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REVIEW

Non-Pharmacological Therapies for Post-Stroke Spastic Paralysis: A Bibliometric Analysis of Global Research from 2000 to 2024

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Objective: This study aims to explore the research landscape, hot topics, and future trends of non-pharmacological therapies for post-stroke spastic paralysis globally from 2000 to 2024 through a bibliometric analysis.

Methods: We conducted a search in the Web of Science Core Collection database to analyze literature related to non-pharmacological therapies for post-stroke spastic paralysis published between 2000 and 2024. Tools including CiteSpace, VOSviewer, Bibliometrix, Scimago, and R language were used to identify and analyze countries, institutions, journals, references, keywords, as well as the most commonly used therapies and acupuncture points. The results were presented in the form of knowledge maps.

Results: The bibliometric analysis identified a total of 297 publications. Over the study period, the number of publications showed an overall upward trend. China had the highest number of publications. The journal *Archives of Physical Medicine and Rehabilitation* published the most articles. The most frequently occurring keywords were "stroke", "reliability", and "muscle spasticity." The most commonly used therapy was "acupuncture.".

Conclusion: From 2000 to 2024, non-pharmacological therapies have shown positive effects in improving post-stroke spastic paralysis; however, more rigorously designed large-scale, high-quality randomized controlled trials are needed to confirm their long-term efficacy and mechanisms. Moving forward, international and domestic research institutions should strengthen collaboration to produce more impactful research and further explore individualized, precision rehabilitation treatment plans.

Keywords: stroke, spasticity, non-pharmacological, global trends, bibliometric analysis

Introduction

Stroke, as the second leading cause of death and the third leading cause of disability worldwide, is a significant public health issue globally.[1] Spasticity is typically defined as a velocity-dependent increase in muscle tone caused by excessive excitability of the stretch reflex.[2] Studies indicate that approximately 20% to 40% of stroke survivors experience spasticity in their paralyzed limbs.[3,4] Spastic hemiplegia (spasticity and weakness on one side of the body) is a hallmark feature of post-stroke motor disorders and represents a critical stage in the rehabilitation of paralyzed limbs.[5,6] However, over time, spasticity often worsens, with severe spasticity becoming a major obstacle to the functional recovery of paralyzed limbs.[7] This spastic paralysis not only significantly impacts the quality of life for patients but also increases the economic and social burden due to added healthcare costs, treatment expenses, and loss of productivity.[8]

Currently, the commonly used methods for treating post-stroke spastic paralysis include pharmacological and non-pharmacological therapies. Pharmacological options include antispasticity drugs and botulinum toxin. However, due to adverse reactions and side effects of oral antispasticity medications, which may further impair rather than improve quality of life,[9] and the need for personalized, repeated doses of injectable botulinum toxin,[10] pharmacological treatments

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face certain limitations. Therefore, exploring alternative therapies (non-pharmacological therapies) to improve the quality of life for patients with post-stroke spastic paralysis is crucial.

With the further strengthening of international exchange and collaboration, researchers around the world are increasingly focusing on non-pharmacological therapies for the treatment of post-stroke spastic paralysis. Non-pharmacological therapies have three major advantages. First, there is a wide variety of treatment methods available, including acupuncture,[11] extracorporeal shock wave therapy,[12] neurodevelopmental therapy,[13] exercise therapy,[14] mirror therapy,[15] and robot-assisted rehabilitation training,[16] allowing patients to choose treatments flexibly based on their economic conditions and therapeutic needs. Second, many non-pharmacological therapies do not require active patient participation during the treatment process, reducing limitations related to patient adherence and understanding.[17] Lastly, in terms of efficacy and safety, non-pharmacological therapies have demonstrated significant effects comparable to pharmacological treatments, without relying on the gastrointestinal absorption of drugs into the bloodstream, thereby avoiding potential toxic side effects and drug-induced diseases. Their side effects are minimal, making them safer and more gentle. Relevant studies have confirmed that acupuncture can improve post-stroke motor disorders, spasticity, and pain;[18] extracorporeal shock wave therapy has long-lasting effects on both agonist and antagonist muscles;[19] transcutaneous electrical nerve stimulation has similar efficacy to baclofen in improving spasticity.[20] Neurodevelopmental therapies, such as neuromuscular joint facilitation techniques, can enhance joint range of motion and improve upper limb function.[21] Exercise therapy promotes functional recovery of the affected side and reduces muscle spasm.[22] Therefore, exploring the current research status, hot topics, and future trends of non-pharmacological therapies in the treatment and rehabilitation of post-stroke spastic paralysis holds significant research value.

Methods

Data Source and Search Strategy

Bibliometrics is a method that quantitatively analyzes literature and its related data to reveal research hotspots and development trends in a particular field. In recent years, bibliometric analysis has been increasingly applied to research on non-pharmacological therapies, including studies on non-pharmacological treatments for heart disease,[23] knee osteoarthritis,[24] and myofascial pain syndrome,[25] among others. This study uses bibliometric visualization tools to analyze relevant literature on non-pharmacological therapies for post-stroke spastic paralysis from 2000 to 2024. The Web of Science Core Collection (WoSCC) was chosen as the data source for identifying and extracting publications in this field. To prevent issues such as duplication, missing data, or thematic inconsistencies, data filtering and standardization were conducted before analysis to ensure data quality and prevent it from affecting the results. The specific search formula is shown in Table 1. Initially, 511 papers were obtained. Then, after manually removing duplicate records and excluding 214 articles that did not align with the topic of non-pharmacological therapies for post-stroke spastic paralysis, a final set of 297 articles was included. Data collection and analysis were independently conducted by HJJ and ZZY. Any discrepancies were resolved through discussion or by consulting other authors.

Table 1 Search Process

Set	Result	Search Query
#1	43124	TS=("stroke" OR "cerebrovascular accident" OR "CVA" OR "brain attack" OR "cerebral infarction" OR "ischemic stroke" OR "hemorrhagic stroke" OR "brain ischemia" OR "TIA" OR "transient ischemic attack")
#2	1741	TS=("spastic paralysis" OR "spastic hemiplegia" OR "spasticity" OR "spastic hemiparesis" OR "spastic quadriplegia" OR "muscle spasticity" OR "post-stroke spasticity")
#3	1515565	TS=("treatment" OR "therapy" OR "management" OR "intervention" OR "rehabilitation")
#4	511	Indexes = WoS Core Collection Editions = SCI Expanded-1900-present Document Types = Article, Review Article Timespan = 2000–2024 #1 AND #2 AND #3

Statistical Analysis Process

The literature review and selection process included the following steps: (1) Two team members independently evaluated the papers, excluding those that did not align with the topic. (2) Standardization was applied to the selected literature, institutions, and countries to prevent variations in names from affecting the results. We performed bibliometric analysis of key literature characteristics, such as publication volume, countries/regions, institutions, authors, journals, references, and keywords, using CiteSpace (version 6.1.6), VOSviewer (version 1.6.18), and Scimago Graphica (version 1.0.34). The parameter settings in CiteSpace were as follows: Method (LLR), Time Slicing (2000–2024), Year Per Slice (1), Term Source (all selected), Selection Criteria (g-index: k = 25), and Pruning (pathfinder, pruning sliced networks). Additionally, Scimago Graphica was used to create a network illustrating international collaborations. R language (version 4.4.1) was utilized to analyze and plot the frequency of acupuncture points.

