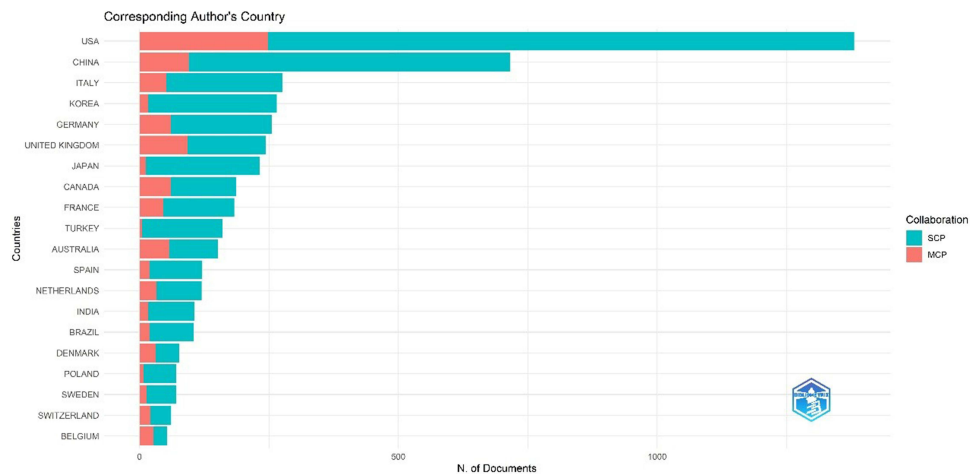
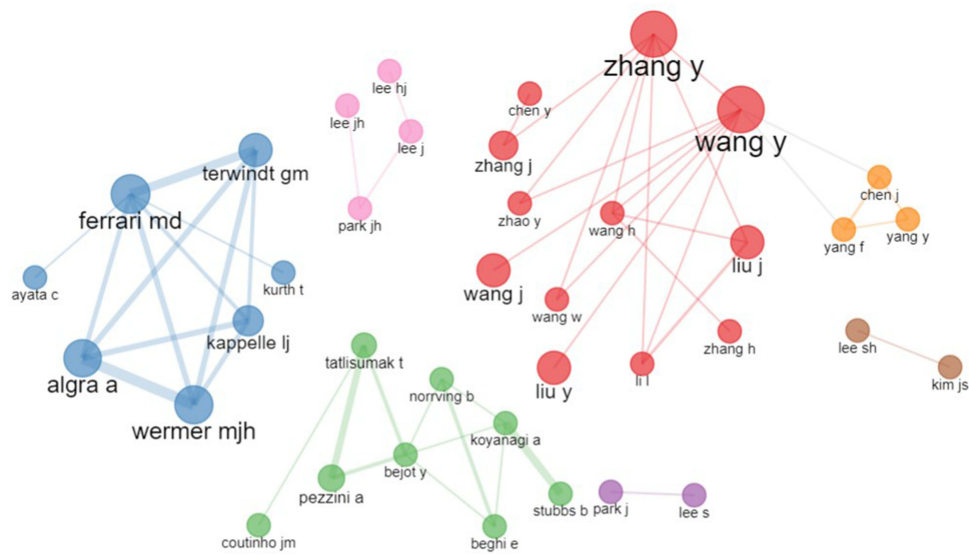
