

Received: 2019.10.18

Accepted: 2019.12.06

Available online: 2020.01.21

Published: 2020.03.17

# A Bibliometric Analysis Using CiteSpace of Publications from 1999 to 2018 on Patient Rehabilitation After Total Knee Arthroplasty

**Authors' Contribution:**

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

**BCDEF Shi-Qi Wang**  
**BCE Ya-Qian Gao**  
**CDG Chi Zhang**  
**CEG Yu-Jie Xie**  
**DFG Jian-Xiong Wang**  
**ADEFG Fang-Yuan Xu**

Department of Rehabilitation Medicine, The Affiliated Hospital of Southwest Medical University, Luzhou, Sichuan, P.R. China

**Corresponding Author:** Fang-Yuan Xu, e-mail: [xu5144@126.com](mailto:xu5144@126.com)

**Source of support:** This study was supported by the Research Fund for the Doctoral Program of Affiliated Hospital of Southwest Medical University (Grant No. 2016-QB-4), the Research Project of Southwest Medical University (Grant No. 2017-ZRQN-115), the Project of Luzhou Science and Technology Bureau (Grant No. 2017-R-72), and the Sichuan Medical Research Youth Innovation Project (Grant No. Q18062)

**Background:** Following total knee arthroplasty (TKA), postoperative patient rehabilitation is important to achieve the optimal level of knee function and mobility. Clinical research in this field is growing, and bibliometric analysis of publication may provide direction for research clinicians and raise awareness of research trends, journal selection, and key topics. Therefore, this bibliometric study aimed to analyze the current status and trends during the past two decades, between 1999 and 2018, of publications on rehabilitation after total knee arthroplasty (TKA) and used CiteSpace.





**Material/Methods:** The global literature was searched between 2018 to 2019 for publications related to rehabilitation after TKA. Publication data were identified using relevant search terms and the Web of Science Core Collection database. CiteSpace (5.3.R11) software was used to analyze the journals, authors, institutions, countries, cited references, and keywords using standard bibliometric indicators.

**Results:** A total of 1,292 publications were retrieved between 1999 to 2018, and the most active journals, countries, authors, and institutions in the field of TKA rehabilitation were identified. Key areas of research included postoperative analgesia, muscle inhibition, range of motion, inhibitors, knee flexion, pain control, self-reporting, spectral analysis, *in vivo* forces, and rotator cuff repair. The emerging research topics included epidural analgesia, physiotherapy, postoperative analgesia, recovery, and the use of ropivacaine local analgesia.

**Conclusions:** The findings from this bibliometric study provided insight into trends in clinical research publications in the field of rehabilitation following TKA for the past 20 years, including global trends in emerging areas of research.

**MeSH Keywords:** **Arthroplasty, Replacement, Knee • Bibliometrics • Rehabilitation • Research**

**Full-text PDF:** <https://www.medscimonit.com/abstract/index/idArt/920795>

 4016  6  6  43



## Background

Several chronic diseases can affect the function of the knee joint, including rheumatoid arthritis and osteoarthritis. Total knee arthroplasty (TKA) is recognized as an effective treatment with a success rate of >90% [1,2]. The number of TKA procedures performed worldwide has recently increased [3,4]. Following TKA, postoperative patient rehabilitation is important to achieve the optimal level of knee function and mobility [5]. With advances in medical technology, several protocols have been developed to improve for recovery following TKA [6,7]. However, there is no consensus regarding standardized methods for postoperative rehabilitation [8]. Therefore, research in this field continues and is important for the development of TKA rehabilitation with improvement in clinical outcome [9].

Bibliometrics is the quantitative analysis of research publications using mathematical and statistical methods and involves the use of a defined set of metrics to assess published research output, impact, and trends [10,11]. Bibliometrics can be used to identify patterns associated with publications in a particular field, and citation data can be evaluated quantitatively to understand key areas of research and to predict future research directions [11,12].

Worldwide, many authors have published clinically relevant research findings on TKA rehabilitation, including studies on the best time, duration, and intensity for rehabilitation training, the efficacy, ease, and safety of methods to improve core function, and postoperative pain management [13–15]. Clinical research in this field is growing, and bibliometric analysis of this field may provide direction for research clinicians and raise awareness of research trends, journal selection, and key topics. However, there have been few bibliometric studies on postoperative rehabilitation for patients who undergo TKA. Previous bibliometric studies have focused on nonsurgical treatment or the surgical approach for orthopedic disorders but did not address postoperative rehabilitation [16,17].

The Web of Science Core Collection is an online science citation database that can be used to obtain citation, topic, author, institution, and impact factor (IF) data [18]. This online database provides search analysis tools that can produce representative figures, which is convenient for evaluating the scientific and technical influence of authors, institutions, and countries [19,20]. Importantly, the search results can be directly processed and exported for analysis using CiteSpace, which analyzes publication data [21].

Therefore, this bibliometric study aimed to analyze the current status and trends between 1999 and 2018 of publications on postoperative rehabilitation following TKA and used CiteSpace to analyze publications identified from the Web of Science

Core Collection database. The patterns of the research publications in this field were mapped to determine key authors, research topics, institutions, collaborations, research trends, and emerging areas of research in the field of postoperative rehabilitation following TKA.

## Material and Methods

### Data acquisition and search terms

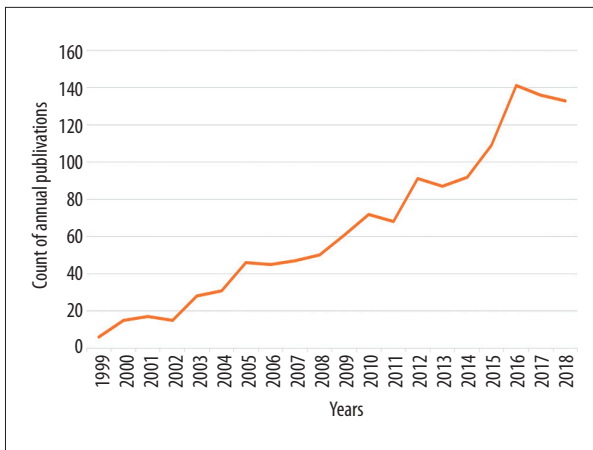
The Web of Science Core Collection was analyzed to obtain data on publications, authors, institutions, countries, topics, and impact factor (IF). The search results were directly processed and exported for analysis using CiteSpace (5.3.R11) software [21].

