

# Global Status and Future Trends of Fascia and Pain Research in 2013–2022: Bibliometric Analysis Based on CiteSpace and VOSviewer

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**Background:** Fascial pathological pain is the main type of chronic pain in older adults today, and studying the relationship between fascia and pain can help in the clinical search for effective treatments. However, in the face of the vast amount of research findings, there is no systematic assessment of the relationship between fascia and pain in a bibliometric analysis. Therefore, the purpose of this study is to analyze studies on fascia and pain using CiteSpace and VOSviewer to identify research hotspots and future directions.

**Materials and Methods:** A total of 744 papers related to fascia and pain from 2013 to 2022 were collected from the core collection database of Web of Science, and the authors, countries, institutions, keyword co-occurrence, keyword clustering, and keyword emergence were analyzed by CiteSpace and VOSviewer to construct a knowledge map.

**Results:** Literature publication has shown an overall upward trend over the past decade, but there have been some fluctuations. Carmelo Pirri, Caterina Fede, and Raffaele De Caro are the top three authors with the most articles. The United States, China, and Spain are major contributors to fascial and pain research. The University of Padua, Universidad Complutense and Harvard Medical School are leading institutions in this field. However, it is noteworthy that the collaboration between authors, countries and institutions is not active. Keyword analysis showed that hot spots and trends in research on fascia and pain focused on hot diseases, major interventions, and mechanism exploration.

**Conclusion:** This analysis identifies the most influential authors, institutions, and countries in the field of fascial and pain research and provides a reference for assessing their academic impact. The analysis of keywords and co-cited literature is useful for analyzing research hotspots and their evolution, as well as for predicting future trends.

**Keywords:** fascia, pain, bibliometrics analysis, knowledge graph, research progress

## Introduction

Fascia has traditionally been thought of as a simple structure that encircles muscles and organs.<sup>1</sup> However, as research continues, it has been discovered that fascia is found throughout the body and has the potential to influence the whole body. This is reflected in the fascia's ability to support and shape,<sup>2</sup> coordinate body movements and maintain biomechanical balance,<sup>3</sup> maintain internal environmental homeostasis,<sup>4</sup> receive and transmit signals and respond to stimulation accordingly,<sup>5</sup> promote wound repair and regeneration,<sup>6</sup> and regulate the aging process<sup>7</sup> and so on. In addition, studies have shown that fascia is also closely associated with lymphoedema, gastrointestinal symptoms, and cancer processes.<sup>8,9</sup> With the development of traditional Chinese medicine culture, the theory of traditional Chinese medicine is gradually understood by modern medicine and plays an important role. The two-system theory (Fasciology) proposed by Professor

Yuan et al<sup>10</sup> explains the biological basis and treatment mechanism of traditional Chinese medicine therapy and provides a medical-biological basis for the realization of modern Chinese medicine meridian research. At the same time, it also provides a new way for the mechanism research of clinically difficult diseases such as tumors. It is evident that the in-depth study of fascia is of great significance.

Recent studies have shown that there is a close relationship between fascia and pain. According to epidemiological surveys, fascial pathological pain accounts for 85% of pain in outpatient visits, and 95% of chronic pain patients in the elderly and sports population are related to this.<sup>11</sup> Fascial aging is an important cause of chronic pain. The patient's pain site has also been found clinically to have thickened fascial thickness, increased density, altered fibrous composition, and reduced gliding ability at the site of pain and other phenomena.<sup>12,13</sup> These changes may be associated with stress changes in fibroblasts<sup>14</sup> and a decrease in hyaluronic acid secretion by fascial cells,<sup>15</sup> and the presence of injury receptors in the fascia may be a source of local pain and referred pain.<sup>16</sup> These findings suggest that the role of fascia in pain cannot be underestimated. However, the exact relationship between fascia and pain and how it intervenes is not clear and further research is needed.

In the current era of information explosion, it has become a challenge for researchers to obtain valid information from the vast amount of research findings. Bibliometrics is a quantitative method that helps researchers quickly grasp the dynamics and progress of a discipline or research area by visually analyzing relevant literature using correlation analysis software.<sup>17</sup> CiteSpace and VOSviewer are currently recognized as professional software for mapping knowledge domains. To our knowledge, no researcher has yet conducted a bibliometric analysis of the field of fascia and pain. To fill this gap, this study uses CiteSpace 6.1.R6 software and VOSviewer 1.6.18 to analyze the English literature related to fascia and pain research in the past ten years, and draw a network map of authors, countries, institutions, and keywords to interpret the hotspots of pain and fascia related research and speculate the frontier direction to provide a reference for future scholars in this field to carry out relevant research.

## Data and Methods

### Data Source

The Web of Science Core Collection (WoSCC), the world's leading database of scholarly information, has been following strict selection criteria for many years to select the world's most influential and high-quality journals, and is the most commonly used database for bibliometric analysis. Similar studies in the past have also demonstrated the scientific validity of bibliometric analyses based solely on the WoSCC database.<sup>18,19</sup> Therefore, we selected the WoSCC database and used an advanced search strategy for the literature collection. After several pre-searches, we identified the search formula as ((TS= (fascia)) OR TS= (connective tissue)) AND TS= (pain). The search time period was from 1 January 2013 to 31 December 2022 and the literature types were Article and Review.

### Inclusion Criteria

All studies with titles, abstracts and keywords related to the search subject terms were included, WoSCC language was limited to English, and the type of study was not restricted.

### Exclusion Criteria

(1) The subject of the article is "fascia" and the type of disease is not related to "pain". (2) Only "pain" is covered, not "fascia" related content. (3) The types of literature are news stories, contracted information and newspaper articles, dissertations and conference papers. (4) The literature is duplicated.

### Data Analysis

In this study, VOSviewer (<https://www.vosviewer.com/>, version 1.6.18), CiteSpace (<http://cluster.cis.drexel.edu/~cchen/citespace/>, version 6.1.R6) and Excel Office 2019 were used for bibliometric analysis and data visualization. First of all, we will export the documents retrieved from WoSCC as a complete record in plain text and name it download\_.txt. Then import the data into NoteExpress (version 3.5.0) for data cleaning and screening. Two researchers independently screened

the search results to exclude irrelevant, repetitive and inconsistent articles, and the documents with differences were resolved by consultation with the third researcher, resulting in 744 documents being included. Then these data are imported into VOSviewer and CiteSpace for bibliometric and visual analysis. VOSviewer is used to analyze and draw the co-occurrence map of keywords. CiteSpace is used to analyze the temporal distribution and spatial distribution of documents, analyze the keyword clusters that appear at the same time, capture the keywords with strong citation bursts over time, and determine the research frontiers and emerging trends. Excel is used to analyze the time distribution of documents, and the growth of publications in the following year is estimated by a polynomial model:  $y = 0.009x^6 - 109.33x^5 + 55164x^4 - 1E + 09x^3 + 2E + 12x^2 - 2E + 15x + 6E + 17$ .

## Results

### Posting Trend

The search yielded 1841 papers, excluding 1031 not related to the research topic, 17 duplicates, 26 conferences, 12 editorial materials and 11 replies to letters, resulting in 744 papers, including 124 Reviews and 620 Articles (Figure 1). The number of papers published by a discipline in a certain period can not only explain the development speed of this discipline, but also reflect the attention of researchers to this discipline to a certain extent. A statistical analysis of the annual publication volume and publication trends of these 744 articles (Figure 2) shows an overall fluctuating upward trend in the number of articles published from 2013 to 2022. It can be roughly divided into three phases: the first phase, from 2013–2016, shows a slow growth in the number of publications, indicating that at this stage, the relevant theories in the field have not yet been fully validated and the pain field is gradually focusing on the role played by fascia in this. The second phase is from 2017–2019, during which the number of publications decreases, indicating that the field may have hit a bottleneck during this period and new insights are needed to seek new breakthroughs. The third phase, from 2020 to the present, shows a rapid increase in the number of articles published in this phase, which indicates that more and more scholars are focusing on this area and conducting research, resulting in more research findings. The above results suggest that research on the relationship between fascia and pain has become a hot topic and is entering a phase of rapid development.