Results

Trend of Annual Publication Volume

From 2000 to 2024, the number of publications on non-pharmacological therapies for post-stroke spastic paralysis showed an overall fluctuating upward trend, with a total of 297 publications. After 2012, there was a notable increase in publication volume, peaking in 2021, followed by a downward trend over the past three years (Figure 1).

Global Analysis

A total of 34 countries participated in research on non-pharmacological therapies for post-stroke spastic paralysis between 2000 and 2024. As shown in Table 2 and Figure 2, China leads in the number of published articles, with 103 publications. However, the average citation per article is relatively low (12.6), indicating high output but relatively lower impact per paper. In contrast, Italy demonstrates a higher average citation rate (27.8) and substantial total citations (657), reflecting significant international recognition and influence, potentially due to innovation in research directions or methodologies. Regionally, Asia, Europe, and the Americas serve as major hubs for this research, displaying a clear clustering effect.

Institutional Analysis

An analysis of 539 institutions involved in research on non-pharmacological therapies for post-stroke spastic paralysis this century revealed that 45 institutions published more than three articles. Among them, Tehran University of Medical Sciences in Iran had the highest number of publications (11),[26] followed by Kagoshima University in Japan (8)[27] and

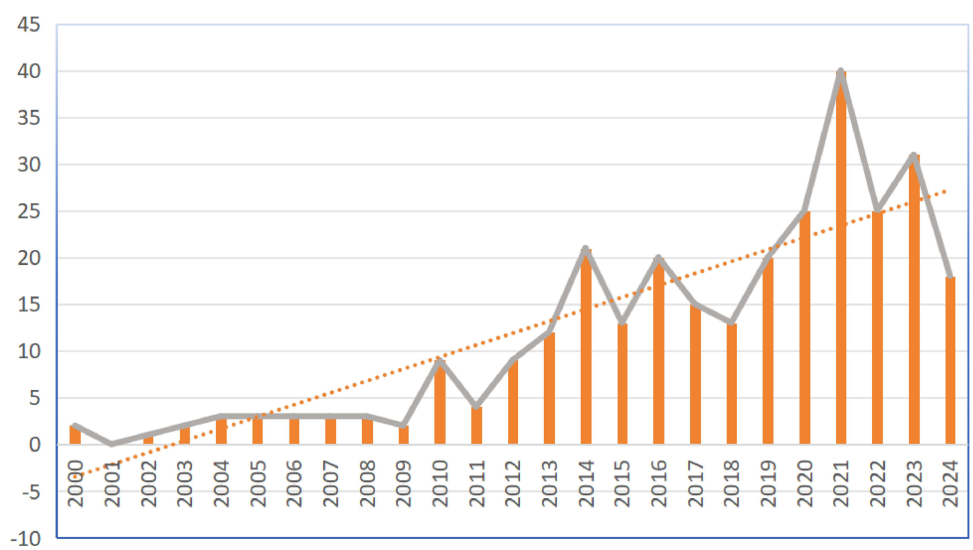

Figure 1 Annual number of publications on non-pharmacological therapies for post-stroke spasticity (2000–2024).

Table 2 Top Ten Productive Countries

Country	Articles	Citations	Country	TC	Average Article Citations
China	103	1338	China	1290	12.6
Italy	26	657	Italy	611	27.8
Spain	25	404	Japan	435	18.1
USA	24	538	Iran	381	22.4
Korea	24	377	Korea	377	15.7
Japan	24	435	Spain	356	17.0
Iran	17	381	Brazil	281	28.1
Turkey	10	213	USA	281	23.4
Brazil	10	281	Turkey	213	21.3
Canada	8	176	India	193	64.3

Changchun University of Chinese Medicine in China (7)[28](Table 3). Using publication volume and inter-institutional relationships, we constructed a collaboration network, as shown in Figure 3. Institutions such as Shanghai University of Traditional Chinese Medicine and Nanjing University of Chinese Medicine, as well as Changchun University of Chinese Medicine and Jilin Provincial Hospital of Traditional Chinese Medicine, are closely linked, reflecting the regional nature of collaborations between universities and between universities and hospitals.

Journal Analysis

A total of 297 articles related to non-pharmacological therapies for post-stroke spastic paralysis were published across 121 journals. *Archives of Physical Medicine and Rehabilitation* had the highest number of publications, with 17 articles, followed by *Frontiers in Neurology* with 15 articles. The top 10 journals collectively published 105 articles, accounting for 38.72% of the total, indicating that these journals play a critical role in disseminating research on acupuncture and stroke treatment (Table 4, Figure 4A).

These 297 articles cited a total of 2007 journals. The top three most-cited journals were *Archives of Physical Medicine and Rehabilitation*,[29] *Stroke*,[3] and *Clinical Rehabilitation*.[30] According to the JCR 2021 standards, among the top 10 co-cited journals, six were classified in the first quartile and four in the second quartile. Founded in 1920, *Archives of Physical Medicine and Rehabilitation*, published by the American Congress of Rehabilitation Medicine (ACRM), is one of the most influential journals in rehabilitation medicine and physical therapy. *Stroke* is a leading journal in the fields of peripheral vascular disease and clinical neurology, especially in stroke research (Table 4, Figure 4B).

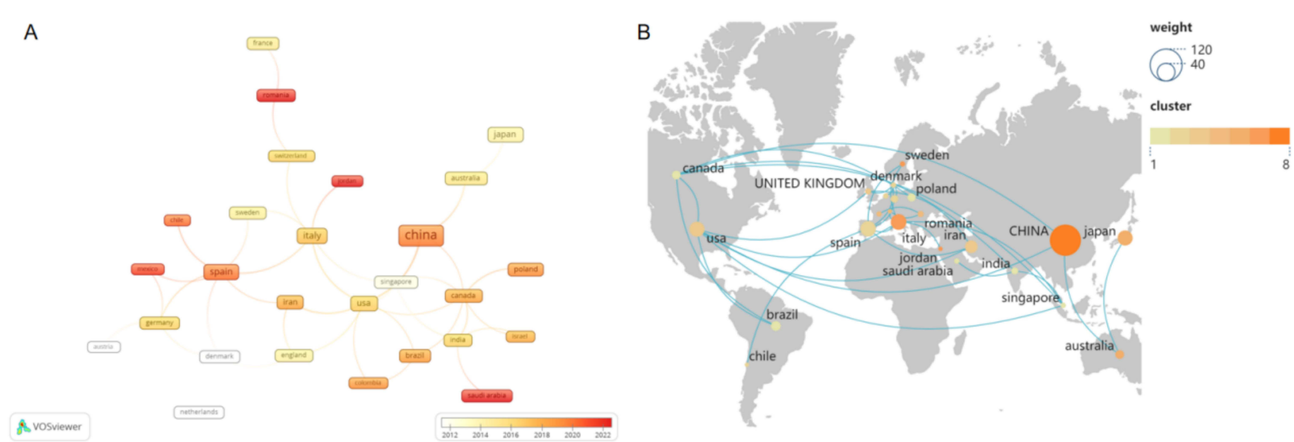

Figure 2 Visualization Analysis of Countries in Publications on Non-Pharmacological Therapies for Post-Stroke Spasticity (2000–2024): **(A)** National Collaboration Network; **(B)** Global Research Distribution Map.

