Bibliometric Study of Exercise and Tendinopathy Research from 2001 to 2020

Yuanchun Zhu 1
Tiantian Chang 1
Xueqiang Wang 1
Zhijie Zhang 2

1 Department of Sport Rehabilitation, Shanghai University of Sport, Shanghai, PR China
2 Rehabilitation Therapy Center, Luoyang Orthopedic Hospital of Henan Province, Orthopedic Hospital of Henan Province, Luoyang, Henan, PR China

Background: Tendinopathy is a tendon disease that often occurs in athletes. Many studies have revealed that exercise therapy is beneficial for the nonoperative management of tendinopathy. However, the general aspect bibliometric analysis of this global research topic associated with exercise and tendinopathy is lacking. The present study aimed to make a bibliometric analysis of worldwide development tendency and research hotspots in exercise and tendinopathy research from 2001 to 2020.

Material/Methods: Using the Web of Science, articles and reviews published between 2001 and 2020 were retrieved from the Science Citation Index Expanded database. CiteSpace was used to analyze the relationship among publications, countries, institutions, journals, authors, references, and keywords.

Results: In total, 857 articles were found in this study. Over the past 20 years, there was a marked increase in the number of publications. A total of 194 different scholarly journals were dedicated to the categories Sport Sciences, Orthopedics, and Rehabilitation. The USA and La Trobe University were the most prolific country and institution, respectively. The British Journal of Sports Medicine was the prominent journal for research on exercise and tendinopathy and had the most publications. The analysis of keywords showed that rehabilitation, rotator cuff tendinopathy, stiffness, and disability of individuals with tendinopathy had become the research focus in this field.

Conclusions: Bibliometric analysis provides a historical and scientific perspective on exercise and tendinopathy research, providing relevant researchers, funding agencies, and policymakers with valuable information to explore the current research status, hotspots, and new directions for future research.

Keywords: Bibliometrics • Exercise • Tendinopathy

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/934016
Background

Tendinopathy is a common clinical syndrome characterized by pain, localized or diffuse swelling, and dysfunction [1]. The main pathological conditions related to tendinopathy include tendinosis and peritendinitis, which are characterized by collagen disorganization and fiber breakdown, increase in mucus matrix, ingrown nerves and blood vessels, local swelling, and inflammatory cell infiltration [2,3]. Achilles and patellar tendinopathy are common in athletes, resulting in restricted function and even disability of athletes and affecting their sports career [4,5]. For example, the prevalence of patellar tendinopathy was 14.4% and 11.8% among non-elite volleyball and basketball players [6], respectively, and the prevalence among elite athletes was 45% and 32% [7]. In addition, the Achilles tendon is the most commonly affected tendon among runners, and about 30% of runners will experience Achilles tendinopathy during exercise [3]. These data indicate that the population prevalence of tendinopathy is relatively high, and tendinopathy needs more in-depth research.

The clinical management of tendinopathy is still debated; operative management and nonoperative treatment are applied in alleviating this disease. However, operative managements are unsatisfactory compared with nonoperative measures; they are more costly and involving perioperative and postoperative complications [1]. Various nonoperative modalities for tendinopathy have been used, such as exercise therapy [8], extracorporeal shockwave therapy [9], nonsteroidal anti-inflammatory drugs [10], platelet-rich plasma injection [11], and stem cell therapy [12]. Many studies have revealed that exercise therapy is beneficial for tendinopathy. For example, isometric exercise, eccentric exercise, and resistance training reduce pain and improve tendon function [13-15]. Therefore, exploring exercise for tendinopathy is meaningful, as it can help patients relieve pain and improve their quality of life. However, there is no clear clinical evidence to support the superiority of any specific exercise intervention, and general aspect bibliometric analysis of this global research topic associated with exercise and tendinopathy is lacking.

Bibliometrics is a quantitative statistical tool used to analyze published scientific literature and assess the trend of research activities over time [16]. In addition, this genre of research can provide audiences with quantitative information distributed by country/region, institution, journal, and author in a particular area [17]. In recent years, bibliometric research has been used in various fields, such as pain [18], cancer [19], immunotherapy [20], and lncRNAs [21]. In the existing systematic review and meta-analysis of exercise for tendinopathy, the common defects are that the number of included papers is insufficient, and the result indicators are also significantly different. In comparison to systematic review and meta-analysis, bibliometrics can detect the evolution and development of a research domain in a more comprehensive and intuitive way [22]. On this basis, crucial characteristics of exercise and tendinopathy can be explored via bibliometrics and visualization and provide an objective database for future research and application.