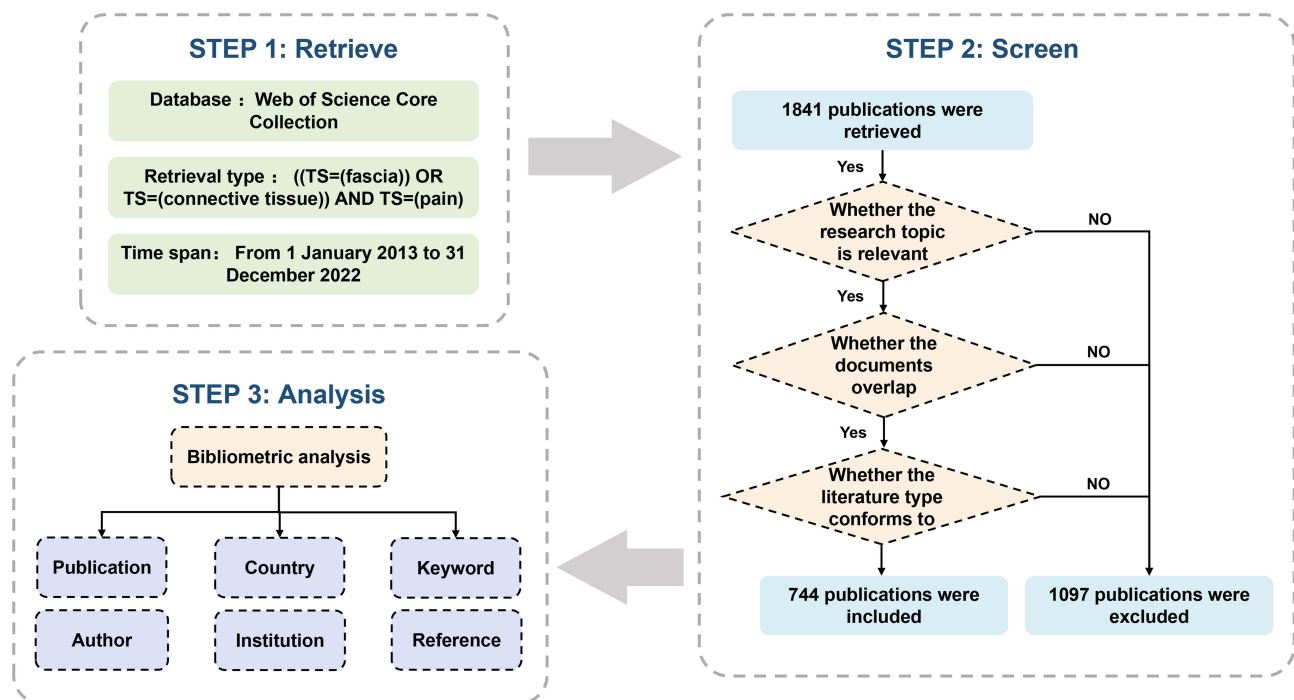
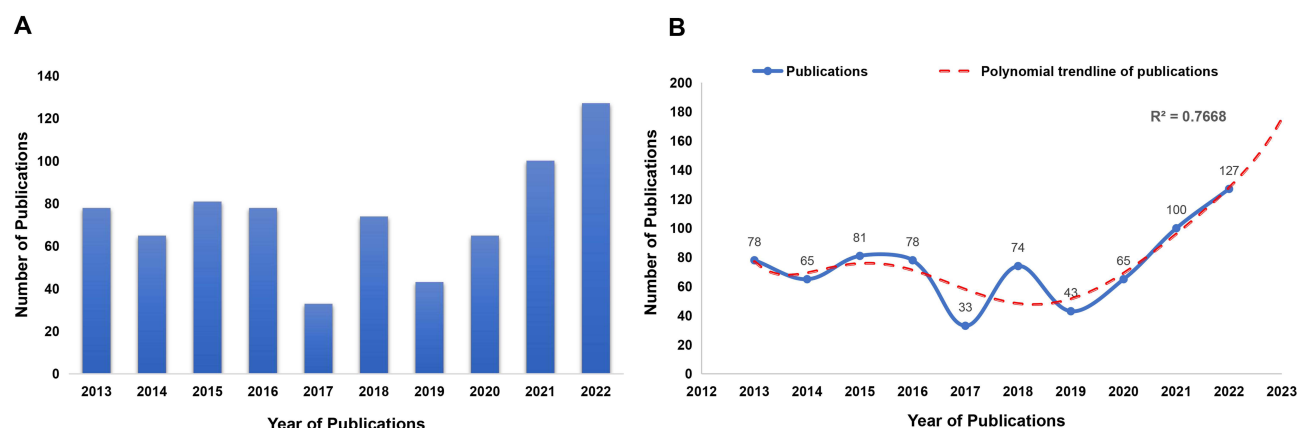


Figure 1 Literature screening process.



**Figure 2 (A)** Annual number of publications from 2013 to 2022. **(B)** Polynomial curve fitting for publication growth.

**Notes:** The fitted formula is  $y = 0.009x^6 - 109.33x^5 + 55164x^4 - 1E + 09x^3 + 2E + 12x^2 - 2E + 15x + 6E + 17$ .

## Distribution of Authors

A total of 3386 authors participated in the research on fascia and pain. Carla Stecco (16 articles, H-index 35), followed by Carmelo Pirri (10 articles, H-index 12), Caterina Fede (9 articles, H-index 17), Raffaele De Caro (8 articles, H-index 40), Wolnei Caumo (8 articles, H-index 35) and Felipe Fregni (8 articles, H-index 94) published the most articles as shown in Table 1. CiteSpace 6.1.R6 software is used to visually analyze the Author collaboration network (Figure 3). The node is “author” and the size of the node is directly proportional to the number of articles published by the author. The collaboration and closeness between different authors are represented by the connecting line and the thickness between the nodes. The graph shows the number of author nodes is 335, the line of communication between authors is 339 and the density is 0.0061. Several author sub-network structures have been formed in the atlas, with three groups working more closely together: first, the network structure formed by Carla Stecco, Caterina Fede, Carmelo Pirri, Raffaele De Caro and others; second, the network structure formed by Wolnei Laumo, Fellpe Fregni, Iraci L S Torres, Allcia Deltos and others form the network structure; third, Daniel Lopez-lopez, Cesar Calvo-lobo, Ricardo Becerro-de-bengoa-vallejo and others form the network structure. These three network structures are densely connected in the visual knowledge map, reflecting the close collaboration of the groups they form, but the groups are not yet collaborating to form a more stable network system. Secondly, there are many individual researchers, such as Mark Driscoll, who has a high volume of dispersed publications. The above results show that there is still a lot of room for research in the field of fascia and pain, and that the awareness of communication and cooperation between researchers and academic exchange needs to be strengthened.

## Distribution of Countries and Institutions

From 2013 to 2022, 2259 institutions in 240 countries or regions published articles in the field of fascia and pain (Figure 4). As shown in Table 2, the top three countries with the most articles are the United States (186 articles, 25%,

**Table 1** Top 6 Authors from 2013 to 2022 According to the Publications Related to Fascia and Pain

Rank	Authors	Publications	Year	H-Index
1	Carla Stecco	16	2013	35
2	Carmelo Pirri	10	2020	12
3	Caterina Fede	9	2020	17
4	Raffaele De Caro	8	2020	40
5	Wolnei Caumo	8	2013	35
6	Felipe Fregni	8	2013	94



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Timespan: 2013-2022 (Slice Length=1)  
Selection Criteria: g-index (k=25), LRF=3.0, L/N=10, LB=5, e=1.0  
Network: N=335, E=339 (Density=0.0061)  
Largest CC: 19 (5%)  
Nodes Labeled: 1.0%  
Pruning: None

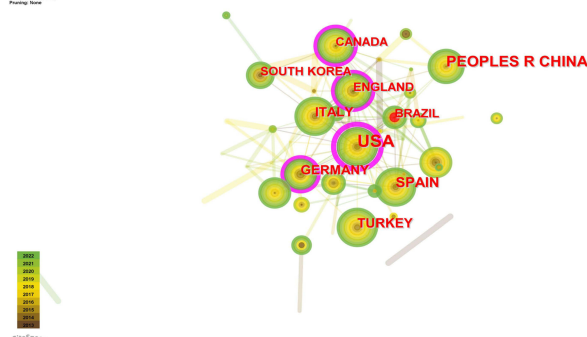


**Figure 3** Co-occurrence network of authors in the field of fascia and pain.

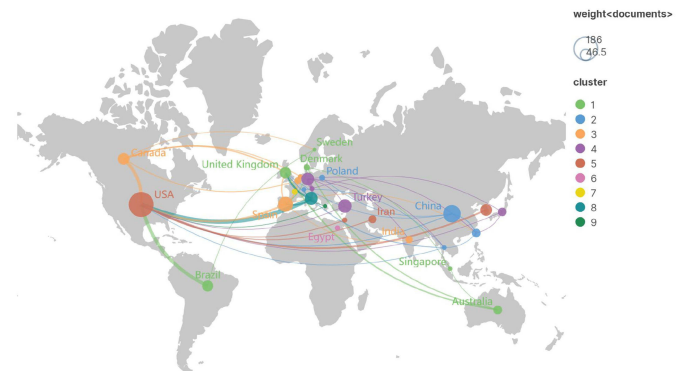
**Notes:** The size of nodes represents the number of papers published by authors, and the connection between nodes reflects the strength of cooperative relationship.