The search terms used to identify publications included: topic: (“total knee arthroplast\*” OR “total knee replacement”) AND topic: (“occupational therap\*” OR “physical therap\*” OR “physical medicine” OR “rehabilitation”) NOT topic: (“total hip arthroplast\*” OR “total hip replacement” OR “total shoulder arthroplast\*” OR “total shoulder replacement” OR “total ankle arthroplast\*” OR “total ankle replacement”). The search was conducted for publications between 1999 to 2018, and the date of the retrieval was 4<sup>th</sup> March 2019. The search index used included Science Citation Index Expanded (SCI-Expanded), the Conference Proceedings Citation Index–Science (CPCI-S), Index Chemicus (IC), and Current Chemical Reactions Expanded (CCR-Expanded). The total number of publications identified was 1,292.

### Bibliometric indicators and data processing

This study measured the impact of scientific research using standard bibliometric indicators [22]. After searching the Web of Science Core Collection, the number of publications and the total and average citations for the authors and journals were recorded. For authors actively publishing on TKA rehabilitation, the following indicators were measured: the h-index, which is the number of publications and the number of times the publication is cited; the R-index, which is the square-root of the total citation frequency in the h-core, defined by the h-index; the h<sup>(2)</sup>-index, or the number of publications h<sup>(2)</sup> that are cited at least [h<sup>(2)</sup>]<sup>2</sup> times; and the i10-index, or number of publications cited at least 10 times [11,23–25]. The higher the values of these bibliometric indicators, the greater the influence of the authors and their publications.

CiteSpace (5.3.R11) software was used to analyze the overall structure of the network, the network clusters, the links between clusters, the key nodes or pivot points, and the pathways. A node in the map represented the type of study being analyzed, and links between the nodes represented relationships



**Figure 1.** Trends in the count of publications from 1999 to 2018 on patient rehabilitation after total knee arthroplasty. The horizontal coordinates represent the year of publication. The vertical coordinates represent the number of publications.

or collaborations, co-occurrence, or co-citations. The color of each annual ring represented the distribution time. Adjacent clusters corresponded to related topics, and the knowledge that flowed between clusters could be seen from the changes in time, with a change from a cool to a warm color [21,26].

The modularity (Q-value) and silhouette-values were calculated when the cluster analysis was performed.  $Q > 0.3$  identified the cluster structure as significant. If the silhouette-values were  $> 0.5$ , the clusters obtained were reasonable. If the silhouette-values were  $> 0.7$ , the clusters obtained were considered credible [27].

**Table 1.** The top 10 active journals that published on rehabilitation of total knee arthroplasty from 1999 to 2018.

Ranking	Journal	Frequency	Times cited	Times cited (per article)	IF 2017
1	<i>Journal of Arthroplasty</i>	105	2,456	23.94	3.338
2	<i>Knee Surgery Sports Traumatology Arthroscopy</i>	51	639	12.84	3.21
3	<i>Clinical Orthopaedics and Related Research</i>	48	1,801	37.83	4.091
4	<i>Archives of Physical Medicine and Rehabilitation</i>	43	807	19.07	3.077
5	<i>Journal of Bone and Joint Surgery (American Volume)</i>	34	1,666	49.32	4.583
6	<i>Knee</i>	33	699	21.39	1.903
7	<i>Anesthesia and Analgesia</i>	30	1,531	52.30	3.463
8	<i>BMC Musculoskeletal Disorders</i>	27	462	79.22	1.998
9	<i>Regional Anesthesia and Pain Medicine</i>	26	762	30.00	4.382
10	<i>American Journal of Physical Medicine Rehabilitation</i>	22	411	18.82	1.843

IF – impact factor.

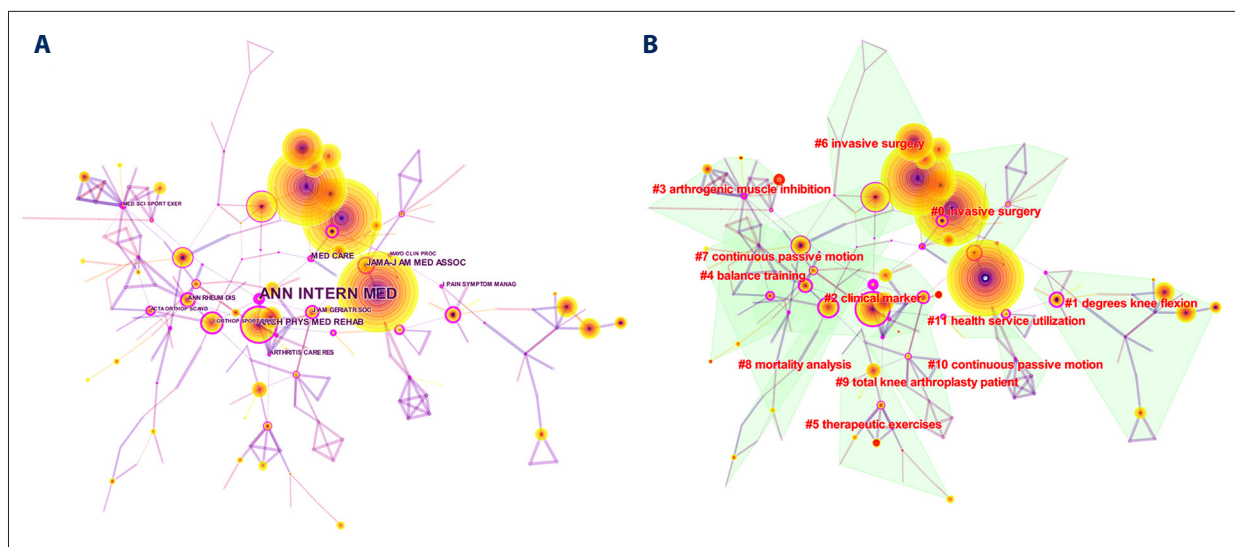
## Parameter settings

There were seven specific parameter settings used in CiteSpace, as follows: the time-slicing was set to 1999–2018; the number of years per slice was set to 1; the selected term sources used were title, abstract, author, keyword, and keywords plus; for the node type, only one option was selected at a time from author, institution, country, reference, cited journal, and keyword; the default option in CiteSpace was used for the selection criteria; for the pruning parameter, ‘pathfinder,’ and ‘pruning the merged network’ were selected; for the visualization parameter, ‘cluster view-static,’ and ‘show merged network’ were selected.

## Results

### Bibliometric analysis of publication output

Between 1999 and 2018, 1,292 clinical research publications were identified on the topic of postoperative patient rehabilitation following total knee arthroplasty (TKA). The publications included 1,118 research articles, 100 review articles, 85 proceedings manuscripts, 27 meeting abstracts, 16 editorials, and 11 letters. The language of most publications was English, accounting for 94.7% of the publications identified. As shown in Figure 1, the annual publication output showed slow growth between 1999 and 2013, with 678 publications, representing 52.5% of the total publications in the 20-year study. Between 2014 and 2018, the annual publication output showed a rapid increase, with 613 publications in 5 years, representing 47.5% of the total publications. The number of publications ( $n=141$ ) reached a peak in 2016.