Table 3 Top Ten Productive Institutions

Affiliation	Articles	Citations	Average Citation
Univ Tehran Med Sci	11	257	23.4
Kagoshima Univ	8	211	26.4
Changchun Univ Chinese Med	7	18	2.6
Iran univ med sci	6	149	24.8
Shanghai Univ Tradit Chinese Med	6	42	7.0
Gachon Univ	5	59	11.8
Guangzhou Univ Chinese Med	5	95	19.0
Kagoshima Univ Hosp	5	99	19.8
Univ Cadiz	5	72	14.4
Univ Valencia	5	50	10.0

The journal dual-map overlay in Figure 4C illustrates citation dynamics: citing journals are listed on the left, and cited journals on the right, with citation links represented by colored lines extending from left to right. These colored paths represent citation trajectories, with a main pink path and four minor branches. This main path shows that research in clinical medicine, neurology, and kinesiology frequently cites journals in kinesiology, rehabilitation, nursing, molecular biology, and genetics. Notably, the citation path linking kinesiology and rehabilitation to neuroscience and clinical medicine highlights that treatments for motor disorders (eg stroke rehabilitation, spastic paralysis) rely heavily on clinical research, particularly recent advancements in neurological rehabilitation.

The document coupling analysis in Figure 4D reveals a strong citation network among journals in neuroscience, rehabilitation medicine, and clinical medicine, with significant cross-referencing in studies on neurorehabilitation and

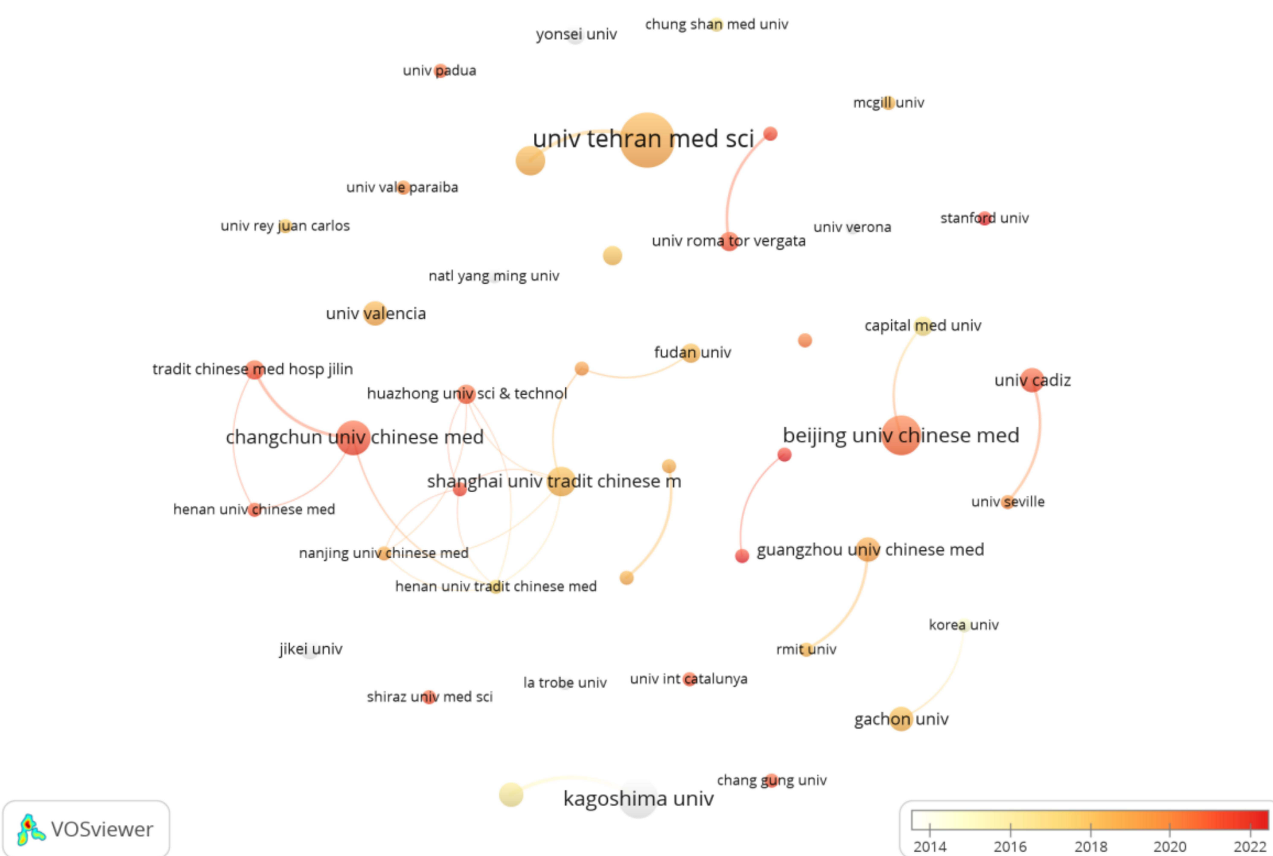

Figure 3 Network diagram of co-authorship among institutions in non-pharmacological therapy research (2000–2024).

Table 4 Top Ten Most Productive and Co-Cited Journals

Rank	Journal	Frequency	IF (2023)	Q (2023)	Rank	Co-Cited Journal	Frequency
1	Archives of physical medicine and rehabilitation	17	3.1	Q1	1	Arch Phys Med Rehab	609
2	Frontiers in neurology	15	4.1	Q1	2	Stroke	469
3	Clinical rehabilitation	14	3.2	Q1	3	Clin Rehabil	328
4	Neurorehabilitation	12	2.0	Q3	4	Phys Ther	319
5	Journal of stroke & cerebrovascular diseases	11	2.3	Q3	5	Neurorehab Neural Re	243
6	Topics in stroke rehabilitation	11	2.9	Q2	6	J Rehabil Med	220
7	Journal of clinical medicine	8	5.0	Q1	7	Neurology	209
8	Disability and rehabilitation	7	3.0	Q2	8	Neurorehabilitation	208
9	PLoS one	6	3.8	Q2	9	Disabil Rehabil	206
10	European journal of physical and rehabilitation medicine	6	3.3	Q1	10	Eur J Phys Rehab Med	179

geriatric medicine. Journals focused on traditional Chinese medicine, such as the *Journal of Traditional Chinese Medicine* and *Acupuncture & Electro-Therapeutics Research*, are gradually integrating into this academic network. Color variations indicate that research hotspots have evolved, with neuroscience and brain research emerging as prominent focuses in recent years.