**A**

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Timespan: 2013-2022 (Slice Length=1)  
Selection Criteria: g-index (k=25), LRF=3.0, L/N=10, LB=5, e=1.0  
Network: N=335, E=339 (Density=0.0061)  
Largest CC: 19 (5%)  
Nodes Labeled: 1.0%  
Pruning: None



**B**



**Figure 4** (A) Distribution of publications by country/region. (B) A national/regional collaboration map for fascia and pain.

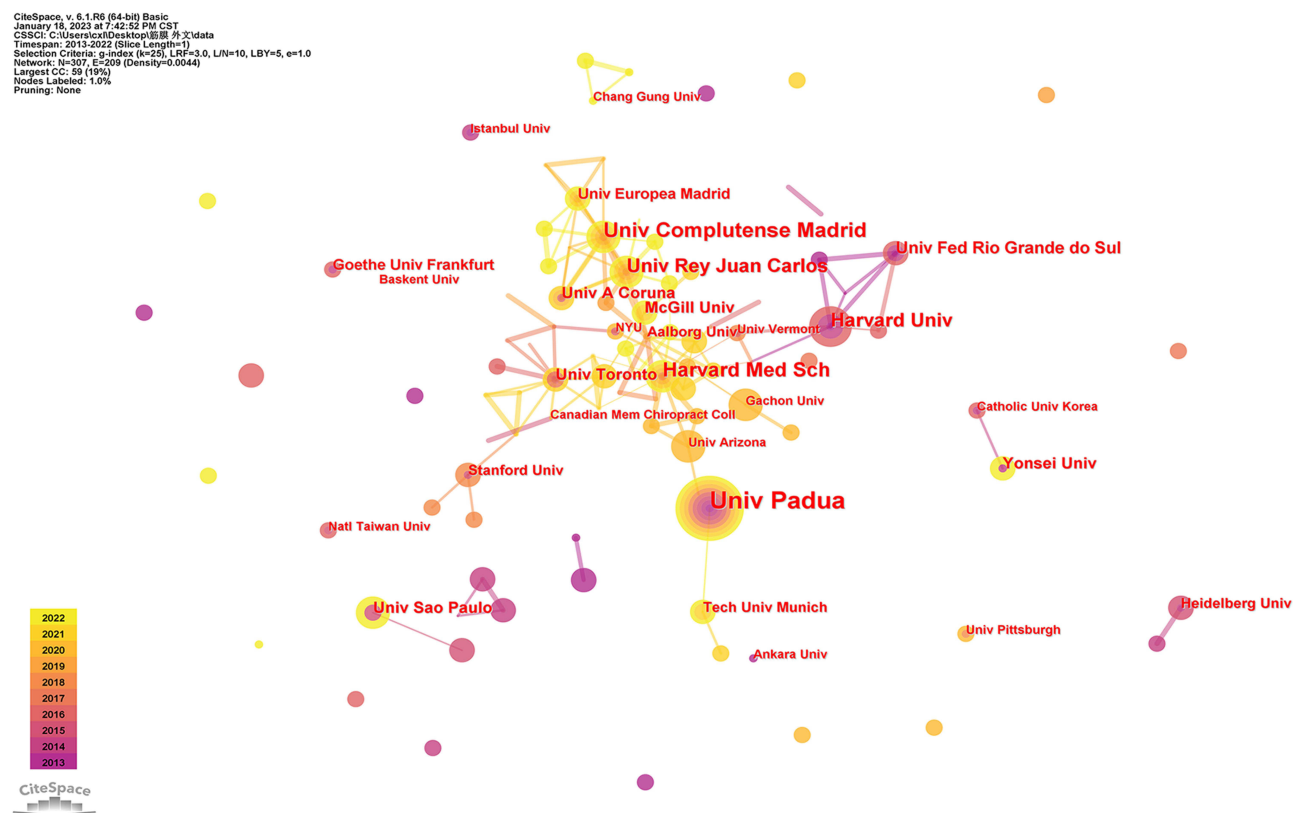
**Notes:** (A) The size of the nodes represents the number of papers published in that region, and the connection between nodes reflects the strength of the collaboration. The region with the purple outer ring represents the high centrality (> 0.1). (B) The closer the connection between countries, the thicker the connection.

Citations 3743), China (91 articles, 12.23%, Citations 489) and Spain (68 articles, 9.14%, Citations 695). Among these, the centrality of the United States is the highest at 0.53, indicating that the United States also maintains its core position in the field of fascia and pain. In addition, the centrality of Germany (0.16), the UK (0.15) and Canada (0.13) are all greater than 0.1, suggesting that these four countries have close collaborations with other countries and regions. Although China has the second largest number of published documents, its collaborations with other countries are not close. The above results show that the international collaborative environment of fascia in pain research has begun to form, but more forces are still needed to participate in it.

**Table 2** Top 10 Countries/Regions with the Most Publications from 2013 to 2022

Rank	Country/Region	Publications	% of (744)	Citations	Centrality
1	USA	186	25.00	3743	0.53
2	China	91	12.23	489	0.03
3	Spain	68	9.14	695	0.04
4	Turkey	55	7.39	623	0
5	Italy	51	6.85	930	0.03
6	Germany	48	6.45	774	0.16
7	Canada	41	5.51	1102	0.13
8	South Korea	41	5.51	444	0
9	United Kingdom	39	5.24	531	0.15
10	Brazil	37	4.97	805	0.03

Figure 5 shows the symbiotic network between the 307 institutions with the highest number of papers, with 209 lines of connection and a density of 0.0044. Table 3 lists the top five institutions with the highest number of papers, among which the University of Padua is the first among the core publishing institutions (25 papers, 3.36%), followed by Complutense University of Madrid (14 papers, 1.88%), Harvard Medical School (13 papers, 1.75%), Universidad Rey Juan Carlos (12 papers, 1.61%) and Harvard University (11 papers, 11.61%). The top five institutions are mainly from

**Figure 5** Institutional co-occurrence network of documents in the field of fascia and pain.

**Notes:** The size of nodes represents the number of papers published by institutions, and the connection between nodes reflects the strength of cooperative relationship.