**Figure 2.** Maps of the cited journals that published manuscripts from 1999 to 2018 on patient rehabilitation after total knee arthroplasty. **(A)** Co-citation network map of cited journals. The nodes in the map represent cited journals. **(B)** The cluster of cited journals. The name of the cluster represents the topics of cited journals. Lines between the nodes represent co-citation relationships. The smaller the number, the more nodes the clustering contains.

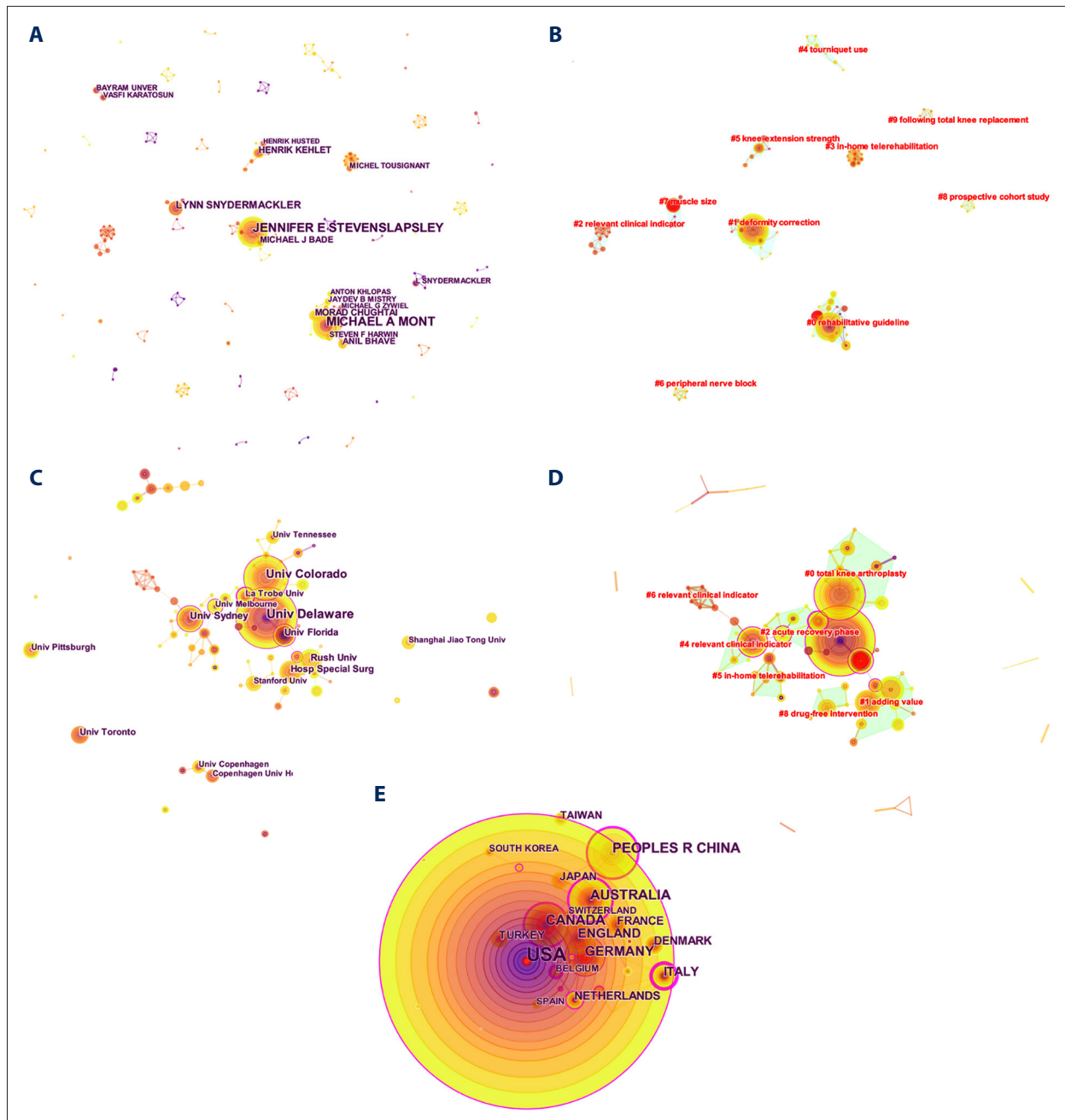
**Table 2.** The top 10 active authors who published literature on rehabilitation of total knee arthroplasty from 1999 to 2018.

Ranking	Frequency	Author	Institution	Times cited (per article)	h-index	h <sup>(2)</sup> -index	R-index	i10-index
1	26	Snyder-Mackler L	University of Delaware	54.04	18	7	38.35	20
2	26	Stevens-Lapsley JE	University of Colorado System	21.58	13	5	24.45	15
3	24	Mont MA	Cleveland Clinic	15.58	11	5	19.85	12
4	12	Bade MJ	University of Colorado System	23.67	8	5	18.36	7
5	12	Kehlet H	University of Copenhagen	33.42	9	5	21.73	8
6	11	Bhave A	Sinai Hospital of Baltimore	9.45	7	3	10.91	11
7	11	Ilfeld BM	University of California, San Diego	44.73	10	6	22.61	10
8	11	Karatosun V	Dokuz Eylul University	7.81	6	3	8.66	2
9	11	Moffet H	Laval University	48.00	9	6	23.87	9
10	11	Unver B	Dokuz Eylul University	7.18	8	4	13.96	7

**Bibliometric analysis of the journals**

A total of 306 journals published papers related to the field of TKA rehabilitation during the past two decades, between 1999 and 2018. Active journals were defined as journals that had the most publications within a certain period. The top 10 most active journals are shown in Table 1. In total, 419 publications in the field were published in these 10 journals, accounting for 32.48% of the total publications. The highest-ranking journal was the *Journal of Arthroplasty*, with 105 publications and an

impact factor (IF) of 3.524. The second was *Knee Surgery, Sports Traumatology, Arthroscopy*, with 51 publications and an IF of 3.149. The third was *Clinical Orthopaedics and Related Research*, with 48 publications and an IF of 4.154. However, only one of the top 10 journals had an IF of >5.000 (maximum, 5.113). Six journals had an IF of 2.000 to 5.000 (maximum, 4.716), while three journals had an IF of <2.000 (minimum, 1.834).