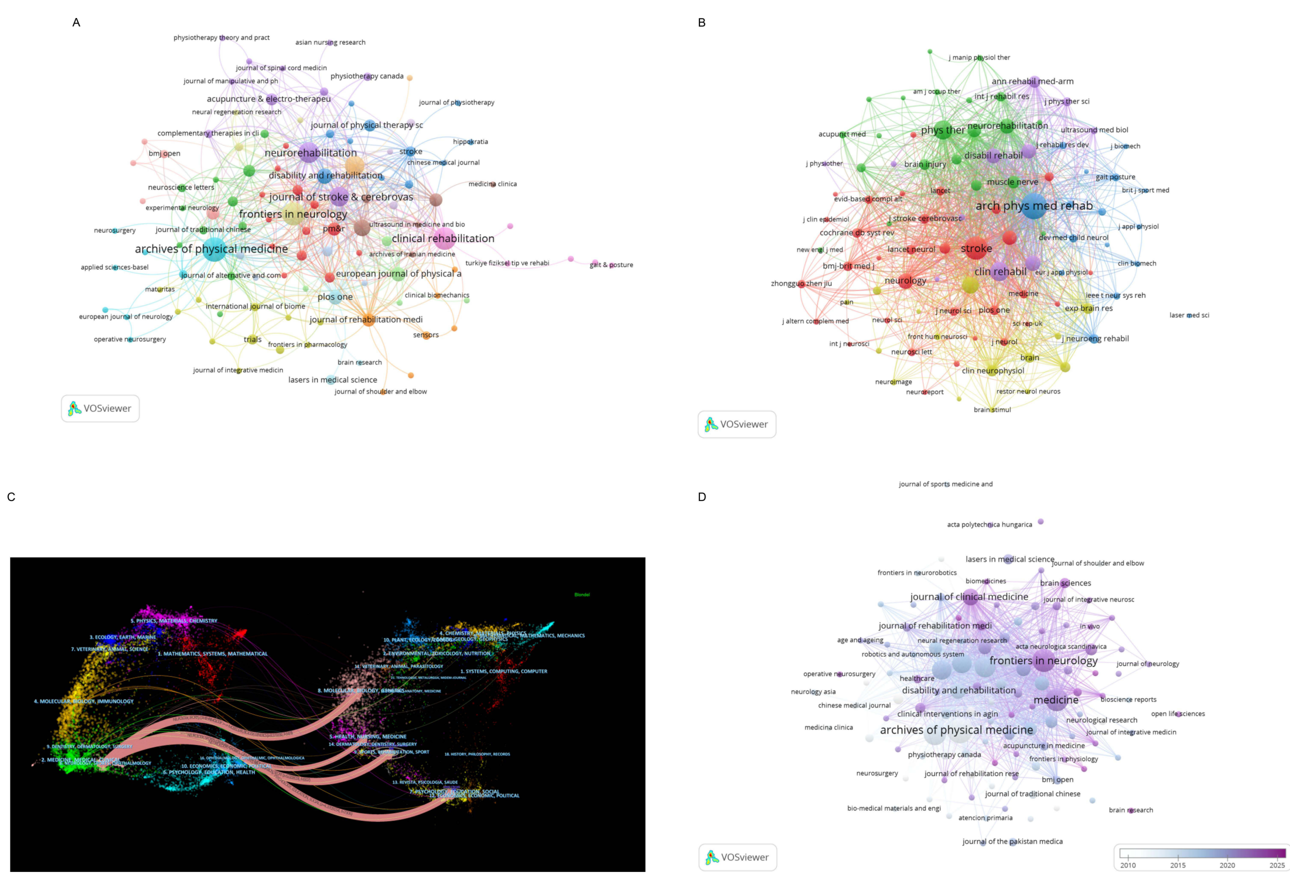

Figure 4 Journal network diagram: (**A**) Journal Graph; (**B**) Co-Cited Journals; (**C**) Overlay of Journal Dual Graph; (**D**) Journal Coupling Analysis Graph.

Author Analysis

Over the past 24 years, 1477 authors have contributed to research on non-pharmacological therapies for post-stroke spastic paralysis, with 14 authors publishing more than five articles. The top three authors by publication volume are Ansari NN, Shimodozono M, and Wang Yufeng (Table 5). Ansari NN's research indicates that dry needling, as a novel neurorehabilitation approach for post-stroke spasticity, offers additional benefits in improving motor neuron excitability and passive wrist extension.[31,32] Shimodozono M primarily focuses on vibration therapy for post-stroke spastic paralysis, finding that vibratory stimulation exerts antispasmodic effects on the hemiplegic upper limbs of stroke patients, with significant improvements in F-wave parameters, MAS scores, and P-ROM after whole-body vibration, as well as a sharp increase in sensorimotor cortex activation.[27,33,34] Wang Yufeng's research includes clinical protocol design, systematic reviews, and meta-analyses, with a primary focus on tuina or combined non-pharmacological therapies for post-stroke spastic paralysis.[35]

We developed a collaboration network, mapping the output and relationships among these authors. Figure 5A and 5B show a relatively well-established research group focused on non-pharmacological therapies for post-stroke spasticity. However, most authors collaborate with members from the same institution, highlighting the need for more cross-institutional and international collaboration. The co-cited author network in Figure 5C shows that authors like Bohannon RW, Lance JW, and Gracies JM have larger nodes, indicating that they are frequently cited in this field and are influential contributors to the research area.

Reference Analysis

We selected the most representative literature on non-pharmacological therapies for post-stroke spastic paralysis from 2000 to 2024 (Table 6). Orange lines represent articles from 2021 to 2023 with clusters labeled "dry needling" and "upper limb function." Yellow lines represent articles from 2018 to 2020, with the cluster label "extracorporeal shock wave therapy." Green lines represent articles from 2012 to 2017, with the cluster label "review" (Figure 6).