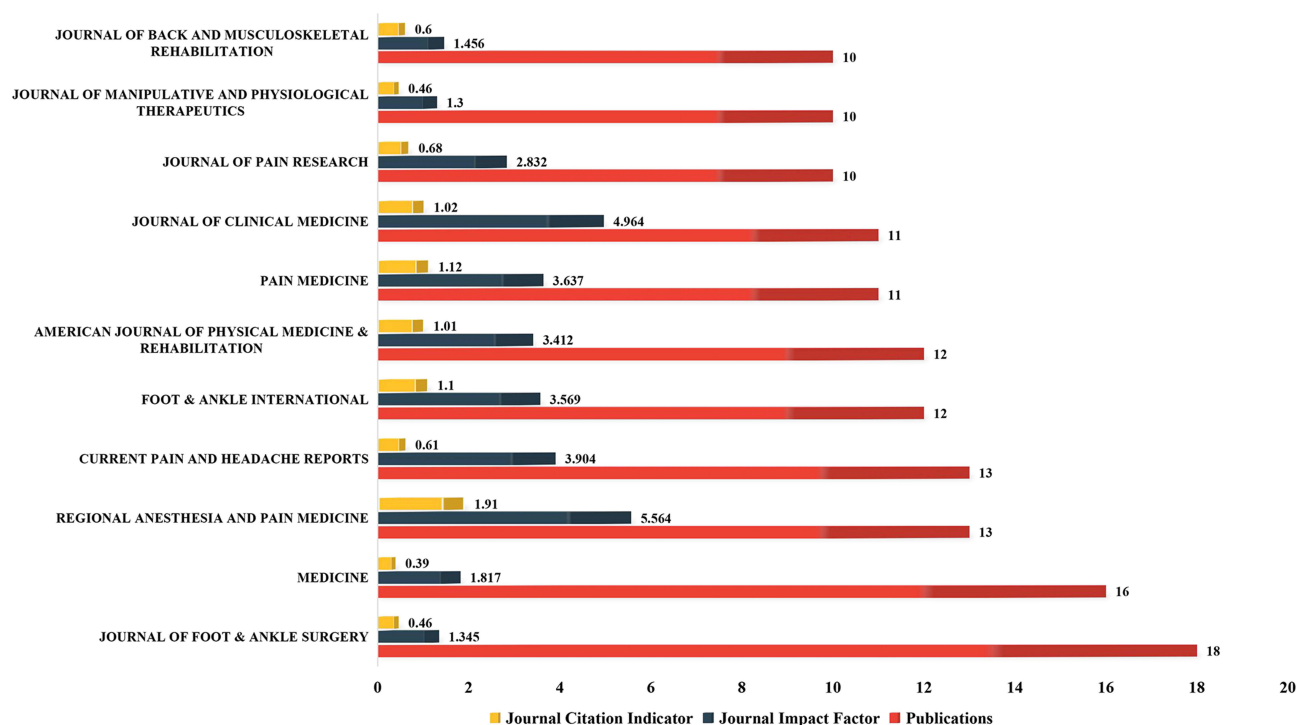
**Table 3** Top 5 Institutions with the Most Publications from 2013 to 2022

Rank	Institutions	Publications	% of (744)	Centrality
1	Univ Padua	25	3.36	0
2	Univ Complutense Madrid	14	1.88	0.01
3	Harvard Med Sch	13	1.75	0.05
4	Univ Rey Juan Carlos	12	1.61	0.03
5	Harvard Univ	11	1.48	0.01

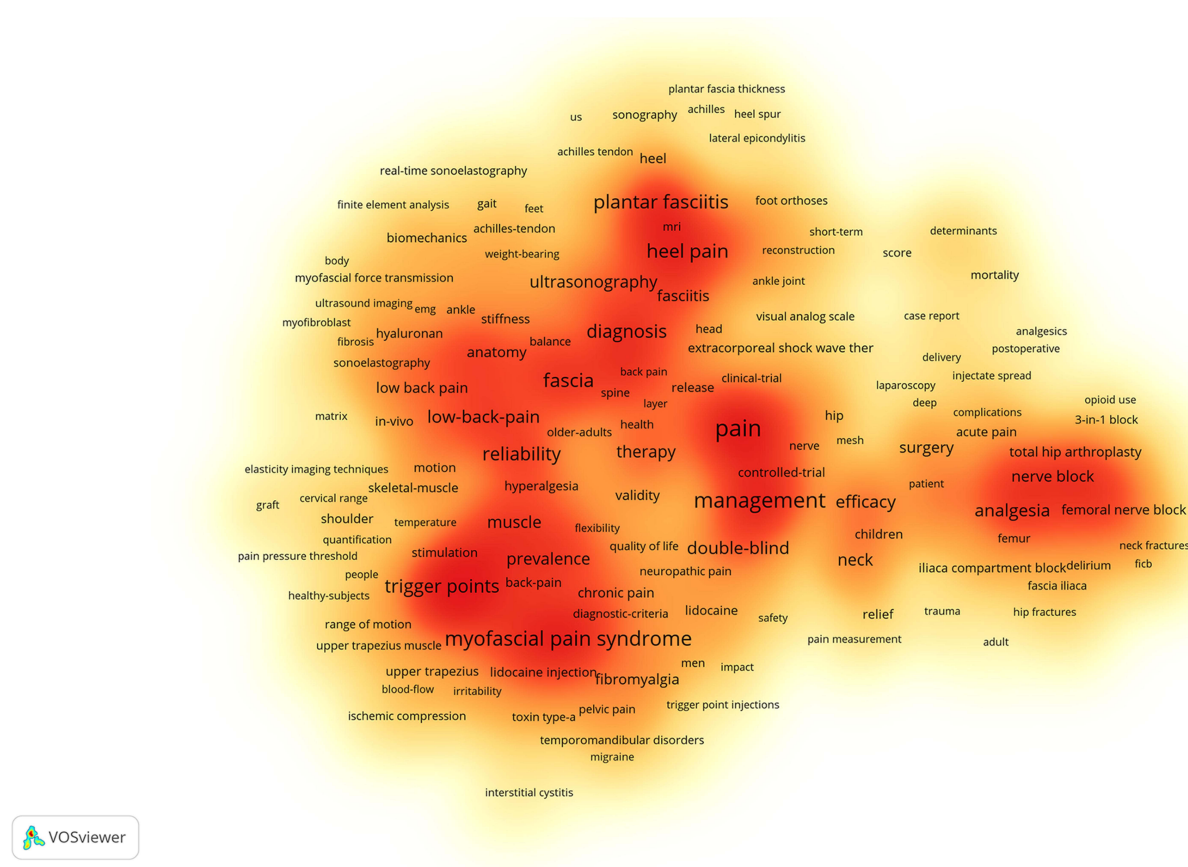
Italy (n=1), the United States (n=2) and Spain (n=2), which shows that Italy, the United States and Spain have great influence in the field of fascia and pain. However, the centrality of these institutions is low, suggesting that the communication between them is not close.

## Distribution of Journals

The articles were published in 323 journals. Figure 6 shows 11 journals with 10 articles or more. Impact factor is a common index for periodical evaluation among nations. It is not only an index to measure the usefulness and display of periodicals, but also an important index to measure the academic level of periodicals and even the quality of papers. The Journal Citation Indicator (JCI) is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three years, and it is another important index for evaluating periodicals besides Journal Impact Factor (JIF). According to the data, JOURNAL OF FOOT AND ANKLE SURGERY (18 articles) published the most articles, followed by MEDICINE (16 articles), Regional Anesthesia and Pain Medicine (13 articles) and Current Pain and Headache Reports (13 articles). Among the top 11 journals, the influence factors and citation index of Regional Anesthesia and Pain Medicine (IF 5.564, JCI 1.91) are the highest, followed by Journal of Clinical Medicine (IF 4.964, JCI 1.02), PAIN MEDICINE (IF 3.637, JCI 1.12), Foot and Ankle International (IF 3.569, JCI 1.1), JOURNAL OF BACK AND MUSCULOSKELETAL REHABILITATION (IF 1.456, JCI 0.6), JOURNAL OF MANIPULATIVE AND PHYSIOLOGICAL THERAPEUTICS (IF 1.3, JCI 0.46), JOURNAL OF PAIN RESEARCH (IF 2.832, JCI 0.68), AMERICAN JOURNAL OF PHYSICAL MEDICINE & REHABILITATION (IF 3.412, JCI 1.01), FOOT & ANKLE INTERNATIONAL (IF 3.569, JCI 1.1), CURRENT PAIN AND HEADACHE REPORTS (IF 3.904, JCI 0.61), REGIONAL ANESTHESIA AND PAIN MEDICINE (IF 5.564, JCI 1.91), MEDICINE (IF 1.817, JCI 0.39), JOURNAL OF FOOT & ANKLE SURGERY (IF 1.345, JCI 0.46).

**Figure 6** Distribution of productive journal publications.





**Figure 8** Density view of keywords.

**Notes:** The greater the number of items in the neighborhood of a point, the higher the weight of the items in the neighborhood, and the closer the point is to red.

syndrome, chronic pain, fibromyalgia and prostatitis are the main research contents. In terms of treatment, the main keywords contained in #1 suggest that the use of fascia iliaca compartment block in analgesia has been widely addressed. The keywords in #7 suggest that surgery is the main treatment for fasciitis necrosis and diabetic foot.