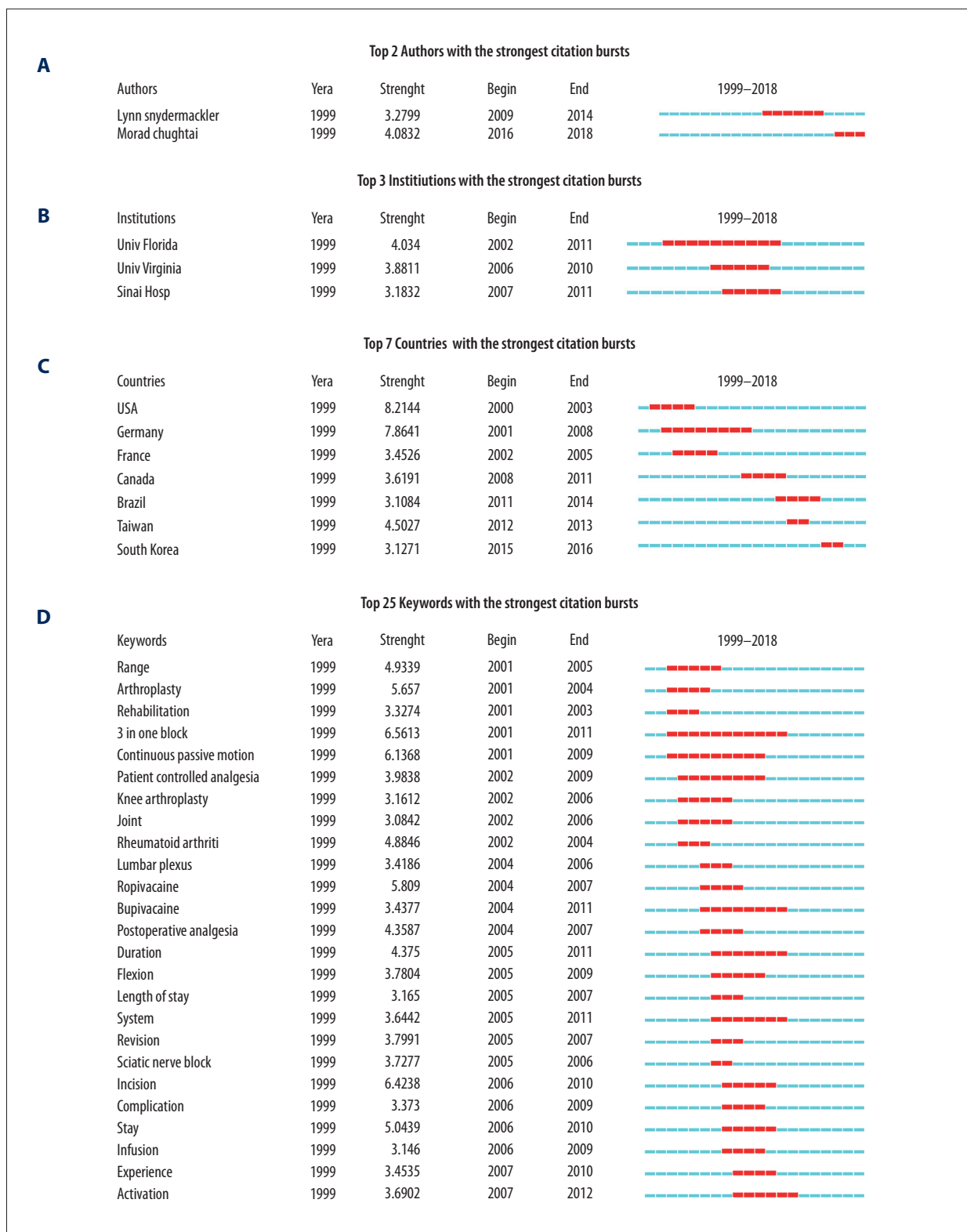


**Figure 3.** Maps of authors who published between 1999 to 2018 on patient rehabilitation after total knee arthroplasty. (A) Co-authorship map of authors. (B) Cluster map of authors (top 10). (C) Co-authorship map of institutions. (D) Cluster map of institutions. (E) Co-authorship map of countries. The nodes in the map represent different authors, institutions, countries, or territories. The lines between the nodes represent co-citation relationships. The larger the node area, the greater the number of co-citations. The smaller the number, the more nodes the clustering contains.

### Bibliometric analysis of co-citations

The co-citation network map and cluster map were obtained by CiteSpace (Figure 2A, 2B). Twelve clusters were obtained. The Q-value was 0.7958, and all silhouette-values were >0.7. The highest-ranking item by citation counts was *Clinical*

*Orthopaedics and Related Research* in Cluster #6 (invasive surgery), with a citation count of 849. The second was the *Journal of Arthroplasty* in Cluster #6, with a citation count of 848. The third was the *Journal of Bone and Joint Surgery, American Volume* in Cluster #0 (invasive surgery), with a citation count of 817. Six of the top 10 most frequently cited journals are shown in Table 1.



**Figure 4.** The strongest citation bursts in publications from 1999 to 2018 on patient rehabilitation after total knee arthroplasty. **(A)** The author with the strongest citation bursts. **(B)** Institutions with the strongest bursts. **(C)** Countries with the strongest citation bursts. Burst authors, institutions, countries, or territories are expected to contribute significantly to this field in the future. **(D)** Keywords with the strongest citation bursts. Burst keywords show the frontier topics and key areas of research.

**Table 3.** The top 10 active institutions and countries that published literature on rehabilitation of total knee arthroplasty from 1999 to 2018.

Ranking	Frequency	Institution	Frequency	Country
1	36	University of Delaware	494	U.S.A.
2	33	University of Colorado System	87	Canada
3	31	University of Colorado Health Science Center	87	P.R. China
4	29	State University System of Florida	82	Australia
5	26	University of Copenhagen	74	Germany
6	25	University of Toronto	63	England
7	22	University of California System	45	Italy
8	20	Pennsylvania Commonwealth System of Higher Education Pcshe	39	Denmark
9	20	Rush University	39	France
10	20	University of Florida	39	Netherlands

### Bibliometric analysis of the authors

A total of 4,924 authors published manuscripts on rehabilitation following TKA during the last two decades. Table 2 shows the top 10 most active authors and their affiliates from 1999 to 2018. The co-authorship map and cluster map of authors are shown in Figure 3A and 3B, where each node represents an author. In total, 57 clusters were generated, with a Q-value of 0.9117. However, only 37 clusters had silhouette-values of >0.7. The highest-ranked item by citation counts was from the author, Stevens-Lapsley in Cluster #1 (deformity correction, citation count of 25), followed by Mont in Cluster #0 (rehabilitative guideline, citation count of 23), and Snyder-Mackler in Cluster #7 (muscle size, citation count of 12). Stevens-Lapsley (h-index=13; h<sup>(2)</sup>-index=5; R-index=24.45; i10-index=15), Mont (h-index=11; h<sup>(2)</sup>-index=5; R-index=19.85; i10-index=12), and Snyder-Mackler (h-index=18; h<sup>(2)</sup>-index=7; R-index=38.35; i10-index=20) were among the top 10 authors.