Although previous studies had offered an overview of the relationship between exercise and tendinopathy research [23,24], to the best of our knowledge, a specific bibliometric analysis of exercise and tendinopathy research had not yet been conducted. This study aimed to investigate the crucial researchers, journals, countries, and institutions and the cooperation networks between them. In addition, we aimed to explore current research interests and topic hotspots by co-citation analysis, as well as analysis of keywords and references. CiteSpace software is a Java-based scientometric mapping application for bibliometric analysis. We used CiteSpace (5.8.R3) software to execute a bibliometric investigation of general research information, hotspots, and global trends concerning exercise and tendinopathy in the Web of Science (WoS) database.

Material and Methods

Data Acquisition

We searched and downloaded published papers from the Science Citation Index Expanded (SCI-EXPANDED) database of WoS on 1 June 2021. Our retrieval strategy consisted of TI=(exercise OR kinesitherapy OR train* OR “physical activity” OR strength* OR eccentric* OR plyometric* OR concentric* OR isometric* OR isokinetic* OR aerobic* OR endurance OR resistance OR stability OR walk* OR run* OR jump* OR basketball OR volleyball OR football OR soccer OR badminton OR “motor control” OR stretch* OR load* OR “mechanical load” OR “habitual load”*) AND TS=(tendinopathy OR tendonitis OR tendinosis OR “tendon disease” OR “tendon disorder” OR “tendon dysfunction”*). Our bibliometric study aimed to explore the development of research on exercise and tendinopathy in the 21st century. Through searching, we found that there were 8 related papers published in 2001, which are in the initial stage of this research topic. Given the above reasons, we choose the time span of 2001-2020 as our search dates.

Inclusion Criteria

The flow chart of inclusion criteria is seen in Figure 1. We included articles and reviews published in different academic journals. Other document genres, such as letters, editorial materials, meeting abstracts, proceeding papers, corrections, were excluded. Only English literature was included, and no species filters were used. A total of 857 papers during the years 2001-2020 met the inclusion criteria.
Yuanchun Zhu searched and extracted the published papers related to exercise and tendinopathy from WoS databases from 2001 to 2020. Endnote X9 and Microsoft Excel 2019 were applied to analyze publication data. Pertinent information, such as number of publications, citations (including self-citations), Hirsch index (H-index), and citations per paper, were utilized as bibliometric indexes. The number of publications refers to the contribution of the literature, which reflects the productivity of scientific research. The citations of papers measure the real impact of researchers’ academic output, which generally reflects the quality of the publication. The H-index is an indicator measured according to the number of papers and citation density of scholarly researchers or journals. For example, the circumscription of the H-index is that a scholarly researcher or a journal had H publications cited at least H times per paper [25]. In addition, the impact factor (IF), based on Journal Citation Report (2020 edition), represents the overall impact of journals.

**Statistical Methods**

CiteSpace (5.8.R3) (Drexel University, Philadelphia, USA) and Microsoft Excel 2019 were utilized to: (1) acquire the global output and development trend of all selected publications, (2) analyze the general information of years, journals, countries/institutions, and authors, (3) assess cooperation among countries and institutions, (4) conduct analysis of the citations and the value of H-index, and (5) analyze the references and burst citation of keywords. CiteSpace (5.8.R3), based on the Java platform, broadly regarded as a superior scientometric analysis tool, was used to perform statistical analyzes on the literature [19,26]. CiteSpace (5.8.R3) can be used to draw a series of progressively visualized knowledge domain co-citation network maps to help researchers discover emerging development trends, potential implications, landmark publications, and perform cluster analysis and citation bursts based on co-citation network maps. The maps include different nodes and lines. A larger node represents a higher occurrence or citation frequency of the publication, and a wider line indicates a stronger relationship of collaboration or co-citations. Different colors represent different years. The burst of citations demonstrates that attention to the field has increased within a certain period and is a crucial indicator for identifying emerging trends [27]. We used Microsoft Excel 2019 to tabulate data from Web of Science and draw trending figures of publication and citation count with years. In addition, IBM SPSS Statistical 26.0 (SPSS, Inc., Chicago, IL, USA) was utilized to execute linear regression analysis and determine whether the changes were statistically significant. Each year was used as the independent variable and individual category as the dependent variable. $P<0.05$ was considered to represent statistical significance.