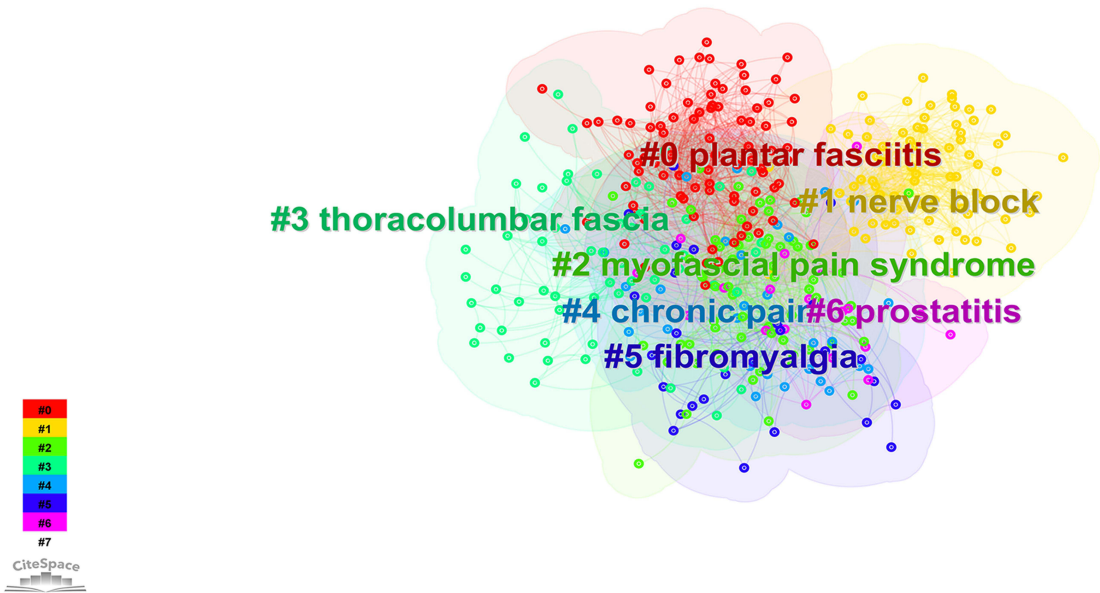
**Table 4** Top 10 Keywords with High Centrality

Rank	Keywords	Centrality	Frequency	Year
1	Pain	0.16	86	2013
2	Low back pain	0.11	73	2013
3	Acupuncture	0.10	19	2013
4	Muscle	0.09	56	2013
5	Mechanism	0.09	23	2013
6	Management	0.09	114	2013
7	Trigger point	0.08	100	2013
8	Injury	0.08	19	2013
9	Pain management	0.07	34	2014
10	Injection	0.07	35	2013



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Network: N=370, E=2372 (Density=0.0347)  
Largest CC: 367 (99%)  
Nodes Labeled: 1.0%  
Pruning: None  
Modularity Q=0.4631  
Weighted Mean Silhouette S=0.7805  
Harmonic Mean(Q, S)=0.5813

#7 surgical procedures - operative



**Figure 9** Visualization of the keyword clustering analysis.  
**Note:** The same color represents a category.

**Keyword Emergence**

Burst detection is used to detect the rise or fall of a subject term or keyword and can reveal the most active areas and emerging trends on the web. To further explore the research hotspots and frontiers of fascia and pain, we use the burst detection algorithm to analyze the keywords (Figure 10). It can be broadly divided into two phases. The first phase, from

**Table 5** Keyword Clustering for Fascia and Pain

Classify	Cluster Number	Size	Year	Silhouette	Clustering Label	Main Keywords
Research objects	#3	60	2017	0.778	Thoracolumbar fascia	Thoracolumbar fascia; fascia; low back pain; connective tissue; sensory innervation
Disease	#0	86	2016	0.769	Plantar fasciitis	Plantar fasciitis; plantar fascia; heel pain; plantar heel pain; myofascial pain
	#2	64	2015	0.665	Myofascial pain syndrome	Myofascial pain syndrome; dry needling; trigger point; plantar fasciitis; neck pain
	#4	31	2016	0.819	Chronic pain	Chronic pain; quantitative sensory testing; cortical excitability; myofascial pain syndrome; noninvasive brain stimulation
	#5	27	2014	0.839	Fibromyalgia	Fibromyalgia; quality of life; chronic pelvic pain; abdominal muscles; central sensitization
	#6	19	2014	0.84	Prostatitis	Prostatitis; cystitis; interstitial; neuropathic pain; overlapping conditions

(Continued)

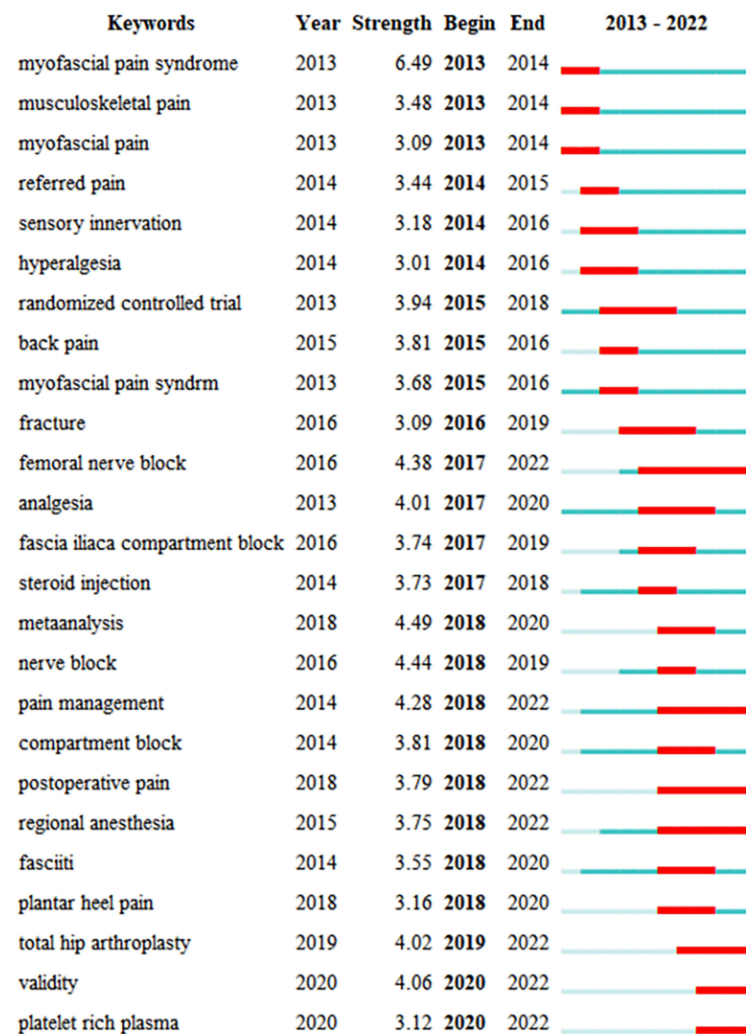


**Table 5** (Continued).

Classify	Cluster Number	Size	Year	Silhouette	Clustering Label	Main Keywords
Treatment	#1	76	2017	0.839	Nerve block	Nerve block; fascia iliaca compartment block; analgesia; hip fracture; fascia iliaca block
	#7	4	2014	0.99	Surgical procedures operative	Surgical procedures operative; diabetes; fasciitis - necrotizing; serbia; diabetic foot

2013 to 2016, focused on clinically relevant fascia-related pain conditions, including myofascial pain syndrome, back pain, musculoskeletal pain, myo-abdominal pain syndrome and referred pain. The research methodology consists mainly of randomized controlled trials. Mechanistic studies include sensory innervation and nociceptive hyperalgesia. The second phase is from 2017 to the present, where the use of fascial tissues in analgesia has been identified, including

### Top 25 Keywords with the Strongest Citation Bursts

**Figure 10** Quote the top 25 keywords with the strongest outbreak.

**Notes:** The year indicates the time when the keyword first appeared. Intensity describes the degree of the cited variation. The start and end indicate the start and end times of each burst. The red bar indicates the time when keywords frequently appear, and the blue bar indicates the time when keywords rarely appear.