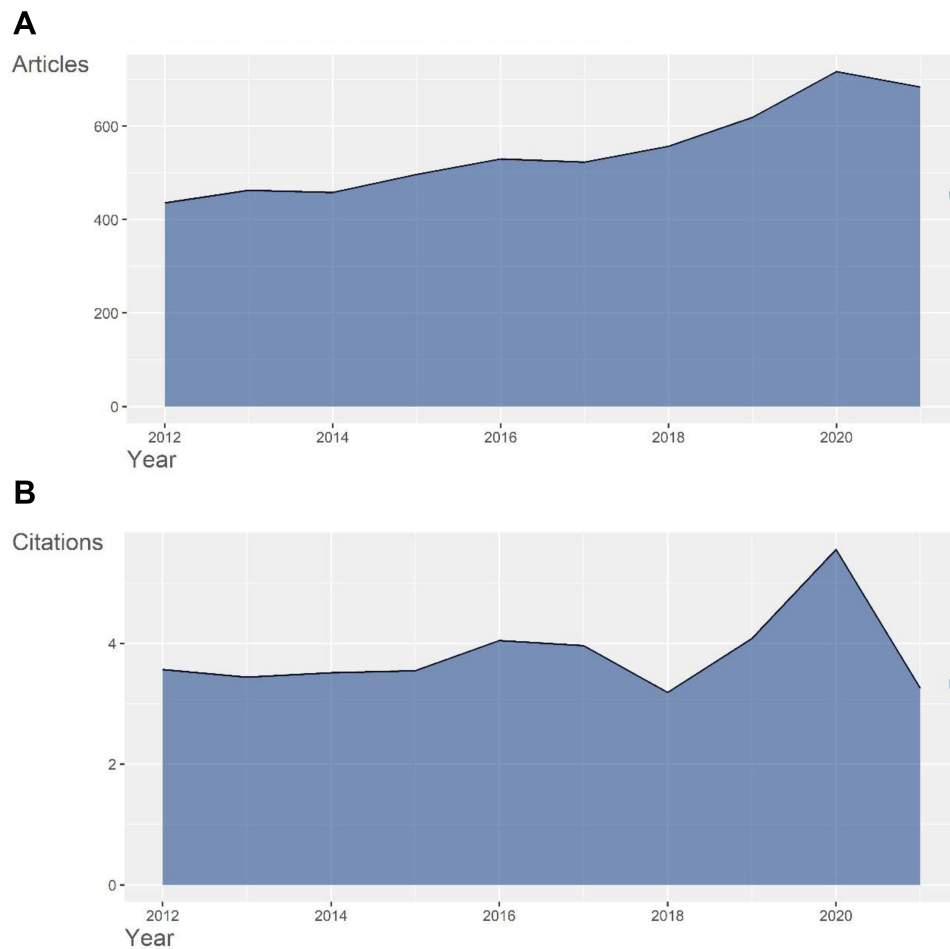