The centrality of the author, Stevens-Lapsley in Cluster #1 (deformity correction), and Mont in Cluster #0 (rehabilitation guideline) was 0.01, while the other authors had a centrality of <0.01. Also, Snyder-Mackler and Chughtai showed an increase in the number of publications from 2009 to 2014 and from 2016 to 2018, respectively (Figure 4A).

### Bibliometric analysis of the institutions

From 1999 to 2018, a total of 1,564 research institutions published in this field. The co-authorship map and cluster map of the institutions are shown in Figure 3C and 3D, respectively. Seven clusters were obtained, with a Q-value of 0.9117, and

all silhouette-values were >0.7. The top 10 most active institutions are shown in Table 3. The highest-ranked item by citation counts was the University of Delaware in Cluster #2 (acute recovery phase, citation count of 32), followed by the University of Colorado System in Cluster #0 (TKA, citation count of 23) and the University of Sydney in Cluster #4 (relevant clinical indicator, citation count of 14). The highest-ranked item by centrality was La Trobe University (centrality, 0.22), followed by the University of Melbourne (centrality, 0.17) and the University of Delaware (centrality, 0.16). They were all in Cluster #2 (acute recovery phase). The main institutions that collaborated with the University of Delaware were the University of Frida, Eastern Washington University, and La Trobe University. La Trobe University also collaborated closely with the University of Colorado, the University of Delaware, the University of the Sunshine Coast, and the University of Melbourne. A sudden increase in publications from the University of Florida occurred between 2002 and 2011, from the University of Virginia between 2006 to 2010, and from Mount Sinai Hospital between 2007 and 2011 (Figure 4B).

### Bibliometric analysis of the countries

From 1999 to 2018, research institutions from 65 countries published in this field. Figure 3E shows the co-authorship map of these countries. The top 10 most active countries are shown in Table 3. The highest-ranked country by citation count was the United States (citation count, 481), followed by Canada (citation count, 83) and China (citation count, 83). The highest-ranked country by centrality was Belgium (centrality, 0.57), followed by Italy (centrality, 0.48), and Canada (centrality, 0.36). The main country that collaborated with the United States

**Table 4.** The largest 10 clusters of references in the co-citation network.

Cluster	Size	Silhouette mean	Year	Label
0	55	0.919	2007	Continuous sciatic nerve block
1	54	0.9	2012	Preoperative body mass index
2	53	0.915	2003	1-and 2-year outcome
3	51	0.999	2005	Medial subvastus approach
4	49	0.884	2011	Total knee arthroplasty
5	36	0.974	2001	Manual therapy
6	36	0.896	2008	Conditioning professional
7	36	0.982	2001	Hip fracture surgery
8	35	0.962	1998	Inpatient rehabilitation
9	34	0.896	2004	Following total knee replacement

**Table 5.** The top 10 active references cited by the literature on rehabilitation of total knee arthroplasty from 1999 to 2018.

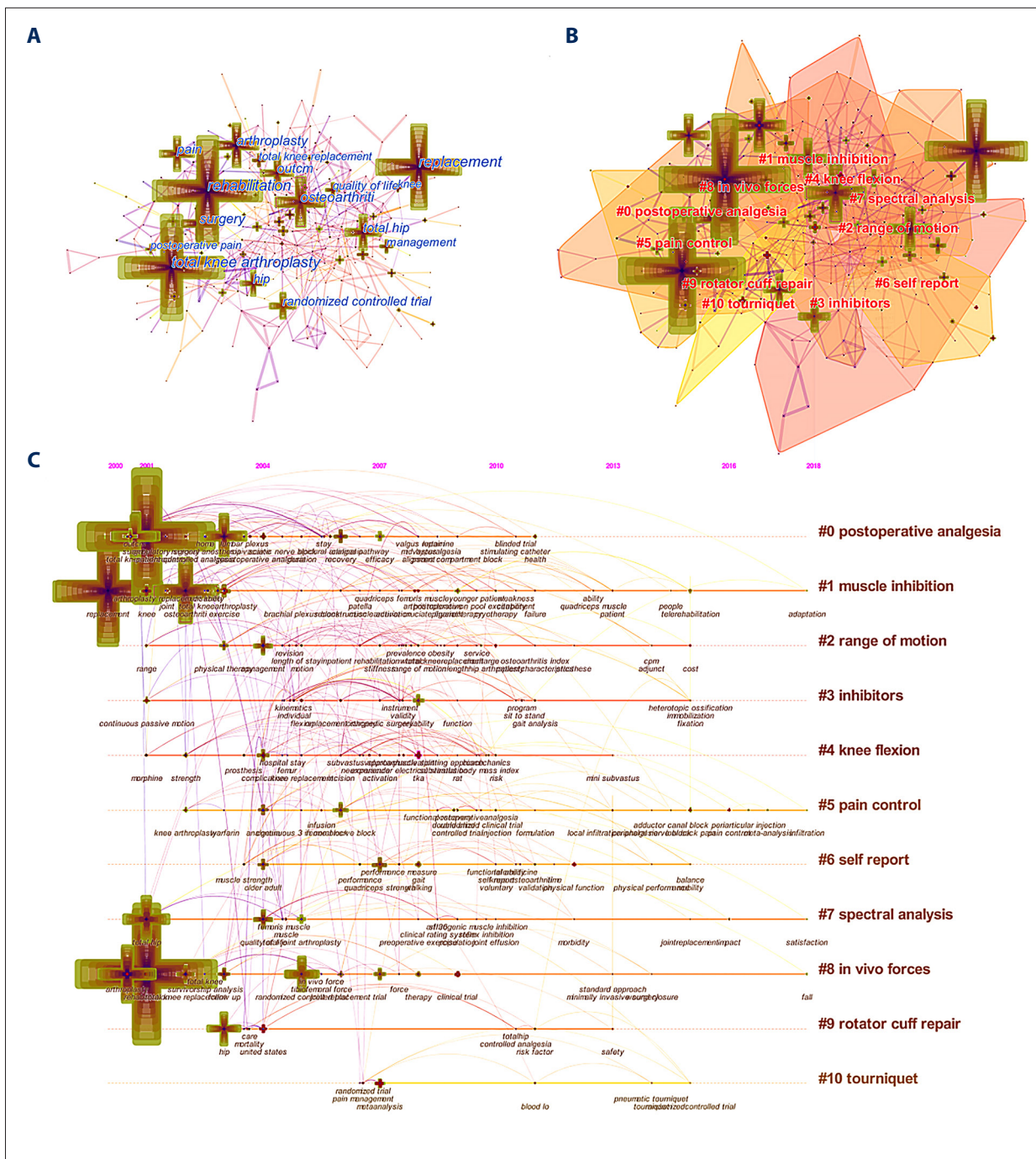
Ranking	Times cited	Reference	Representative author (publication year)	Cluster
1	54	Improved function from progressive strengthening interventions after total knee arthroplasty: a randomized clinical trial with an imbedded prospective cohort	Petterson SC, (2009)	4
2	54	Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery	Capdevila X, (1999)	7
3	48	Effects of intravenous patient-controlled analgesia with morphine, continuous epidural analgesia, and continuous three-in-one block on postoperative pain and knee rehabilitation after unilateral total knee arthroplasty	Singelyn FJ, (1998)	7
4	47	Femoral nerve block improves analgesia outcomes after total knee arthroplasty: a meta-analysis of randomized controlled trials	Paul JE, (2010)	0
5	47	Quadriceps strength and the time course of functional recovery after total knee arthroplasty	Mizner RL, (2005)	2
6	43	Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030	Kurtz S, (2007)	4
7	39	Outcomes before and after total knee arthroplasty compared with healthy adults	Bade MJ, (2010)	4
8	38	Early quadriceps strength loss after total knee arthroplasty. The contributions of muscle atrophy and failure of voluntary muscle activation	Mizner RL, (2005)	2
9	36	Examining outcomes from total knee arthroplasty and the relationship between quadriceps strength and knee function over time	Yoshida Y, (2008)	13
10	35	Early neuromuscular electrical stimulation to improve quadriceps muscle strength after total knee arthroplasty: a randomized controlled trial	Stevens-lapsley JE, (2012)	12