## Related Areas of Analysis

## Analysis of Co-Cited Literature

**Notes:** The length of the horizontal axis of the ellipse represents the number of authors, the length of the vertical axis of the ellipse indicates the number of published literatures, and the curves are citation curves; the higher the z-Scores function score, the thicker the curve.

**Table 6** The Top 15 Most Cited Publications

Rank	Title	Journal	First Author	Year	Citation Times	Total Citations
1	A Longitudinal Supra-Iliac Fascia Compartment Block Reduces Morphine Consumption After Total Hip Arthroplasty	Reg Anesth Pain Med	Desmet, M	2017	22	82
2	Sensory innervation of the thoracolumbar fascia in rats and humans	Neuroscience	Tesarz, J	2011	19	146
3	Innervation of the thoracolumbar fascia	Eur J Transl Myol	Mense, S	2019	17	43
4	The Lumbodorsal Fascia as a Potential Source of Low Back Pain: a Narrative Review	Biomed Res Int	Wilke, J	2017	14	55
5	Objective Sonographic Measures for Characterizing Myofascial Trigger Points Associated With Cervical Pain	J Ultrasound Med	Ballyns, J J	2011	13	104
6	Ultrasound guided corticosteroid injection for plantar fasciitis: randomised controlled trial	BMJ	McMillan, A M	2012	13	88
7	Etiology of myofascial trigger points	Curr Pain Headache Rep	Bron, C	2012	12	142
8	Novel applications of ultrasound technology to visualize and characterize myofascial trigger points and surrounding soft tissue	Arch Phys Med Rehabil	Sikdar, S	2009	12	234
9	Imaging of plantar fascia disorders: findings on plain radiography, ultrasound and magnetic resonance imaging	Insights Imaging	Draghi, F	2017	11	53
10	International Consensus on Diagnostic Criteria and Clinical Considerations of Myofascial Trigger Points: A Delphi Study	Pain Med	Fernandez-de-Las-Penas, C	2018	11	126
11	Reduced thoracolumbar fascia shear strain in human chronic low back pain	BMC Musculoskelet Disord	Langevin, H M	2011	11	171
12	Sensory findings after stimulation of the thoracolumbar fascia with hypertonic saline suggest its contribution to low back pain	Pain	Schilder, A	2014	11	84
13	The effect of dry needling in the treatment of myofascial pain syndrome: a randomized double-blinded placebo-controlled trial	Clin Rheumatol	Tekin, L	2013	11	123
14	Steroid injection for inferior heel pain: a randomised controlled trial	Ann Rheum Dis	Ball, E M	2013	10	59
15	Comparison of the postoperative analgesic efficacy of an ultrasound-guided fascia iliaca compartment block versus 3 in 1 block in hip prosthesis surgery	Agri	Deniz, S	2014	10	41

**Notes:** Citation times refer to the number of citations in the current dataset. Total citations refer to the total number of citations in Web of Science.

## Discussion

### Basic Information

This study used CiteSpace and VOSviewer to analyze the literature on fascia and pain in the WOS database core collection from January 1, 2013, to December 31, 2022. The visualization of the knowledge map intuitively reflects the

## Top 25 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2013 - 2023
Sikdar S, 2009, ARCH PHYS MED REHAB, V90, P1829, DOI 10.1016/j.apmr.2009.04.015, <a href="#">DOI</a>	2009	6	2013	2014	
Tesarz J, 2011, NEUROSCIENCE, V194, P302, DOI 10.1016/j.neuroscience.2011.07.066, <a href="#">DOI</a>	2011	5.32	2013	2016	
Bron C, 2012, CURR PAIN HEADACHE R, V16, P439, DOI 10.1007/s11916-012-0289-4, <a href="#">DOI</a>	2012	4.54	2013	2015	
Tough EA, 2009, EUR J PAIN, V13, P3, DOI 10.1016/j.ejpain.2008.02.006, <a href="#">DOI</a>	2009	3.99	2013	2014	
McMillan AM, 2012, BMJ-BRIT MED J, V344, P0, DOI 10.1136/bmj.e3260, <a href="#">DOI</a>	2012	3.62	2013	2016	
Xu YM, 2010, J PAIN, V11, P1348, DOI 10.1016/j.jpain.2010.03.010, <a href="#">DOI</a>	2010	3.49	2013	2014	
Schilder A, 2014, PAIN, V155, P222, DOI 10.1016/j.pain.2013.09.025, <a href="#">DOI</a>	2014	4.25	2014	2016	
Tekin L, 2013, CLIN RHEUMATOL, V32, P309, DOI 10.1007/s10067-012-2112-3, <a href="#">DOI</a>	2013	4.25	2014	2016	
Ballyns JJ, 2011, J ULTRAS MED, V30, P1331, DOI 10.7863/jum.2011.30.10.1331, <a href="#">DOI</a>	2011	3.62	2014	2016	
Goff JD, 2011, AM FAM PHYSICIAN, V84, P676	2011	3.39	2014	2015	
Turo D, 2013, ULTRASONIC IMAGING, V35, P173, DOI 10.1177/0161734612472408, <a href="#">DOI</a>	2013	3.39	2014	2015	
Elkhodair S, 2011, EUR J EMERG MED, V18, P340, DOI 10.1097/MEJ.0b013e32834533dd, <a href="#">DOI</a>	2011	3.08	2014	2016	
Willard FH, 2012, J ANAT, V221, P507, DOI 10.1111/j.1469-7580.2012.01511.x, <a href="#">DOI</a>	2012	3.34	2015	2016	
Diakomi M, 2014, REGION ANESTH PAIN M, V39, P394, DOI 10.1097/AAP.0000000000000133, <a href="#">DOI</a>	2014	3.49	2016	2019	
Deniz S, 2014, AGRI, V26, P151, DOI 10.5505/agri.2014.76993, <a href="#">DOI</a>	2014	4.88	2017	2019	
Fujihara Y, 2013, J ORTHOP SCI, V18, P793, DOI 10.1007/s00776-013-0417-y, <a href="#">DOI</a>	2013	4.59	2017	2018	
Groot L, 2015, WEST J EMERG MED, V16, P1188, DOI 10.5811/westjem.2015.10.28270, <a href="#">DOI</a>	2015	4.39	2017	2019	
McRae PJ, 2015, J EMERG MED, V48, P581, DOI 10.1016/j.jemermed.2014.12.016, <a href="#">DOI</a>	2015	3.08	2018	2019	
Chesters A, 2014, EMERG MED J, V31, PE84, DOI 10.1136/emmermed-2013-203073, <a href="#">DOI</a>	2014	3.08	2018	2019	
Desmet M, 2017, REGION ANESTH PAIN M, V42, P327, DOI 10.1097/AAP.0000000000000543, <a href="#">DOI</a>	2017	3.83	2019	2023	
Fernandez-de-las-Penas C, 2018, PAIN MED, V19, P142, DOI 10.1093/pm/pnx207, <a href="#">DOI</a>	2018	3.55	2020	2023	
Mense S, 2019, EUR J TRANSL MYOL, V29, P151, DOI 10.4081/ejtm.2019.8297, <a href="#">DOI</a>	2019	6.85	2021	2023	
Fede C, 2020, J ORTHOP RES, V38, P1646, DOI 10.1002/jor.24665, <a href="#">DOI</a>	2020	4.01	2021	2023	
Wilke J, 2017, BIOMED RES INT, V2017, P0, DOI 10.1155/2017/5349620, <a href="#">DOI</a>	2017	3.52	2021	2023	
Wilke J, 2018, J APPL PHYSIOL, V124, P234, DOI 10.1152/japplphysiol.00565.2017, <a href="#">DOI</a>	2018	3.2	2021	2023	

**Figure 12** The top 25 references with the strongest citation bursts.

**Notes:** The year indicates when the citation first appeared. Intensity describes the degree of variation in citations made. Start and end indicate when each burst began and ended.

publication trend of literature in the field of fascia and pain, the cooperation network of main research countries/regions and institutions, the main research content, and the research frontier hotspots to provide a reference for the further research of fascia in the field of pain.