Figure 7 Top 20 corresponding author's country based on the number of publications. (red line: Multiple Countries Publication (MCP), blue line, Single Country Publication (SCP)).

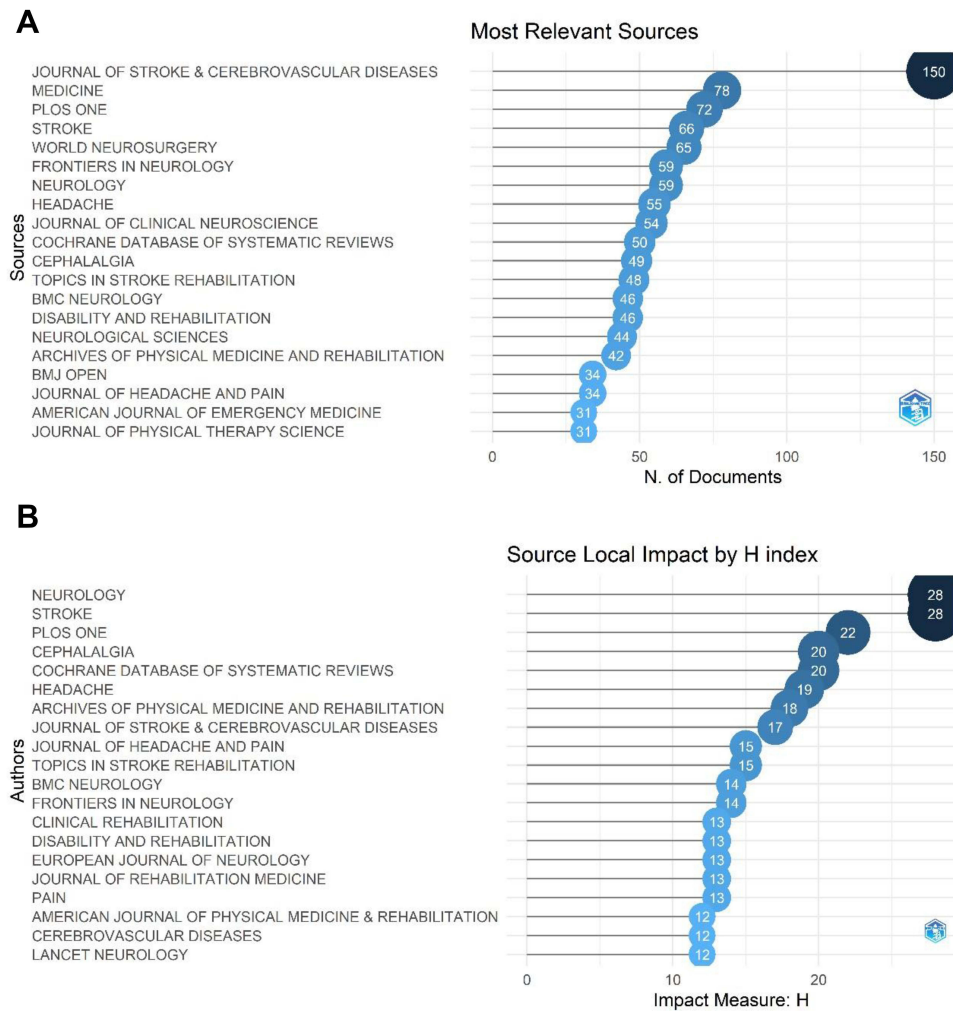




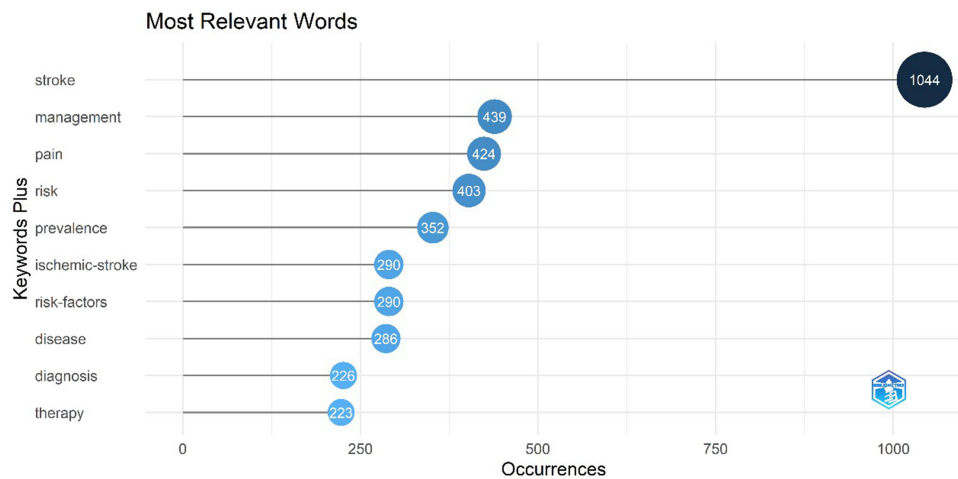
**Figure 8** Social structure: Authors' collaboration network in post stroke pain research. The edges show that the connected authors have published at least two documents together. The size of the nodes indicates the number of documents published by the author in collaboration, and the thickness of the edges indicates the frequency of collaboration; a thicker edge means more collaborations between the connected authors (nodes). Different colors represent different clusters and the size of the ball reflects the number of publications.



**Figure 9** (A) Annual scientific growth of post stroke pain. (B) Average article citations per year of post stroke pain.



**Figure 10 (A)** Top 20 most relevant journals based on the number of publications. **(B)** Top 20 journals based on the number of H-index. The number of publications or H-index determines the intensity of the colour of the ball and its size; deeper colour and bigger size indicate a higher number of publications or H-index.



**Figure 11** Top 10 most relevant journals based on the number of occurrences. The number of occurrences determines the intensity of the colour of the ball and its size; deeper colour and bigger size indicate a higher number of occurrences.



Figure 12 Most relevant keywords in post stroke pain research. The size of a keyword is determined by its frequency of occurrence in the entire dataset.