The most cited article is *Inter- and intra-rater reliability of the modified Ashworth Scale: a systematic review and meta-analysis,* which notes that the modified Ashworth Scale is the most widely used clinical scale for measuring increased muscle tone, showing better reliability when assessing the upper limbs compared to the lower limbs.[36] Among the top 10 most-cited articles, three discuss the impact of extracorporeal shock wave therapy on spasticity in stroke patients, indicating that this therapy has gained significant attention from researchers.[37–39]

Three systematic reviews analyzed the evidence-based efficacy of non-pharmacological therapies, electroacupuncture, and acupuncture for treating spasticity. The studies reveal that, despite a variety of non-pharmacological interventions for spasticity, there remains a lack of high-quality evidence for many approaches.[40] Acupuncture significantly reduces spasticity in the wrist, knee, and elbow in post-stroke patients, although long-term studies are needed to confirm the durability of these effects.[41] Electroacupuncture combined with standard care may reduce spasticity in the upper and lower limbs and improve overall and lower limb motor function and activities of daily living within 180 days post-stroke.[42]

Table 5 Top Ten Most Productive Authors

Rank	Author	Publications	Citations	Average Citations
1	Ansari, Noureddin Nakhostin	10	263	26.3
2	Shimodozono, Megumi	7	155	22.1
3	Wang, Yufeng	7	126	18.0
4	Cong, Deyu	6	59	9.8
5	Matsumoto, Shuji	6	160	26.7
6	Naghdi, Soofia	6	26	4.3
7	Noma, Tomokazu	6	181	30.2
8	Dymarek, Robert	5	17	3.4
9	Etoh, Seiji	5	126	25.2
10	Rosinczuk, Joanna	5	150	30.0

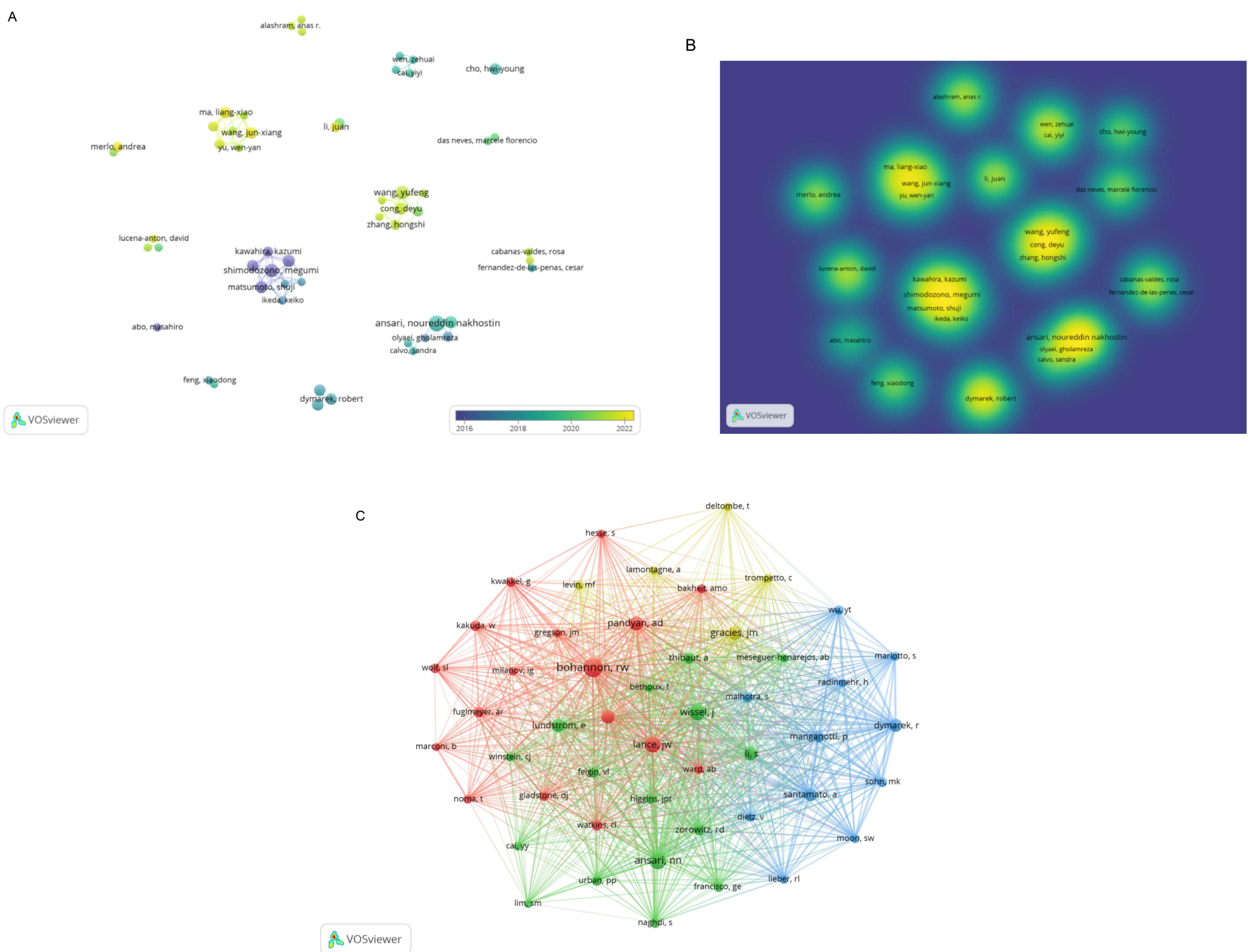

Figure 5 Author network diagram: (**A** and **B**) Author Co-Authorship Network; (**C**) Co-Cited Author Co-Authorship Network.

Keyword Analysis

Frequently used keywords reveal the primary focus of past research, while keywords with high burst intensity may indicate emerging hotspots in future research areas. We analyzed the literature on non-pharmacological therapies for post-stroke spastic paralysis from the 21st century. The top 10 keywords ranked by co-occurrence frequency are shown in Table 7 and Figure 7A, with the top three being “stroke”, “reliability”, and “muscle spasticity.”

Table 6 Top Ten References by Citation Count

Rank	Count	Year	Cited References
1	21	2018	Meseguer-Henarejos AB, 2018, EUR J PHYS REHAB MED, V54, P576, DOI 10.23736/S1973-9087.17.04796-7
2	19	2019	Chen CL, 2019, EUR J PHYS REHAB MED, V55, P754, DOI 10.23736/S1973-9087.19.05545-X
3	18	2019	Khan F, 2019, ANN PHYS REHABIL MED, V62, P265, DOI 10.1016/j.rehab.2017.10.001
4	15	2018	Kuo CL, 2018, INT J GERONTOL, V12, P280, DOI 10.1016/j.ijge.2018.05.005
5	13	2014	Santamato A, 2014, TOP STROKE REHABIL, V21, PS17, DOI 10.1310/tsr21S1-S17
6	13	2017	Cai YY, 2017, ARCH PHYS MED REHAB, V98, P2578, DOI 10.1016/j.apmr.2017.03.023
7	13	2018	Wu YT, 2018, EUR J PHYS REHAB MED, V54, P518, DOI 10.23736/S1973-9087.17.04801-8
8	13	2018	Sánchez-Mila Z, 2018, ACUPUNCT MED, V36, P358, DOI 10.1136/acupmed-2017-011568
9	13	2019	Lee CH, 2019, PM&R, V11, P363, DOI 10.1016/j.pmrj.2018.08.379
10	12	2015	Lim SM, 2015, EVID-BASED COMPL ALT, V2015, P0, DOI 10.1155/2015/870398