was England. The main collaborators with China were India, Canada, and Japan. The main collaborators with Canada were Australia, China, and Belgium. However, some countries published a small number of papers but collaborated closely with

other countries. For example, Belgium only published 15 papers during the past two decades, but Belgium collaborated with Australia, Canada, the Netherlands, Scotland, Argentina, Spain, and Italy. A sudden increase in publications was seen







**Figure 6.** Maps of keyword co-occurrence in publications from 1999 to 2018 on patient rehabilitation after total knee arthroplasty. (A) The keyword co-occurrence network map. The nodes in the map represent keywords. (B) The keyword co-occurrence cluster map. The name of the cluster represents the key areas of research. (C) The keyword co-occurrence cluster map in the timeline view. The chronological order in which keywords appear in each cluster can be found. The smaller the number, the more nodes the clustering contains.

total knee arthroplasty (TKA) using the Web of Science Core Collection database and CiteSpace. The findings provided insight into recent developments in published clinical research in the field of TKA rehabilitation, the most active journals,

global research collaborations, the core clinical research areas, and emerging areas of research. The analysis of publication output showed that the study period could be divided into two stages. In the first stage, from 1999 to 2013, the clinical

**Table 6.** The largest 10 clusters in the keyword co-occurrence network.

Cluster	Size	Silhouette mean	Year	Keyword
0	41	0.819	2005	Postoperative analgesia
1	37	0.89	2007	Muscle inhibition
2	31	0.904	2008	Range of motion
3	31	0.897	2008	Inhibitors
4	29	0.887	2007	Knee flexion
5	22	0.937	2010	Pain control
6	22	0.916	2010	Self report
7	20	0.782	2008	Spectral analysis
8	20	0.934	2006	<i>In vivo</i> forces
9	13	0.934	2006	Rotator cuff repair

research publications focused on the importance of postoperative TKA rehabilitation. In the second stage, from 2014 to 2018, the clinical research publications reflected a period of rapid development with a small peak in 2016. These findings support that the field of TKA rehabilitation is developing well and has a bright future. It is anticipated that authors will begin to focus on further emerging research directions in this field, including the best time, duration, and intensity for rehabilitation training, the ease and safety of rehabilitation methods for core body function, effective methods of local nerve block to reduce pain, and the selection of rehabilitation methods [13,14,38–40].

The identification of core journals with high publication and co-citation counts provide important information for authors to select high-quality journals. The top 10 most active journals published less than half (32.48%) of the research in the field of TKA rehabilitation. This finding suggests that publications are widely distributed between different journals. Authors might not have the required knowledge or experience to select the most appropriate journals for publication of their research. However, the findings from the present bibliographic study may provide some guidance to clinical research authors in the field of orthopedic and knee surgery and rehabilitation. The top three most active journals, the *Journal of Arthroplasty*; *Knee Surgery, Sports Traumatology, Arthroscopy*, and *Clinical Orthopaedics and Related Research*, were identified as relevant journal choices that would be likely to accept studies on TKA rehabilitation and have a certain impact in this field. Also, only one of the top 10 most active journals had an impact factor (IF) >5.000, and most journals had an IF of 2.000 to 5.000. Additionally, the concordance rate was only 60% between the top 10 most active journals and the top 10 most frequently cited journals. There may be two reasons for this finding. It is possible that these authors did not engage in self-citation, or that the authors had different research directions, resulting in

lower citation rates. Also, the literature in this field lacked references to journals with a high IF. This finding indicates that the level and quality of research in the field of TKA rehabilitation should be improved, which will require authors worldwide to strengthen their contacts and communication and to collaborate in performing high-quality clinical research.

This study used CiteSpace software, which allowed analysis of the current state of global research collaborations in this field. Authors around the world do not engage in close collaboration, as shown by the findings from the co-occurrence network analysis, as too many clusters were formed. However, collaborative research partnerships were identified between institutions. This finding indicates that the authors from collaborating institutions might participate in different research areas within this field, such as the development of postoperative rehabilitation guidelines, deformity correction, development of muscle mass, knee extension strength, and clinical follow-up. Because of these different research directions, collaboration between authors has become less common. The degree of collaboration between different countries also varied. The United States had the largest number of publications, but only one country collaborated with it. In contrast, Belgium published a small number of papers, but nine countries collaborated with Belgium. Therefore, countries such as the United States, as a core source of published studies, could strengthen collaborations with other countries to promote the development of this field of clinical research.

The authors, institutions, countries, or territories that publish the largest number of papers demonstrate not only contributions to the field, but also their research capabilities and degree of influence in this field. A citation burst occurs when these sources of authors suddenly publish a large number of papers within a certain amount of time. These authors, institutions, countries, or territories are expected to contribute

significantly to this field in the future. The top 10 most active authors and their affiliates in this field during the most recent 20 years were from Europe and America. Japan had high-level research authors and institutions, but the number of publications was small. China was the only developing country from Asia in the top 10 most active countries. Almost all of the remaining countries were developed countries in Europe and North America. This finding indicated that European and North American countries are still the main sources of clinical research publications in this field. However, publications from China in the field of TKA rehabilitation have begun to increase. South Korea and Brazil also showed a recent increase in publications and are expected to make important contributions to this field in the future.