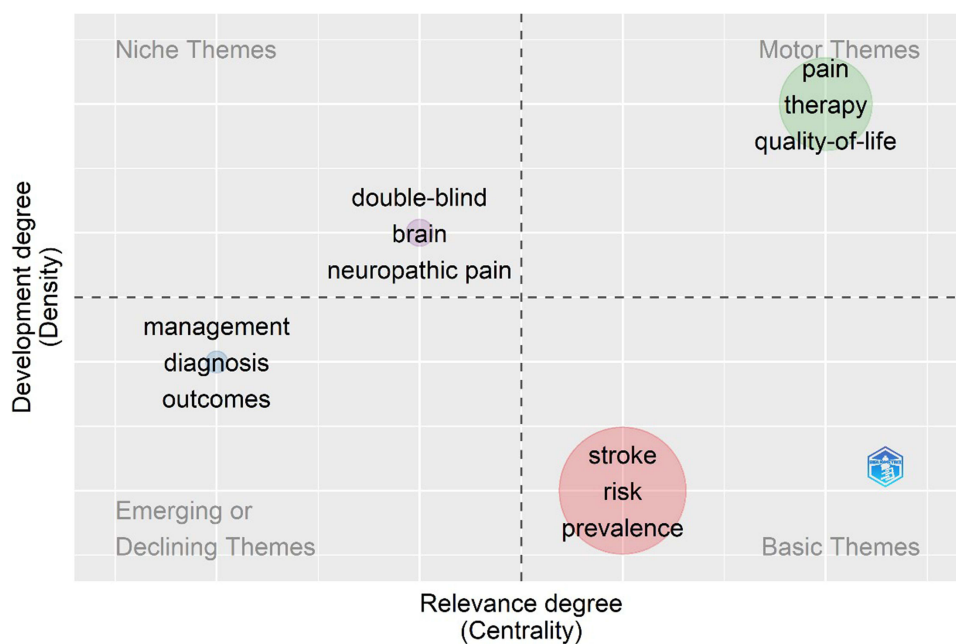


Figure 13 Thematic map of concepts in post stroke pain research. The upper-right quadrant shows the driving or motor themes, the lower-right quadrant shows the basic themes, the lower-left quadrant shows the emerging or declining themes, and the upper-left quadrant shows the developed themes less used and possibly understudied. Each bubble represents a keyword network cluster. The cluster name is the word with the highest existence rate. The bubble size is relative to the cluster word occurrences, and its position depends on cluster centrality and density.

### Characteristics of the Top 100 Papers Cited Most Frequently

The 100-most highly cited articles are shown in Table 2. All 100 of these articles were published between 2012 and 2020. According to further analysis, among the top 100 papers, 25 was published in 2012, 15 was in 2013, 14 was in 2014, 22 was in 2015, 14 was published in 2016, 7 was in 2017, 3 was published in 2018, only 1 was in 2020. Therefore, we conclude that 2012~2015 was a fast-growing period in published research on PSP. The frequently used subjects in top-cited 100 articles include “Central post-stroke pain”, “poststroke hemiplegic shoulder pain”, “thalamus”, “ischemic

**Table 2** Top 100 Articles with Their Local Citations and Global Citations

Rank	Title	Year	Local Citations	Global Citations
1	Pain following stroke: a prospective study	2012	60	87
2	Reversible cerebral vasoconstriction syndrome	2012	60	397
3	Post stroke pain: identification, assessment, and therapy	2015	59	104
4	Chronic pain syndromes after ischemic stroke: PROFESS trial	2013	42	68
5	Migraine and stroke: a complex association with clinical implications	2012	41	155
6	Assessing the risk of central post-stroke pain of thalamic origin by lesion mapping	2012	38	70
7	Migraine and risk of cardiovascular disease in women: prospective cohort study	2016	34	147
8	Incidence and associations of hemiplegic shoulder pain poststroke: prospective population-based study	2015	33	45
9	Presentation, management and outcomes in acute pituitary apoplexy: a large single-centre experience from the United Kingdom	2014	31	70
10	Painful hemiplegic shoulder in stroke patients: causes and management	2012	30	40
11	Thalamic sensory strokes with and without pain: differences in lesion patterns in the ventral posterior thalamus	2012	30	58
12	Prevalence and Time Course of Post-Stroke Pain: A Multicenter Prospective Hospital-Based Study	2016	30	54
13	Pituitary Apoplexy	2015	28	128
14	Antiplatelet treatment compared with anticoagulation treatment for cervical artery dissection (CADISS): a randomised trial	2015	28	262
15	Does botulinum toxin type A decrease pain and lessen disability in hemiplegic survivors of stroke with shoulder pain and spasticity?: a randomized, double-blind, placebo-controlled trial A	2012	27	43
16	Hemiplegic shoulder pain: an approach to diagnosis and management	2014	26	35
17	Migraine and structural changes in the brain: a systematic review and meta-analysis	2013	24	161
18	Management of sickle cell disease: summary of the 2014 evidence-based report by expert panel members	2014	24	771
19	Migraine mutations increase stroke vulnerability by facilitating ischemic depolarizations	2012	23	117
20	Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS)	2014	23	1065
21	Modulating the pain network-neurostimulation for central poststroke pain	2015	23	52
22	Guidelines for Adult Stroke Rehabilitation and Recovery: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association	2016	23	979
23	Development and pharmacological verification of a new mouse model of central post-stroke pain	2014	22	30

(Continued)

Table 2 (Continued).