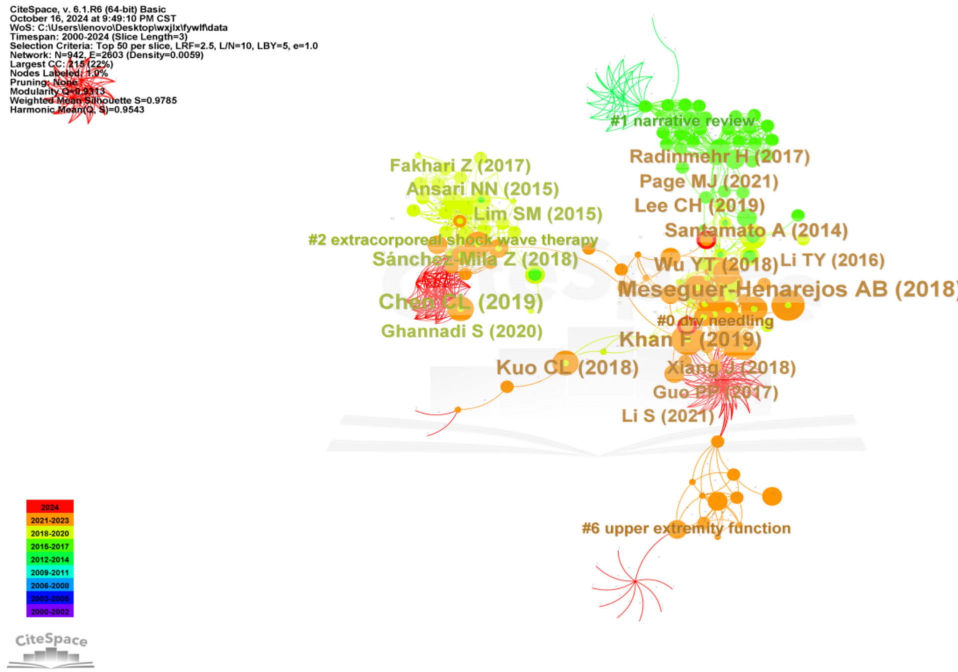

Figure 6 Reference diagram.

As shown in Figure 7B, all keywords are divided into 10 distinct clusters, with the strongest burst clusters being "f-wave", "modulation", and "systematic review", suggesting a current research focus on peripheral nerve modulation and the detection and treatment of neural damage. The timeline in Figure 7C illustrates that in the field of neurorehabilitation, motor dysfunction, and related therapies, research hotspots have gradually shifted from foundational neurophysiological studies to the application of rehabilitation techniques and therapies. In recent years, traditional Chinese acupuncture, Western anatomy and physiology-based dry needling, and electrostimulation therapies have gained increasing attention in rehabilitation medicine. Moreover, the rise of systematic reviews signals that this field is moving into a more systematic, evidence-based phase.

The top 23 keywords with the highest citation bursts are shown in Figure 7D. Research on post-stroke spasticity, particularly upper limb spasticity, has garnered sustained attention since 2021. Systematic review studies in the field of post-stroke spastic paralysis have emerged as a popular research type in this area since 2020. Topics such as ischemic stroke, chronic stroke, repetitive transcranial magnetic stimulation, and exercise have also become prominent in the past two years. This trend highlights the ongoing focus on stroke and its sequelae, especially in the areas of post-stroke rehabilitation and prevention, emphasizing the importance of long-term rehabilitation management after stroke.

Table 7 Top Ten Most Frequently Occurring Keywords

Rank	Count	Centrality	Year	Cited References
1	66	0.01	2005	Stroke
2	62	0.02	2008	Reliability
3	58	0.02	2004	Muscle spasticity
4	58	0.03	2006	Recovery
5	52	0.05	2006	Modified ashworth scale
6	47	0.02	2010	Rehabilitation
7	34	0.05	2004	Management
8	30	0.01	2007	Therapy
9	29	0.05	2004	Botulinum toxin
10	27	0.02	2012	Upper limb spasticity

Figure 7 Keyword network diagram: (**A**) Visualization Analysis; (**B**) Keyword Cluster Diagram; (**C**) Keyword Timeline Diagram; (**D**) Keyword Strength Coefficient.

Analysis of Interventions and Acupoint Selection

To understand which non-pharmacological interventions receive the most attention in treating post-stroke spastic paralysis, we conducted a statistical analysis using VOSviewer and SCImago Graphica. The results identified 19 types of non-pharmacological interventions, with 11 having a frequency of over 10 occurrences (Table 8). Acupuncture was the

Table 8 Top Ten Most Frequently Occurring Interventions

Rank	Interventions	Occurrences
1	Acupuncture	133
2	Extracorporeal shock wave therapy	64
3	Electroacupuncture	42
4	Repetitive transcranial magnetic stimulation	33
5	Rehabilitation training	28
6	Shock wave	21
7	Movement therapy	18
8	Transcranial direct current stimulation	18
9	Transcutaneous electrical nerve stimulation	18
10	Cryotherapy	12

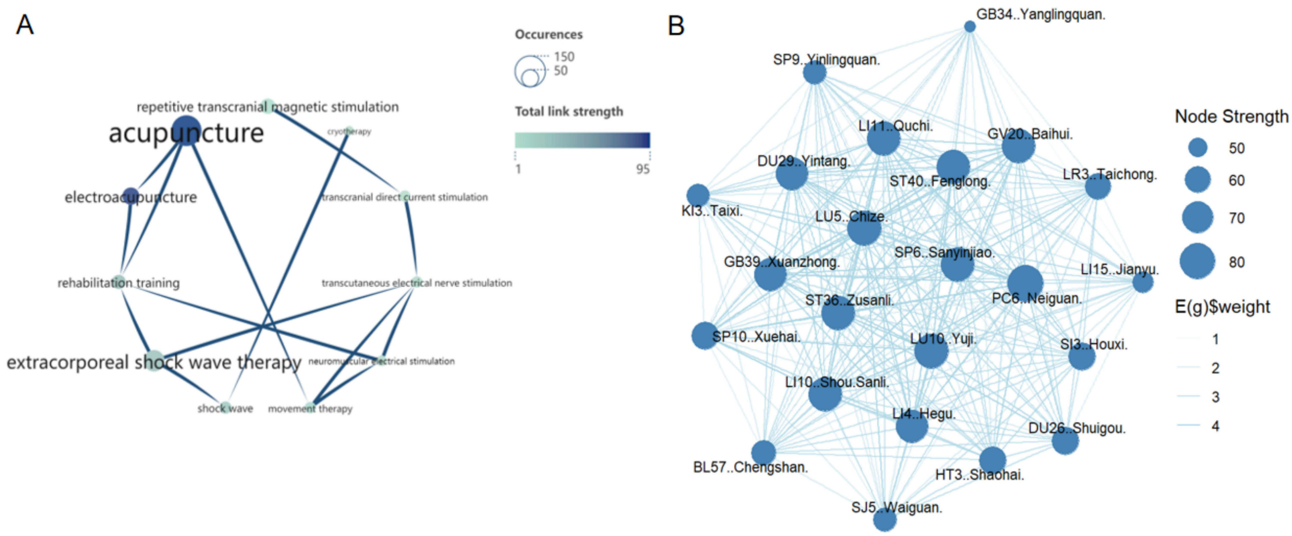

Figure 8 Network diagram of interventions and acupoint selection.

most frequently mentioned intervention, followed by extracorporeal shock wave therapy and electroacupuncture. Combined applications of therapies such as acupuncture with exercise therapy, and extracorporeal shock wave therapy with transcutaneous electrical nerve stimulation,[43] were also observed, as shown in Figure 8A.