**Results**

**Analysis of Publications**

In total, 857 references were identified in this analysis. The main types of studies on exercise and tendinopathy were clinical studies investigating the effects of treatments. Other studies types included in vitro studies, animal models, and in vivo studies. The number of annual publications grew from 8 in 2001 to 83 in 2020 (Figure 2A). The feedback of linear regression analysis showed that the percentage of publications had risen significantly in the last 20 years ($t=13.29, P<0.001$). The 857 selected articles were cited 23,004 times (H-index 78, citations per paper 28.55). As presented in Figure 2B, the number of citations per year grew from 3 in 2001 to 3306 in 2020, and the percentages had a remarkable increase ($t=18.32, P<0.001$). We partitioned the 20-year research period into 5 sets (2001-2004, 2005-2008, 2009-2012, 2013-2016, and 2017-2020), finding that 2017-2020 had the most papers (295) and open access papers (138), 2005-2008 had the highest number of citations (6686) and H-index value (48), 2001-2004 had the highest number of citations per paper (84.71), and 2013-2016 had the most citations in 2020 (1059) (Figure 3).

**Distribution by Journals**

The 857 publications associated with exercise and tendinopathy research were published in 194 different journals. We recorded the top 20 journals by the number of published papers (Table 1). The scholarly journal British Journal of Sports Medicine, with IF, 2020=13.800, published the most articles on exercise and tendinopathy research (68) and was cited 4782 times, followed by the Scandinavian Journal of Medicine & Science in Sports (publications, 48; IF, 2020=4.221; citations, 1766), and American Journal of Sports Medicine (publications, 36; IF, 2020=6.202; citations, 2730). The British Journal...
Figure 2. The number of publications and citations. (A) The number of annual publications on exercise and tendinopathy research from 2001 to 2020. (B) The number of annual citations on exercise and tendinopathy research from 2001 to 2020. (Office Excel 2019, Microsoft).

Figure 3. Number of papers, citations, citations per paper, open access paper, H-index, and citations in 2020 for each 4-year time period. (Office Excel 2019, Microsoft).
British Journal of Sports Medicine had the highest H-index value (45), while the American Journal of Sports Medicine had the most citations per paper (75.83).

**Subject Categories of WoS**

A total of 52 subject categories were generated from the 857 papers on exercise and tendinopathy research. The first 20 subject categories according to the quantity of papers are represented in Figure 4. Sport Sciences had the largest number of articles (512), open access papers (139), citations (16,451), and the highest H-index value (68). The Surgery had the highest number of citations per paper (39.96). In addition, the outcome of linear regression analysis showed that the percentage had significant growth in the last 2 decades ($P<0.01$) in the top 20 subject categories: Sport Sciences, Orthopedics, Rehabilitation, Surgery, Medicine General Internal, Neurosciences, Rheumatology, Radiology Nuclear Medicine, Medical Imaging, Multidisciplinary Sciences, Biophysics, Cell Biology, Medicine Research Experimental, Veterinary Sciences, Primary Health Care, Biochemistry Molecular Biology, Acoustics, Cell Tissue Engineering, and Clinical Neurology.