Rank	Title	Year	Local Citations	Global Citations
24	Epidemiology, pathophysiology, diagnosis, and management of intracranial artery dissection	2015	22	182
25	Cervical artery dissection: trauma and other potential mechanical trigger events	2013	21	106
26	Hydroxycarbamide versus chronic transfusion for maintenance of transcranial Doppler flow velocities in children with sickle cell anaemia—TCD With Transfusions Changing to Hydroxyurea (TWiTCH): a multicentre, open-label, Phase 3, non-inferiority trial	2016	21	245
27	Suprascapular nerve block for shoulder pain in the first year after stroke: a randomized controlled trial	2013	20	29
28	Hemiplegic shoulder pain: evidence of a neuropathic origin	2013	20	30
29	Toward an epidemiology of poststroke spasticity	2013	20	148
30	Safety and efficacy of abobotulinumtoxinA for hemiparesis in adults with upper limb spasticity after stroke or traumatic brain injury: a double-blind randomised controlled trial	2015	20	100
31	Pain after stroke: A review	2018	20	35
32	Left-sided hemiparesis, pain frequency, and decreased passive shoulder range of abduction are predictors of long-lasting poststroke shoulder pain	2012	19	27
33	Pituitary apoplexy: pathophysiology, diagnosis and management	2015	19	62
34	Management and outcomes of pituitary apoplexy	2015	19	51
35	Evidence for therapeutic interventions for hemiplegic shoulder pain during the chronic stage of stroke: a review	2012	18	29
36	Central poststroke pain: somatosensory abnormalities and the presence of associated myofascial pain syndrome	2012	18	23
37	Management of Central Poststroke Pain: Systematic Review of Randomized Controlled Trials	2015	18	40
38	Hemiplegic Shoulder Pain Reduces Quality of Life After Acute Stroke: A Prospective Population-Based Study	2016	18	24
39	The Typical Thunderclap Headache of Reversible Cerebral Vasoconstriction Syndrome and its Various Triggers	2016	18	68
40	Migraine and the risk of stroke: an updated meta-analysis of prospective cohort studies	2017	18	44
41	Neural correlates of the antinociceptive effects of repetitive transcranial magnetic stimulation on central pain after stroke	2012	17	49
42	Subacromial corticosteroid injection on poststroke hemiplegic shoulder pain: a randomized, triple-blind, placebo-controlled trial	2012	17	22
43	Changes in spasticity, widespread pressure pain sensitivity, and baropodometry after the application of dry needling in patients who have had a stroke: a randomized controlled trial	2014	17	37

(Continued)

**Table 2** (Continued).

Rank	Title	Year	Local Citations	Global Citations
44	Cervical arterial dissections and association with cervical manipulative therapy: a statement for healthcare professionals from the American Heart Association/American Stroke Association	2014	17	100
45	Hormonal contraceptives and risk of ischemic stroke in women with migraine: a consensus statement from the European Headache Federation (EHF) and the European Society of Contraception and Reproductive Health (ESC)	2017	17	76
46	Sonography and physical findings in stroke patients with hemiplegic shoulders: a longitudinal study	2012	16	29
47	Variable presentations of postpartum angiopathy	2012	16	74
48	Shoulder taping reduces injury and pain in stroke patients: randomized controlled trial	2013	16	27
49	Levetiracetam in patients with central neuropathic post-stroke pain—a randomized, double-blind, placebo-controlled trial	2013	16	26
50	Hemiplegic Shoulder Pain	2015	16	24
51	Effect of Dry Needling on Spasticity, Shoulder Range of Motion, and Pressure Pain Sensitivity in Patients With Stroke: A Crossover Study	2016	16	31
52	Suprascapular nerve block for the treatment of hemiplegic shoulder pain in patients with long-term chronic stroke: a pilot study	2017	16	21
53	Current and future interventions for glenohumeral subluxation in hemiplegia secondary to stroke	2012	15	21
54	Acupuncture for shoulder pain after stroke: a systematic review	2012	15	38
55	The prevalence of central poststroke pain according to the integrity of the spino-thalamo-cortical pathway	2012	15	27
56	Population-based study of central post-stroke pain in Rimini district, Italy	2013	15	19
57	Establishment of a central post-stroke pain model using global cerebral ischaemic mice	2013	15	21
58	Onset headache predicts good outcome in patients with first-ever ischemic stroke	2013	15	21
59	Migraine is not associated with enhanced atherosclerosis	2013	15	45
60	Peripheral nerve stimulation compared with usual care for pain relief of hemiplegic shoulder pain: a randomized controlled trial	2014	15	56
61	Analgesic effect of transcranial direct current stimulation on central post-stroke pain	2014	15	31
62	Central poststroke pain in young ischemic stroke survivors in the Helsinki Young Stroke Registry	2014	15	22
63	A Comprehensive Review of Central Post-Stroke Pain	2015	15	24
64	Targeting P(2)X(7) receptor for the treatment of central post-stroke pain in a rodent model	2015	15	29

(Continued)

Table 2 (Continued).