The trend of literature published over the last decade shows a general increase in the amount of literature on fascia in pain, particularly in the last three years, indicating that this area is being actively researched. The United States, China, and Spain contributed the most. Half of the top ten countries with the most published articles are from Europe, which means that European countries have a positive academic influence on fascial and pain research. Among the national cooperation networks, the United States, Germany, the United Kingdom, Canada, and other countries have extensive national cooperation networks, among which the United States has the highest centrality and plays a bridge role in the cooperation between various countries. The above results indicate that the international cooperation environment of fascia in pain research has initially formed, but more forces are still needed to participate in it. The analysis of institutions showed that the top 10 institutions by volume of publications were from many countries, but the collaboration between institutions was not close. This phenomenon is also reflected in the co-occurrence map of author cooperation. Three main network structures have been formed, represented by Carla Stecco, Wolnel Laumo, and Daniel Lopez-lopez, but there is no cooperation among these groups. Establishing high-quality academic exchange relations between institutions of different countries and promoting the friendly collaboration of researchers from other countries are conducive to the



emergence of high-quality research results. Therefore, encouraging national researchers to establish collaborative partnerships with global institutions to enhance their literary influence further is a crucial move to expand research outcomes.

## Research Frontiers and Hotspots

Global research trends in fascia and pain can be explored by analyzing keyword bursts, reference bursts, and timelines. We found that myofascial pain syndrome, nerve blocks, ultrasound, and treatment in keyword bursts appeared late and continued to increase attention, which was at the forefront of current research.

Fascia has the continuity of non-adjacent areas that envelop the human body's viscera, muscles, etc., forming a three-dimensional system.<sup>24</sup> Nowadays, the medical community is looking at fascia with a new perspective. The functional characteristics of the fascia are mainly reflected in the following aspects. (1) Support and shaping: the capsule, ligament, septum, and intermembrane formed by fascia play a mechanical role, such as fixing the position of organs and maintaining their morphology,<sup>25</sup> and it can limit the spread of diseases on different fascial planes.<sup>26</sup> (2) The generation and conduction of force: the fascial structure essentially gives its ability to transmit the produced power. The latter is a transporter of the created tension and stores mechanical energy in order to save myoelectric energy.<sup>27</sup> This function is determined to a large extent by fibroblasts.<sup>4,28</sup> (3) Maintenance of internal environmental homeostasis: the rich capillaries in the fascia provide the necessary nutrients for the metabolism of various organ cells.<sup>27</sup> The fibroblasts contained in it can maintain the homeostasis of the internal environment by regulating the pressure and flow of fluid penetrating the fascia and releasing growth factors.<sup>6</sup> (4) Information communication: sensory neurons, special receptors, and micro-particle receptors contained in the fascia can play an essential role in the reception and transmission of information.<sup>5,12</sup> In addition, studies have found that it regulates emotions<sup>29</sup> and forms memory.<sup>30</sup> (5) Repair and regeneration: the collective migration of the fascial fibroblasts and the mobilization of the fascial matrix play a crucial role in wound repair and resurrection.<sup>6</sup> (6) Life span: the aging process of the human body is a process of gradual depletion of stem cell reserve in the fascia.<sup>10</sup> Therefore, maintaining the fascia's normal state and differentiation of stem cells is critical to prolonging life. It can be seen that the balance of the fascial system plays an essential role in all aspects of the body.

Recent studies have found a close relationship between fascia and pain. Clinical data show that the pain nerve content of lumbar fascia in patients with low back pain is several times higher than that of ordinary people,<sup>31</sup> and ultrasound shows that pain is related to increased fascia thickness and decreased shear force.<sup>32</sup> This may be related to fascial aging caused by reduced secretion of fascial cells, such as fibroblasts, fibroblasts and telangiectasia, leading to fascial adhesions.<sup>33</sup> In addition, fascia contains many hormone receptors and nociceptors, which also play an essential role in the reception and transmission of pain signals and the corresponding response to stimuli.<sup>34</sup> Myofascial pain syndrome (MPS) is a chronic pain syndrome with complex etiology and mechanism accompanied by neurological dysfunction. It is often believed that MPS pain occurs in any part between muscle and motor endplate.<sup>35</sup> People overuse these areas in their lives, causing them to be in a state of stress, and pain ensues.<sup>36</sup> The fascia is the material basis for MPS to produce pain, and the commonly used treatment methods are mostly acting on the fascia.<sup>37</sup> Therefore, MPS may define the relationship between fascia and pain, and to explore the more scientific definition of MPS is closely related to the relationship between fascia and pain. The prevalence of MPS in clinic due to pain can reach 30% to 93%,<sup>38</sup> and patients and doctors often overlook the importance of MPS as a disease.<sup>39</sup> It often leads to poor prognosis, increased treatment costs, ineffective drug treatment, and the risk of addiction when treated with analgesics. Among various treatment methods, ultrasound and traditional Chinese medicine therapy have become an international trend.<sup>40</sup> A randomized trial found that ultrasound improved fatigue, anxiety, and enhanced pain in MPS patients compared with usual care.<sup>41</sup> Acupuncture is an effective and safe method for treating MPS, and its combination with drug therapy is more effective than single-drug therapy.<sup>42</sup> Baduanjin can relieve pain by stretching the fascia and relaxing muscles.<sup>43</sup> Pain is the leading cause of life expectancy and quality of life. As promising non-drug treatments, ultrasound, and traditional Chinese medicine therapy can relieve chronic pain caused by MPS. However, more evidence is needed to verify the potential mechanisms and clinical efficacy of its intervention for pain relief in MPS.

Nerve block plays an essential role in the management of surgical analgesia. Imaging studies have shown that the fascial system is involved in pain management through nerve block techniques.<sup>44</sup> A prospective, double-blind,

randomized, controlled clinical trial has shown that hyaluronic acid is better for nerve blocking than traditional drugs.<sup>45</sup> Besides, receptors in the fascia can also change the thickness of the fascia in real time in addition to affecting the analgesic effect of a nerve block,<sup>46</sup> and the thickness of the fascia can affect the diffusion of blocking drugs,<sup>47</sup> which may be used as a reliable evaluation index of analgesic effect. Clinically, nerve blocks for neuropathic pain,<sup>48</sup> surgical pain,<sup>49</sup> primary dysmenorrhea,<sup>50</sup> and fibromyalgia<sup>51</sup> involve the central nervous system. Studies have shown that mechanical force applied to the fascia can affect changes in brain activity, which affects the dissociation or interaction between the anterior cingulate cortex and the S1 brain area.<sup>52</sup> Or the activated orbitofrontal cortex, superior temporal sulcus, and somatosensory cortex to achieve the effect of pain relief.<sup>53</sup> Therefore, in using nerve block analgesia, we should consider the collocation of drugs and be supplemented by fascial intervention.

In summary, the research hotspots and trends of fascia and pain mainly focus on hot diseases, primary interventions, and mechanism exploration. This study summarizes current research hotspots, trends, and ways to improve the quality of research to provide valuable insights for researchers interested in investigating fascial effects on pain.

## Knowledge Base

Highly co-cited references can be considered domain-specific knowledge bases; references with intense citation bursts can also characterize the research foundation of a field.<sup>54</sup> Through co-citation analysis of references, this study found some influential fascial and pain studies with high co-citation counts and intense citation bursts published between 2013 and 2022. We found that the top 15 commonly cited reference studies can be grouped into three periods: (1) Early (2009–2013) studies focused on the pathophysiology of fascial pain such as myofascitis, quantifying painful fascia, and effective ways of analgesia. (2) The mid-term (2014–2018) improved the fascia theory and further broadened the diagnosis of fascial pain-related diseases. (3) In the later period (2019–present), with the increasing rise of traditional Chinese medicine therapy, the related research in the past three years mainly focused on the clinical and mechanism research of traditional Chinese medicine therapy such as meridian sinew, moxibustion and plantar pressure. These studies have well explained how the fascia, as the material basis of pain, interacts with pain and what kind of external intervention can reverse pain. These results provide a research reference for the readers and help locate the development status and hotspots in fascial pain research.