The most frequently cited publications were from the authors, Petterson (2009) and Capdevila (1999) [28,29]. These cited references represented the core clinical research areas in the field of TKA rehabilitation. This finding may help future authors to understand the basic research principles of clinical research in this field, and may provide important references for further understanding of key clinical findings. The cluster map of references identified mainstream research during the past 20 years. The cluster of the largest co-citation network was regarded as mainstream research publications. The largest cluster was Cluster #0 (continuous sciatic nerve block), which contained 105 cited publications. Analysis of the top 10 references and names of the clusters showed that TKA rehabilitation could be performed during the perioperative period. The research methods included cohort studies, randomized clinical trials, and meta-analysis, and the intervention measures included preoperative weight management, methods of anesthesia, postoperative training to improve muscle strength, and physical therapy.

The keyword co-occurrence network map identified the popular topics in the field of TKA postoperative rehabilitation, and burst keywords were used to identify the emerging areas of research and key research topics. Some of the most important areas of research in this field in recent years included postoperative analgesia, muscle inhibition, range of motion, inhibitors, knee flexion, pain control, self-reporting, spectral analysis, *in vivo* forces, and rotator cuff repair. These key areas of research have represented the core research directions worldwide for the past 20 years. These topics are good choices for research teams in this field. However, as these research directions develop, it may become more difficult for research teams to make further innovations and breakthroughs. Therefore, the burst keywords that were associated with emerging areas of research that included epidural analgesia, physiotherapy, postoperative analgesia, recovery, and ropivacaine use may be better choices for authors considering publishing in this field in future. As this study has shown, CiteSpace can be

used to detect burst keywords, which are considered indicators of emerging areas of research. Through the keyword co-occurrence cluster map in the timeline view, the trends of different key areas of research may be identified to make better research choices. The latest clustering in the co-citation networks identified adductor canal block (2013), liposomal bupivacaine suspension (2013), tourniquet use (2013), preoperative body mass index (2012), and recent controlled studies (2010). The newest clustering in the keyword co-occurrence network included pain control (2010), self-reporting (2010), tourniquet use (2010), range of motion (2008), inhibitors (2008), and spectral analysis (2008). By analyzing the co-occurrence relationships of these keywords, the research findings and research direction in the field of TKA postoperative rehabilitation may be understood further.

A comparison of the findings from this study with previous bibliometric studies showed that previous studies mainly used the Web of Science Core Collection as the publication database [16,17]. These studies mainly focused on the surgical or nonsurgical treatment of orthopedic disease and highlighted the contribution of Asian countries to the clinical orthopedic research literature [16,17,41]. The results of the present study showed that Asian countries, including China, Japan, and South Korea, contributed significantly to the literature on postoperative rehabilitation following TKA.

This study had several limitations. The data were retrieved from the single database of the Web of Science Core Collection and did not include other databases. A limitation of bibliometric studies is that they can only be conducted on publications in journals that are cited and indexed, and they do not include unpublished studies or publications in non-indexed journals, dissertations, books, or government reports and documents [42]. The study did not use the newly-defined dissemination (D) index, which is the ratio of the number of citations to the number of documents between a single entity versus a group [43]. These limitations may be addressed in future studies.

## Conclusions

This bibliometric study aimed to analyze the current status and trends during the past two decades, between 1999 and 2018, of publications on rehabilitation after total knee arthroplasty (TKA) using CiteSpace. The findings from this bibliometric study provided insight into trends in clinical research publications in the field of rehabilitation following TKA for the past 20 years, including global trends in emerging areas of research.

The findings from this bibliometric analysis of clinical research on postoperative TKA rehabilitation, published between 1999 and 2018, showed that the number of publications

has rapidly increased, with potentially emerging areas of research. Several publications were found in journals with an IF <5.000. The *Journal of Arthroplasty*, and *Knee Surgery, Sports Traumatology, Arthroscopy*, and *Clinical Orthopaedics and Related Research* were the main journals that published clinical studies on postoperative rehabilitation following TKA. European and North American countries were the main countries that published in this field. Asian countries also contributed significantly to the literature on rehabilitation after TKA. China showed increasing numbers of publications, and South Korea and Brazil are expected to make important contributions to this field in the near future. Interventions to improve core

body strength and improved techniques in perioperative analgesia were the most significant core clinical research areas in this field. Postoperative analgesia, muscle inhibition, range of motion, inhibitors, knee flexion, pain control, self-reporting, spectral analysis, *in vivo* forces, and rotator cuff repair were the most significant key areas of research. Epidural analgesia, physiotherapy, postoperative analgesia, recovery, and ropivacaine were identified as potential emerging areas of research.