Rank	Title	Year	Local Citations	Global Citations
65	Reversible Cerebral Vasoconstriction Syndrome, Part I: Epidemiology, Pathogenesis, and Clinical Course	2015	15	111
66	Management of endocrine disease: pituitary tumour apoplexy	2015	15	59
67	Pituitary apoplexy	2015	15	40
68	Migraine and risk of stroke in older adults: Northern Manhattan Study	2015	15	36
69	Thalamic pain: anatomical and physiological indices of prediction	2016	15	41
70	Effects of Kinesio taping for stroke patients with hemiplegic shoulder pain: A double-blind, randomized, placebo-controlled study	2017	15	24
71	Migraine and the risk of cardiovascular and cerebrovascular events: a meta-analysis of 16 cohort studies including 152407 subjects	2018	15	110
72	Neuropathogenesis and Neurologic Manifestations of the Coronaviruses in the Age of Coronavirus Disease 2019: A Review	2020	15	383
73	Differences and similarities between spontaneous dissections of the internal carotid artery and the vertebral artery	2013	14	58
74	Clinical and sonographic risk factors for hemiplegic shoulder pain: A longitudinal observational study	2014	14	18
75	Sex differences in quality of life after ischemic stroke	2014	14	105
76	Effectiveness of functional electrical stimulation in improving clinical outcomes in the upper arm following stroke: a systematic review and meta-analysis	2015	14	52
77	Migraine and risk of ischaemic heart disease: a systematic review and meta-analysis of observational studies	2015	14	75
78	Canadian stroke best practice recommendations: Stroke rehabilitation practice guidelines, update 2015	2016	14	277
79	Ischemic stroke subtypes and migraine with visual aura in the ARIC study	2016	14	43
80	Demystifying Poststroke Pain: From Etiology to Treatment	2017	14	29
81	Migraine and risk of cardiovascular diseases: Danish population based matched cohort study	2018	14	114
82	An early botulinum toxin A treatment in subacute stroke patients may prevent a disabling finger flexor stiffness six months later: a randomized controlled trial	2012	13	39
83	Stable angina pectoris with no obstructive coronary artery disease is associated with increased risks of major adverse cardiovascular events	2012	13	457
84	Central poststroke pain: current diagnosis and treatment	2013	13	22
85	Bilateral central pain sensitization in rats following a unilateral thalamic lesion may be treated with high doses of ketamine	2013	13	18
86	Pharmacological management of central post-stroke pain: a practical guide	2014	13	22
87	Post-stroke pain hypersensitivity induced by experimental thalamic hemorrhage in rats is region-specific and demonstrates limited efficacy of gabapentin	2014	13	22

(Continued)

**Table 2** (Continued).

Rank	Title	Year	Local Citations	Global Citations
88	Dry needling for the treatment of poststroke muscle spasticity: a prospective case report	2015	13	36
89	Practice guideline update summary: Botulinum neurotoxin for the treatment of blepharospasm, cervical dystonia, adult spasticity, and headache: Report of the Guideline Development Subcommittee of the American Academy of Neurology	2016	13	262
90	A Multicenter Study of 1144 Patients with Cerebral Venous Thrombosis: The VENOST Study	2017	13	78
91	Fulminant postpartum cerebral vasoconstriction syndrome	2012	12	45
92	Relationship between disability and health-related quality of life and caregiver burden in patients with upper limb poststroke spasticity	2012	12	66
93	Sickle cell pain: a critical reappraisal	2012	12	257
94	Migraine and vascular diseases: a review of the evidence and potential implications for management	2012	12	77
95	Migraine and stroke: perspectives for stroke physicians	2012	12	41
96	Validity of EQ-5D-5L in stroke	2015	12	108
97	Systematic Review of Central Post Stroke Pain: What Is Happening in the Central Nervous System?	2016	12	15
98	A meta-analysis of case-control studies of the association of migraine and patent foramen ovale	2016	12	43
99	Use of combined hormonal contraceptives among women with migraines and risk of ischemic stroke	2017	12	41
100	Clinical characteristics of symptomatic vertebral artery dissection: a systematic review	2012	11	65

stroke”. “Central post-stroke pain” and “poststroke hemiplegic shoulder pain” is a most frequent research subject, they has been occurred in 19 and 17 articles, respectively.