Acupuncture, with a history spanning over 2000 years, was widely used to treat hemiplegia as early as the Tang Dynasty in China.[44] In recent years, acupuncture has increasingly been incorporated into global clinical practice guidelines.[45] According to a 2019 report by the World Health Organization, acupuncture is the most widely used form of traditional and complementary medicine, with 113 out of 120 surveyed countries employing it.[46] Basic research has demonstrated that acupuncture provides multi-level protection for the neurovascular unit after stroke, making it a promising treatment for post-stroke spastic hypertonia. It has been shown to increase the expression of GABA, KCC2, and Aγ2 in the lumbar spinal cord of rats with post-ischemic stroke spastic hypertonia, significantly alleviating spinal reflex hyperactivity and reducing muscle tone while improving motor function.[47,48]

Extracorporeal shock wave therapy has been found effective in relieving spastic pain, with sustained effects on agonist and antagonist muscles up to four weeks after treatment. However, it shows no significant impact on upper limb functional movement or swelling.[19] Electroacupuncture may help prevent the worsening of spasticity during the follow-up phase. It is well-accepted among post-stroke spasticity patients, with high adherence and no severe adverse events reported during treatment.[49,50] On a molecular level, electroacupuncture reduces inflammation by inhibiting the NF-κB/NLRP3 signaling pathway and modulating the gut-brain axis through increased levels of n-propionyl acetate and butyryl propionate in the gut, thereby alleviating post-stroke spasticity.[51] Using R language, we further analyzed specific acupoints mentioned in literature related to acupuncture therapy.[44,49,50,52–57] The acupoint co-occurrence frequency chart in Figure 8B shows that Sanyinjiao, Zusanli, Neiguan, and Chize are core acupoints used to treat post-stroke spastic paralysis, often in combination with other acupoints. Research indicates that the therapeutic effect of electroacupuncture varies depending on joint and acupoint selection, especially when acupoints are near the motor points of target muscles.[55] Anatomically, certain acupoints like Sanyinjiao and Zusanli are located close to major lower limb muscle groups, such as the gastrocnemius and soleus, while Neiguan is near the flexor carpi radialis and palmaris longus, and Chize is close to the brachioradialis and biceps brachii in the upper limb. These distribution patterns align closely with dry needling therapy, which targets local muscles and myofascial trigger points, further validating the strong relationship between acupoint selection and therapeutic outcomes.[58,59]

Discussion

General Information

This study provides an overview of global research trends on non-pharmacological therapies in the field of post-stroke spastic paralysis in the 21st century. Overall, the number of related publications has shown a fluctuating growth trend, indicating that non-pharmacological therapies hold potential for further development in the treatment of post-stroke spastic paralysis. However, there is an uneven distribution of research output and academic influence across countries, with a tendency for regional concentration. In terms of collaboration, intra-institutional cooperation dominates, while cross-institutional and cross-national collaborations need further strengthening. As research progresses, the academic community's understanding of post-stroke spastic paralysis treatment has deepened, and treatment methods and assessment systems continue to evolve.

Keywords and Development Trends

Keyword analysis reveals that research on non-pharmacological therapies for post-stroke spastic paralysis is deepening and can be summarized into the following phases:

Preliminary Exploration of Fundamental Mechanisms

Between 2000 and 2010, research keywords primarily focused on "h reflex", "muscle spasticity", and "response", reflecting the initial exploration of the physiological mechanisms and therapeutic approaches for post-stroke spastic paralysis, particularly in the areas of neural reflexes and muscle tone regulation.[60,61] This phase laid the theoretical groundwork for subsequent research on specific therapeutic interventions.

Transition to Clinical Application

From 2011 to 2015, the emergence of keywords such as "occupational therapy", "gait", and "association" signaled a shift in research focus toward the practical application of clinical rehabilitation. Non-pharmacological approaches such as occupational therapy and gait training gained increasing attention for improving functional recovery in patients with post-stroke spastic paralysis.[62,63] This period marked the transition of research from theoretical validation to more refined clinical efficacy studies.

Focus on Efficacy and Standardized Evaluation

During the 2016 to 2020 period, a surge in keywords such as "impact", "trigger point", and "interrater reliability" reflected an intensified focus on specific therapeutic interventions and their evaluation. The role of trigger points in treating post-stroke spastic paralysis gradually gained recognition, with research concentrating on alleviating muscle spasticity through localized stimulation.[64] The rise of "interrater reliability" indicated increased emphasis on the standardization and consistency of assessment tools to ensure accurate evaluation of treatment outcomes and data reliability.[65–67]

Precision in Rehabilitation and Establishment of an Evidence-Based System

Starting in 2021, keywords such as "upper limb spasticity" and "motor function" saw a notable increase, highlighting a growing focus on targeted rehabilitation needs, such as recovery from upper limb spasticity and improvement in specific motor functions.[68,69] Keywords like "excitability", "disease", and "rtms" underscored the exploration of pathological mechanisms and non-invasive treatment methods, with particular attention to the critical role of neural excitability in regulating muscle spasticity.[70] Additionally, the rise of "systematic review" reflected the widespread use of systematic reviews to summarize and evaluate existing intervention strategies and outcome measures, providing stronger evidence for clinical practice.[71]

In-Depth Research on Specific Stroke Types and Exercise Interventions

From 2022 to 2024, keywords such as "chronic stroke", "ischemic stroke", and "exercise" became focal points, reflecting the academic community's growing interest in chronic stroke, ischemic stroke subtypes, and the critical role of active exercise interventions in promoting recovery from post-stroke spastic paralysis.[72,73]

In summary, research on non-pharmacological therapies for post-stroke spastic paralysis has progressed from exploring physiological mechanisms to clinical application validation, efficacy evaluation, and personalized applications.

This evolution not only reflects the deepening of academic research but also aligns with clinical practice demands for more effective and sustainable rehabilitation approaches.