## References:

1. Price AJ, Alvand A, Troelsen A et al: Knee replacement. *Lancet*, 2018; 392(10158): 1672–82
2. Insall JN, Dorr LD, Scott RD, Scott WN: Rationale of the Knee Society clinical rating system. *Clin Orthop Relat Res*, 1989; (248): 13–14
3. Inacio MCS, Paxton EW, Graves SE et al: Projected increase in total knee arthroplasty in the United States – an alternative projection model. *Osteoarthritis Cartilage*, 2017; 25(11): 1797–803
4. Koh IJ, Kim TK, Chang CB et al: Trends in use of total knee arthroplasty in Korea from 2001 to 2010. *Clin Orthop Relat Res*, 2013; 471(5): 1441–50
5. Wallace SJS, Berger RA: Most patients can kneel after total knee arthroplasty. *J Arthroplasty*, 2019; 34(5): 898–900
6. Leonard H: Live music therapy during rehabilitation after total knee arthroplasty: A randomized controlled trial. *J Music Ther*, 2019; 56(1): 61–89
7. Sadoghi P, Hasenhuttl S, Gruber G et al: Impact of a new cryotherapy device on early rehabilitation after primary total knee arthroplasty (TKA): A prospective randomised controlled trial. *Int Orthop*, 2018; 42(6): 1265–73
8. Adie S, Harris I, Chuan A et al: Selecting and optimising patients for total knee arthroplasty. *Med J Aust*, 2019; 210(3): 135–41
9. Witjes S, Hoorntje A, Kuijter PP et al: Goal setting and achievement in individualized rehabilitation of younger total and unicompartmental knee arthroplasty patients: A cohort study. *Arch Phys Med Rehabil*, 2019; 100(8): 1434–41
10. Chen C, Dubin R, Kim MC: Emerging trends and new developments in regenerative medicine: A scientometric update (2000–2014). *Expert Opin Biol Ther*, 2014; 14(9): 1295–317
11. Thomson Reuters. 2008. Using Bibliometrics: A guide to evaluating research performance with citation data. White paper. [http://ips.clarivate.com/m/pdfs/325133\\_thomson.pdf](http://ips.clarivate.com/m/pdfs/325133_thomson.pdf)
12. Huang X, Fan X, Ying J, Chen S: Emerging trends and research foci in gastrointestinal microbiome. *J Transl Med*, 2019; 17(1): 67
13. Mechlenburg I, Skoffer B, Dalgas U: Comparison of early high-intensity and low-intensity rehabilitation after total knee arthroplasty: Comment on the article by Bade et al. *Arthritis Care Res (Hoboken)*, 2018; 70(11): 1717
14. Sano Y, Iwata A, Wanaka H et al: An easy and safe training method for trunk function improves mobility in total knee arthroplasty patients: A quasi-randomized controlled trial. *PLoS One*, 2018; 13(10): e0204884
15. Zhong S, Huang H, Xie J et al: Application of electroacupuncture for postoperative pain management after total knee arthroplasty: A study protocol for a single-blinded, randomised placebo-controlled trial. *BMJ Open*, 2019; 9(4): e026084
16. Wang K, Xing D, Dong S, Lin J: The global state of research in nonsurgical treatment of knee osteoarthritis: A bibliometric and visualized study. *BMC Musculoskelet Disord*, 2019; 20(1): 407
17. Eom SH, Bamne AB, Chowdhry M et al: Bibliometric analysis of orthopedic literature on total knee arthroplasty in Asian countries: A 10-year analysis. *Knee Surg Relat Res*, 2015; 27(3): 149–55
18. Bakkalbasi N, Bauer K, Glover J, Wang L: Three options for citation tracking: Google Scholar, Scopus and Web of Science. *Biomed Digit Libr*, 2006; 3: 7
19. Falagas ME, Pitsouni EI, Malietzis GA, Pappas G: Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. *FASEB J*, 2008; 22(2): 338–42
20. AlRyalat SAS, Malkawi LW, Momani SM: Comparing bibliometric analysis using PubMed, Scopus, and Web of Science Databases. *J Vis Exp*, 2019; (152)
21. Chen C: CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *J Am Soc Inf Sci Technol*, 2006; 57(3): 359–77
22. Belter CW: Bibliometric indicators: Opportunities and limits. *J Med Libr Assoc*, 2015; 103(4): 219–21
23. Jin B, Liang L, Rousseau R et al: The R- and AR-indices: Complementing the h-index. *Chin Sci Bull*, 2007; 52(6): 855–63
24. Alonso S, Cabrerizo FJ, Herrera-Viedma E, Herrera F: H-Index: A review focused in its variants, computation and standardization for different scientific fields. *Journal of Informetrics*, 2009; 3(4): 273–89
25. Chopra K, Swanson EW, Susarla S et al: A Comparison of research productivity across plastic surgery fellowship directors. *Aesthet Surg J*, 2016; 36(6): 732–36
26. Ping X: Study of international anticancer research trends via co-word and document co-citation visualization analysis. *Scientometrics*, 2015; 105(1): 611–22
27. Chen C: Searching for intellectual turning points: Progressive knowledge domain visualization. *Proc Natl Acad Sci USA*, 2004; 101(Suppl. 1): 5303–10
28. Petterson SC, Mizner RL, Stevens JE et al: Improved function from progressive strengthening interventions after total knee arthroplasty: A randomized clinical trial with an imbedded prospective cohort. *Arthritis Rheum*, 2009; 61(2): 174–83
29. Capdevila X, Barthelet Y, Biboulet P et al: Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery. *Anesthesiology*, 1999; 91(1): 8–15
30. Singelyn FJ, Deyaert M, Joris D et al: Effects of intravenous patient-controlled analgesia with morphine, continuous epidural analgesia, and continuous three-in-one block on postoperative pain and knee rehabilitation after unilateral total knee arthroplasty. *Anesth Analg*, 1998; 87(1): 88–92
31. Paul JE, Arya A, Hurlburt L et al: Femoral nerve block improves analgesia outcomes after total knee arthroplasty: A meta-analysis of randomized controlled trials. *Anesthesiology*, 2010; 113(5): 1144–62
32. Mizner RL, Petterson SC, Snyder-Mackler L: Quadriceps strength and the time course of functional recovery after total knee arthroplasty. *J Orthop Sports Phys Ther*, 2005; 35(7): 424–36
33. Kurtz S, Ong K, Lau E et al: Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am*, 2007; 89(4): 780–85
34. Bade MJ, Kohrt WM, Stevens-Lapsley JE: Outcomes before and after total knee arthroplasty compared to healthy adults. *J Orthop Sports Phys Ther*, 2010; 40(9): 559–67
35. Mizner RL, Petterson SC, Stevens JE et al: Early quadriceps strength loss after total knee arthroplasty. The contributions of muscle atrophy and failure of voluntary muscle activation. *J Bone Joint Surg Am*, 2005; 87(5): 1047–53

## Conflict of interest

None.

36. Yoshida Y, Mizner RL, Ramsey DK, Snyder-Mackler L: Examining outcomes from total knee arthroplasty and the relationship between quadriceps strength and knee function over time. *Clin Biomech*, 2008; 23(3): 320–28
37. Stevens-Lapsley JE, Balter JE, Wolfe P et al: Early neuromuscular electrical stimulation to improve quadriceps muscle strength after total knee arthroplasty: A randomized controlled trial. *Phys Ther*, 2012; 92(2): 210–26
38. Tan Z, Kang P, Pei FX et al: A comparison of adductor canal block and femoral nerve block after total-knee arthroplasty regarding analgesic effect, effectiveness of early rehabilitation, and lateral knee pain relief in the early stage. *Medicine (Baltimore)*, 2018; 97(48): e13391
39. Kanadli H, Dogru S, Karaman T et al: Comparison of the efficacy of femoral nerve block and fascia iliaca compartment block in patients with total knee replacement. *Minerva Anestesiol*, 2018; 84(10): 1134–41
40. Correia FD, Nogueira A, Magalhães I et al: Home-based rehabilitation with a novel digital biofeedback system versus conventional in-person rehabilitation after total knee replacement: A feasibility study. *Sci Rep*, 2018; 8(1): 11299
41. Lee KM, Ryu MS, Chung CY et al: Characteristics and trends of orthopedic publications between 2000 and 2009. *Clin Orthop Surg*, 2011; 3(3): 225–29
42. Haddaway NR, Collins AM, Coughlin D, Kirk S: The role of Google Scholar in evidence reviews and its applicability to grey literature searching. *PLoS One*, 2015; 10(9): e0138237
43. Lepard JR, Walters BC: A bibliometric analysis of neurosurgical practice guidelines. *Neurosurgery*, 2019 [Epub ahead of print]