## Discussion

### Global Potential and Achievement

Biblioshiny is a method used to manage and visualize knowledge structures. We conducted a novel bibliometric analysis via Biblioshiny on studies investigating PSP over the past decade to comprehensively view global research trends. Our bibliometric analysis revealed increased publications and changes in the contributions of journals, authors, countries, and institutions to this field.

The number of publications and citations in a field can reflect the productivity and development of the subject over time. Our results showed that the output of publications on PSP maintained a steady growth from 2012 to 2021 (Figure 9A). This overall growth trend in the number of related publications indicated that many scientists were investigating PSP. According to the citation analysis (Figure 9B), there was a steady growth in the average article citations per year from 2013 to 2016, but with fluctuating changes from 2017 to 2021, especially a sharp decline from 2020 to 2021. These citation counts are assumed to reflect the quality of an article and its relevance to research and/or clinical practice.<sup>29</sup> Indeed, older publications inevitably received more citations than recent papers regardless of their



impact. This is because newer articles tend to be cited less in their initial years of publication and also because there is shorter span of time to generate citation rates. So this might be one of the reasons for the sharp decline of citations from 2020 to 2021. Delays in reporting, dissemination, and uptake of research evidence as well as embargo periods, may all affect citation frequency. The trend of the present study revealed that in the last 2 years, the average article citations per year decreased; however, it is too early to predict whether these publications will be cited more often over time.

Popular core journals can provide a reliable reference for researchers searching for documents and publishing their work. Among the journals in which PSP-related articles were published, the Journal of Stroke & Cerebrovascular Diseases has published the most articles, while Stroke and Neurology tied for the first place in the H-index. In terms of publications and citations, the most influential journal was Stroke, which, despite ranking fourth in publication, stood first in terms of the H-index.

Identifying the countries or institutions that have contributed the most may guide researchers in pursuing advanced studies and seeking cooperation. According to the number of published papers (Figure 2), the USA, China, Italy, and Korea were the countries that contributed the most to investigating PSP. According to institutional productions, the University of Toronto contributed the most among the institutions (Figure 3B). Among the top 20 institutions, nine were from the US, four from China, two from Canada, one from Sweden, one from Denmark, one from South Korea, one from Brazil, and one from Iran. By analyzing the network map of the cooperation among the countries/institutions, we can easily acknowledge that there are many scientific links between the USA and other countries. Additionally, the USA has, by far, the highest MCP. These results indicate that the USA was the supreme power in this field and at the forefront in this field of research.

## Research Energy and Potential

Keywords tend to provide the main focus of papers and reflect the most popular current and future research topics. We can obtain relevant information about hotspots in the PSP research field based on keyword analysis. Bibliometric analysis revealed the main keywords of papers in the PSP research field over the last 10 years. In the last 10 years, the top 10 keywords on PSP included “stroke”, “management”, “pain”, “risk”, “prevalence”, “ischemic stroke”, “risk factors”, “disease”, “diagnosis” and “therapy”, as shown in Figure 11. Since our search strategy included “stroke” and “pain”, the keywords “stroke” and “pain” were used most frequently. A large cohort with ischemic stroke suggested that chronic pain syndromes are common after ischemic stroke.<sup>10</sup> Management, risk factors, diagnosis and therapy occupied pivotal positions in this field, indicating that clinical practice studies were of vital importance for PSP research.

Generally, a top-cited publication could provide a good view for scholars who want to acquire quick insight in a particular field. In order to obtain more information about post stroke pain in a more effective way, we do further literature reading and analysis on the 100 top cited papers which were published between 2012 and 2020.

As shown in result section, central post-stroke pain and hemiplegic shoulder pain were chosen as important frontier topics in our study.