Hotspots and Frontiers

Looking ahead, research on non-pharmacological therapies for the treatment of post-stroke spastic paralysis will increasingly focus on precise optimization in areas such as the type of stroke, the location and severity of spasticity, and the intensity and frequency of interventions. Ischemic stroke, with its high incidence, large patient population, and long-term rehabilitation needs, has attracted significant attention in both clinical and research practice.[74] Research on chronic stroke is equally important, driven by the dual impact of improvements in acute stroke treatment technologies that have increased survival rates and the global trend of population aging.[75] Furthermore, from an economic perspective, chronic stroke imposes a heavy burden on global healthcare systems. For example, in the United States, the cost of treatment, rehabilitation, and supportive care for a typical chronic stroke patient throughout their lifetime can reach approximately $140,000.[76] Therefore, finding effective and cost-efficient long-term rehabilitation strategies for chronic stroke patients has become a key focus of research.

The location and severity of spasticity influence the goals of functional recovery and the selection of rehabilitation methods. In terms of the location of spasticity, the recovery of upper limb function is crucial for improving a patient's ability to live independently and quality of life, as upper limb function directly affects basic survival activities such as gripping, eating, and dressing. These activities require more complex neuromuscular coordination and fine motor control.[77] At the same time, stroke survivors often exhibit a mismatch between the actual motor ability of the affected upper limb and its functional use in daily life, which places higher demands on the accuracy of assessment tools and the specificity of treatment methods.[78] The introduction of refined upper limb assessment tools, such as high-speed 3D motion capture technology and observational drinking tasks, can provide greater support for the quantification and reliability of upper limb function recovery.[79,80] Additionally, combined rehabilitation approaches, such as focal muscle vibration in conjunction with robotic rehabilitation, may be a promising option for improving upper limb spasticity and motor function.[81] However, some studies have shown that while electroacupuncture combined with standard rehabilitation treatment can alleviate elbow spasticity in chronic stroke survivors, no significant effect has been observed in wrist spasticity.[55] Low-frequency repetitive transcranial magnetic stimulation (rTMS) can improve upper limb motor function in patients with mild to moderate chronic stroke, though its effectiveness for severe chronic stroke patients remains unclear.[82]

The selection of non-pharmacological therapies and their associated parameters (such as intensity, frequency, duration, etc). will be a key focus of future research. A network meta-analysis compared the rehabilitation effects of different acupuncture stimulation therapies on spastic hemiplegia in elderly stroke survivors. The results indicated that warm needling acupuncture was more effective in relieving spasticity, while traditional acupuncture and electroacupuncture had more significant effects on promoting motor function recovery.[83] In terms of acupuncture point selection, there is no unified consensus for the treatment of spasticity. Given that electrical stimulation may induce muscle contraction, electroacupuncture is generally applied to the antagonist muscles to avoid stimulating spastic muscles. The frequency is set at 50–100 hz, with treatment duration ranging from 20 to 30 minutes, using a biphasic continuous wave, and adjusted according to the participant's maximum tolerable intensity.[49] A systematic review of Transcutaneous Electrical Nerve Stimulation (TENS) for chronic stroke survivors showed that applying it to the nerve or muscle belly for more than 30 minutes effectively alleviated lower limb spasticity, with the best effect at a frequency of 100 hz. However, due to the limited number of studies, the efficacy of low-frequency TENS has not been fully verified.[84] Extracorporeal Shock Wave Therapy (ESWT) is more effective when applied to the muscle belly or the junction of the muscle and tendon.[85] However, there is currently no unified standard for the specific parameters of ESWT for treating spasticity, such as intensity, frequency, and pulse count.[86] Additionally, some randomized controlled trials have revealed inconsistencies in the effectiveness of non-pharmacological therapies for post-stroke spastic hemiplegia.[83] Clinical trials related to neuromuscular electrical stimulation have also reported contradictory results.[3] The existing evidence provides little clear guidance for selecting specific types of treatments, determining optimal treatment intensity, and dosage.[87] In conclusion, while non-pharmacological therapies show potential in the treatment of post-stroke spastic hemiplegia, the standardization of their dose-effect parameters requires further research and exploration.

Furthermore, the role of systematic reviews and long-term follow-up in screening and optimizing treatment methods will become more prominent. A systematic review reported that the combination of electroacupuncture and rehabilitation training (such as range-of-motion exercises, antagonist muscle strength training, and stretching exercises) seems to be more effective than using electroacupuncture or rehabilitation training alone.[88] Another systematic review of transcranial direct current stimulation combined with upper limb rehabilitation revealed improvements in upper limb motor function during follow-up periods ranging from 3 months to 1 year. However, the number of included studies was limited, and more research is needed to further validate its long-term effects.[89] Other studies have shown that the improvement in functional recovery through physical rehabilitation typically peaks within a few months after a stroke and gradually diminishes, with only minor improvements observed 12 months later. Many patients remain severely disabled.[90] The American Stroke Association's guidelines on adult stroke rehabilitation and recovery clearly state that although formal rehabilitation programs typically end 3 to 4 months after a stroke, this does not mark the conclusion of the entire recovery process. In fact, patients continue to have unmet needs across multiple dimensions, including social reintegration, health-related quality of life, maintenance of activity, and self-efficacy.[75] Therefore, future efforts should integrate evidence-based approaches, continuously verifying and optimizing existing interventions based on high-quality studies and long-term follow-up, in order to develop more scientifically grounded and effective treatment plans that will comprehensively enhance the clinical outcomes and quality of life for patients with post-stroke spastic hemiplegia.

Limitations

This study has certain limitations in terms of data sources and research methodology. Specifically, only data from the Web of Science Core Collection was used, which may have led to the exclusion of relevant studies published in other databases or languages, and terminological differences may affect data completeness. Additionally, while bibliometric analysis can provide an overview of trends in the field, it is limited in evaluating the specific effects of non-pharmacological therapies. Future studies should incorporate more comprehensive review methods, such as systematic reviews and meta-analyses, to more thoroughly evaluate the efficacy and safety of various therapies.

Conclusion

Non-pharmacological therapies have shown positive effects in improving post-stroke spastic hemiplegia, but they may also have some side effects, such as local skin irritation, muscle fatigue, and mechanical damage. However, these risks are relatively minor, and overall, non-pharmacological therapies remain a safer treatment option. Despite these preliminary findings, key parameters of non-pharmacological therapies, such as intensity, frequency, and their long-term effects, still need to be further validated and clarified through more rigorous, large-scale, high-quality randomized controlled trials. In the future, both international and domestic research institutions should strengthen collaboration to promote more influential research results, and further explore individualized and precise rehabilitation treatment plans to fully leverage the advantages of non-pharmacological therapies, ultimately providing better therapeutic outcomes for patients.

Data Sharing Statement

The primary data used and analyzed in the current study are included in the article. For additional information required to replicate or verify the study's findings, please contact the corresponding author.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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