Previous studies have revealed that the fascia can adapt to various states by reversibly changing biomechanical and physical properties.<sup>55</sup> When the tendon mold is excessively tightened or in a stress state, pain will follow. The mechanism of fascial pain is closely related to the characteristics of the fascia itself, including the innervation of the fascia, the density of the fascia itself, and the sliding between the fascia and the muscle, which all affect the occurrence and development of pain. In a high-cited review, the new direction of fascia biology and its various hypotheses in myofascial pain syndrome were summarized. For the first time, the important position of fascia in myofascial syndrome was systematically demonstrated.<sup>56</sup> Another highly cited review details the multiple possible causes of myofascial trigger points, which play an important role in myofascial syndrome. It suggests that this research stage supports the development of myofascial pain trigger points after muscle overuse. However, whether the overuse of mechanical devices is a key trigger or a persistent noxious input remains controversial and requires further study.<sup>57</sup> In a clinical observational study, intensive sensory innervation in the thoracolumbar fascia, including nociceptive fibers, was described, indicating that it may play an important role in low back pain. Two other highly cited literature studies have also increased the reliability of the thoracolumbar fascia as a source of low back pain.<sup>58,59</sup> Its most sensitive properties to chemical stimuli make it a major candidate for non-specific low back pain rather than local pressure hyperalgesia.<sup>58</sup> The comparison between the inflamed and intact fascia showed that the calcitonin gene-related peptide and substance P-positive fibers in the inflamed thoracolumbar fascia were relatively increased, which caused pain.<sup>22</sup> With the in-depth study of fascia and pain, it has been found that some common pain-related diseases such as low back pain, postpartum pain, and plantar fascia pain are closely related to fascia. Therefore, it is particularly important to accurately identify and diagnose the fascia under pathological conditions. Imaging examination is mainly used to evaluate the morphology of the fascia. Ultrasound technique was used to quantify the myofascial trigger point and measure the shear strain of the fascia. When the ultrasound showed that the fascia became fibrosis, densification, thickness thickening, stiffness increased, shear strain decreased, and focal nodules and abnormal blood flow in the fascia, it was suggested that the fascia was in a pathological



state.<sup>12,23,60,61</sup> In the diagnosis of fascial pain, Fernández-de-Las-Peñas et al improved the basic diagnostic criteria of trigger point (TrP) and provided two directions for future research.<sup>62</sup> One is to investigate the magnitude and duration of pressure during TrP examination. Second, it should be investigated whether the presence of referred pain is a basic diagnostic criterion for TrP, whether it is active or latent, to determine whether there are potential neurophysiological and electromyography differences. In order to dig out the gold standard for the diagnosis of myofascial syndrome from TrP as a starting point. At the same time, Draghi F et al. used imaging techniques to explore the plantar fascia in depth, and described the specific lesion signs more accurately.<sup>63</sup> Ultrasound and MRI should be used as the first-line and second-line examination methods to evaluate the plantar fascia pain disease, respectively. The important conclusion that X-ray plain film examination can exclude the indirect discovery of plantar fascia pain disease. In the treatment of fascial pain, it involves fascial block, steroid injection, dry needle therapy, ultrasound-guided drug injection, etc. In western medicine, Ball et al proposed a new method of steroid injection for the treatment of fascial pain.<sup>64</sup> The effect of dry acupuncture on myofascial syndrome in traditional Chinese medicine is significant. The needle produces mechanical stimulation on myofascial trigger point (MTrP) in order to provide the maximum analgesic effect by piercing the most painful point,<sup>65</sup> indicating that acupuncture MTrP is effective in reducing pain. It is worth noting that according to the meridian theory, traditional Chinese medicine has great potential in the treatment of fascial pain. Among them, many highly co-cited literatures have explained the important role of acupuncture myofascial trigger points, involving gate control theory and specificity theory, quality evaluation of randomized controlled trial reports, etc.<sup>66,67</sup> In addition, related studies have shown that moxibustion can significantly improve the injury of medial vastus muscle tissue in rats with myofascial pain syndrome and increase the thermal pain threshold. Some of its central mechanisms may be related to the inhibition of microglia activation in the spinal dorsal horn and the reduction of BDNF protein expression.<sup>68</sup> At this stage, the research on the sensory function of fascial nerve is more detailed, which provides a neuroanatomical basis for the selectivity and specificity of acupoints in driving specific autonomic nerve pathways.<sup>69</sup> It helps clinicians to study further and improve the performance of erector spinae plane block to optimize the analgesic effect and improve the prognosis of postoperative patients.<sup>70</sup>

In the analysis of the literature on fascia and pain in the past decade, we have discussed that the techniques for quantifying fascia pain are mainly focused on ultrasound or MRI to evaluate fascia thickness and abnormal signals of fascia tissue. Strain elastic ultrasound to evaluate fascia elasticity; Doppler signal to assess whether local fascia congestion.<sup>13,71</sup> There are a large number of clinical efficacy observation studies. Still, there are problems, such as a large number of clinical data that cannot be converted into scientific reference data, which limits the development of research on the mechanism of fascia pain to a certain extent. Here we summarize three main reasons for the failure of clinical transformation. (1) The sample size is small, and there is heterogeneity, which may be related to age and weight. (2) The existing research tends to evaluate the difference in the fascia between the control and treatment groups before and after the treatment and lacks systematic review and collection of specific data. (3) Various new technologies have emerged to evaluate the morphological changes of fascia, but the research is still immature and innovative. For example, MRE has been used to examine the mechanical properties of stiffness increase, viscosity change, and strain reduction, as well as the structural characteristics of scar formation, fibrosis, and structural disorder. It can also quantify the degree of adhesion at the functional myofascial interface. New research using T1p MR imaging shows that high levels of unbound water, indicating hyaluronan aggregation, may also lead to increased stiffness and reduced fascia mobility.<sup>12</sup>

In summary, future research should be based on reliable preclinical data to find ways of quantifying pain and establishing uniform standards. This will help ensure that more clinical data can be used for experimental analysis and research and thus help to improve the clinical management of fascial pain.

## Advantage and Limitation

This study has the following advantages. The study is the first bibliometric analysis article on the research in the field of fascia and pain. Through the statistics and analysis of relevant literature, it sorts out the current global status and future trends in the field of fascia and pain. The authors, countries and institutions that play a central role in the articles have guiding significance for scholars who want to deepen the exchange and research in this field. The analysis of keywords and co-citation literature summarizes the current research hotspots and frontiers. And the analysis of keyword bursts will

provide feasible scientific research ideas or clinical directions for clinical and scientific doctors. Among them, myofascial pain syndrome and nerve block are the representatives of clinical fascia to produce pain and apply fascia to affect body pain. Ultrasound or other methods such as nuclear magnetic resonance can be used to identify and diagnose the pathological state of fascia in anterior myofascial pain syndrome and nerve block, as well as the mechanism between fascia and pain. Whether it is medicine, yoga or acupuncture and moxibustion of traditional Chinese medicine, tai chi, etc. are excellent means of clinical intervention of fascia and are also hot spots in scientific research. Through big data analysis, we integrate time, space and region. Through the analysis and discussion of keywords and frontier hotspots, we explain our understanding of fascia and pain to readers, hoping to give some help to clinical and scientific research.

At the same time, there inevitably existed some limitations in this study. (1) All the articles in this study were obtained from the WoSCC database. Although previous studies have proved that the bibliometric analysis based on the WoSCC database was scientific and practical, it might still be missing. (2) The types of articles included are limited to original articles and reviews published in English, making the analysis somewhat incomplete. (3) Although VOSviewer and CiteSpace were able to provide objective research, there may be some subjective judgment as the previous literature screening was manual.

## Conclusion

Fascia is closely associated with the onset and development of pain, as confirmed by imaging techniques such as ultrasound, magnetic resonance imaging, and infrared thermal imaging. Studying the relationship between fascia and pain will provide new insights into the clinical management of pain. This study used bibliometric analysis to provide researchers with a panoramic and holistic view of research in the field of fascia and pain over the last decade. Based on the 744 articles retrieved from WoSCC, the literature volume in this area shows an overall upward trend, but there are some fluctuations. The significant increase in research output over the last three years suggests that the field has opened up new opportunities. At the same time, we identify the authors, countries, and institutions that play a central role and further analyze the research network. The keywords and co-cited articles analysis revealed that researchers have been discussing fascia from different angles. The current research foci in the fascia and pain are the relationship between fascia and hot spots, critical interventions, mechanism research, and quantification of fascial pain.

## Abbreviations

WoSCC, Web of Science Core Collection; MPS, Myofascial pain syndrome; MTrP, myofascial trigger point; TrP, trigger point.

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## 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.

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## Disclosure

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