(1) In earlier studies, CPSP was described as one of the definitive symptoms of thalamic lesion.<sup>30</sup> However, more recent studies suggest that it is not only seen after thalamic lesions but also seen after vascular lesions in any part of the central nervous system.<sup>30</sup> There are certain hypotheses to explain physiopathologic mechanisms of CPSP, including dissociated sensory loss and central sensitization.<sup>8,31</sup> Oral medications and non-drug treatments are used for the management of CPSP.<sup>30,32</sup> Oral medications include antidepressants (tricyclic antidepressants, selective serotonin-norepinephrine reuptake inhibitors), antiepileptic drugs (carbamazepine, lamotrigine, gabapentin), opioids.<sup>30</sup> Non-drug treatments include neuromodulation, mirror therapy and immersive virtual reality interventions.<sup>30</sup> Studies suggested that these non-drug treatments like neuromodulation, mirror therapy and immersive virtual reality interventions got benefits in improving central post stroke pain symptoms, and might be a promising intervention for the management of CPSP.<sup>33–35</sup> Large randomized trials of good quality trials are needed in the future.<sup>36</sup> Investigators should mount more high-quality trials on pathysiopathologic mechanisms and treatments of CPSP in the future. Revealing the underlying pathophysiological mechanisms of CPSP will definitely help the physician to better understand the disease and will shed light for better treatment options.

(2) Hemiplegic shoulder pain (HSP) is a common complication of stroke, whose prevalence was ranging from 22 to 47%.<sup>37</sup> It may result in a significant loss of function and detriment to quality of life. From 2012 to 2015, many studies

have suggested that the pathogenesis of HSP is multifactorial and includes neurologic and mechanical factors, often in combination.<sup>38–41</sup> Neurologic factors include paralysis, spasticity, central poststroke pain, central sensitization, peripheral neuropathy, brachial plexus injury, complex regional pain syndrome.<sup>38</sup> Mechanical Factors include shoulder subluxation, rotator cuff injury, glenohumeral joint disorders, adhesive capsulitis, myofascial pain, direct trauma.<sup>38</sup> Management of HSP remains challenging. Numerous treatment methods have been suggested, such as botulinum toxin type A, suprascapular nerve block, subacromial corticosteroid injection, shoulder taping and peripheral nerve stimulation, but evidence for these treatments remains insufficient<sup>42–46</sup>.

A more recent study named “Effects of Kinesio taping for stroke patients with hemiplegic shoulder pain: A double-blind, randomized, placebo-controlled study” published in 2017 suggested that Kinesio taping may be an alternative treatment option for stroke patients with hemiplegic shoulder pain.<sup>47</sup> Studies with larger sample sizes and longer follow-up periods on Kinesio taping are recommended in the future. As pain is known to affect our daily activities and quality of sleep, it can have a major role on quality of life and rehabilitation outcome.<sup>47</sup> Most studies focus on their pain status and function outcomes of patients with hemiplegic shoulder pain among these 100 top cited papers. While there are only two studies have paid attention to their quality of life since 2016.<sup>47,48</sup> We suggested that more high-quality studies should focus on the quality of life in hemiplegic shoulder pain patients in the future.

## Strengths and Limitations

This study has some limitations. For instance, we selected only the WoSCC database for the retrieval of articles, some publications in other databases might have been missed. Furthermore, despite performing a bibliometric analysis, we did not conduct methodological quality assessments of the included papers. Notably, an article with a high citation count does not imply that it has high quality. Citation can be affected by factors that are irrelevant to the value of articles. Third, there is an inherent prejudice of bibliometrics against recently published articles or papers which might lead to some extremely vital papers not being involved or included in such analysis as it takes time to amass citations. Newer articles often show less representation in the list of top 100 articles. Bibliometric investigation on newly published high-quality articles would be overlooked or ignored. This is a drawback connected to the effect of the number of times cited. Hence, more robust methods of qualitative assessment such as methodological analysis could be combined with bibliometric parameters to give a more holistic insight into the research dynamics of a field in the future.

## Conclusions

This study provides knowledge on post stroke pain from a visualization and bibliometric perspective. The results of this study showed that the global research interest regarding post stroke pain has maintain growing over the past ten years from the growing trend of publications on this topic. Both central post stroke pain and hemiplegic shoulder pain are the hottest research subjects. There are some unresolved problems about these field. Future research should focus on high-quality well-designed trials of pathophysiologic mechanisms and potential treatments of central post stroke pain. As for managements of hemiplegic shoulder pain, improving quality of life is important as treating pain status and function outcomes. On the one hand, more effort should be directed towards high-quality well-designed trials of potential treatments, on the other hand, future researchers should pay more attention to the quality of life in hemiplegic shoulder pain patients.

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## Disclosure

The authors declare that there is no conflict of interest regarding the publication of this paper.

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