**Table 1.** The top 20 journals of origin of papers in the exercise and tendinopathy research.

| Journals                                      | Papers | Citations WoS | Citations per paper | WoS categories            | IF 2020 | H-index |
|-----------------------------------------------|--------|---------------|---------------------|---------------------------|---------|---------|
| British Journal of Sports Medicine            | 68     | 4782          | 70.32               | Sport Sciences            | 13.800  | 45      |
| Scandinavian Journal of Medicine & Science in Sports | 48     | 1766          | 36.79               | Sport Sciences            | 4.221   | 22      |
| American Journal of Sports Medicine          | 36     | 2730          | 75.83               | Orthopedics               | 4.751   | 27      |
| Journal of Orthopaedic & Sports Physical Therapy | 32     | 813           | 25.41               | Orthopedics; Rehabilitation; Sport Sciences | 2.365 | 11      |
| Physical Therapy in Sport                    | 28     | 336           | 12.00               | Rehabilitation; Sport Sciences | 3.494 | 15      |
| Journal of Orthopaedic Research              | 22     | 769           | 34.95               | Orthopedics               | 3.827   | 13      |
| Foot & Ankle International                   | 22     | 548           | 24.91               | Orthopedics               | 4.319   | 11      |
| Journal of Science and Medicine in Sport     | 22     | 530           | 24.09               | Sport Sciences            | 5.411   | 12      |
| Medicine and Science in Sports and Exercise  | 21     | 435           | 20.71               | Sport Sciences            | 4.342   | 12      |
| Knee Surgery Sports Traumatology Arthroscopy | 20     | 1014          | 50.70               | Orthopedics; Sport Sciences; Surgery | 2.712 | 12      |
| Journal of Biomechanics                      | 17     | 562           | 33.06               | Biophysics; Engineering, Biomedical | 3.638 | 10      |
| BMC Musculoskeletal Disorders                | 17     | 188           | 11.06               | Orthopedics; Rheumatology | 2.362 | 9       |
| Clinical Journal of Sport Medicine           | 16     | 405           | 25.31               | Orthopedics; Sport Sciences; Physiology | 3.531 | 10      |
| Gait & Posture                               | 16     | 221           | 13.81               | Neurosciences; Orthopedics; Sport Sciences | 2.840 | 9       |
| Clinical Biomechanics                        | 13     | 208           | 16.00               | Engineering, Biomedical; Orthopedics; Sport Sciences | 2.063 | 10      |
| Plos One                                     | 13     | 170           | 13.08               | Multidisciplinary Sciences | 3.240 | 6       |
| Journal of Applied Physiology                | 12     | 423           | 35.25               | Physiology; Sport sciences | 3.531 | 10      |
| Journal of Athletic Training                 | 12     | 222           | 18.50               | Sport sciences            | 2.860   | 7       |
| Journal of Sport Rehabilitation              | 12     | 89            | 7.42                | Rehabilitation; Sport Science | 1.931 | 5       |
| Frontiers in Physiology                      | 10     | 119           | 11.90               | Physiology                | 4.566   | 5       |

WoS – Web of Science; IF – impact factor.
**Distribution by Countries and Institutions**

The 857 selected articles on exercise and tendinopathy research were generated from 49 countries. Figure 5 presents the top 10 countries that published the most articles. The USA had the most publications (219), the most citations (4752), and the most open access papers (79). Australia and England had the highest H-index value (37). Sweden had the most citations per paper (62.35). Among the top 10 countries that contributed to exercise and tendinopathy research, the USA was first, followed by Australia (147) and England (120). The extensive collaborations between countries are shown in Figure 6A.

We found that 1064 institutions contributed to 857 articles on exercise and tendinopathy from 2001 to 2020. Figure 7 presents the top 10 institutions that published the most publications. The University of La Trobe had the most papers (51), the most open access papers (24), and the highest H-index value (26). Umea University had the most citations (2408) and the most citations per paper (89.19). The extensive cooperation of institutions on exercise and tendinopathy study is demonstrated in Figure 6B.

**Distribution by Authors and Co-Cited Authors**

The 857 selected articles on exercise and tendinopathy research were generated by 2822 authors. The top 10 authors and co-cited authors of exercise and tendinopathy research are presented in Table 2. Among the authors, Malliaras P published 32 articles, ranking first in accordance with the number of papers, followed by Cook JL (26 papers), Zwerver J (25 papers), and Alfredson H (23 papers). The author with the largest number of citations was Alfredson H (290 citations), followed by Cook JL (252 citations), Khan KM (196 citations), and Maffulli N (189 citations). Alfredson H ranked first among the co-cited authors, cited 290 times, followed by Cook JL, Khan KM, and Maffulli N cited 252, 196, and 189 times, respectively. The top 10 co-cited authors were cited over 100 times, which indicated that they were established and influential authors in the domain of exercise and tendinopathy research.

**Analysis of References**

The relevance of all the selected publications is shown in the co-citation map of the references (Figure 8). A total of 17 clusters had an average silhouette of 0.8661 (over 0.5), which implied a meaningful cluster analysis of the network map. The
score of modularity Q was 0.7208 (over 0.5), representing that the cluster network was relatively rational. The "eccentric exercises" was labeled as the first cluster #0, followed by "jumpers’ knee" #1 and "eccentric exercises" #2.

**Analysis of Keywords**

We utilized CiteSpace (5.8.R3) software to record the distribution of keywords on exercise and tendinopathy research. The top 31 keywords with strongest citation bursts since 2001 were as follows: “tendinitis,” “ultrasonography,” and “etiology,” and the keywords ending in 2020 included “rehabilitation.”
Continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy" published in 2009 in the British Journal of Sports Medicine was the most frequently cited (442 citations). Among the top 10 articles, 3 [28-30] in journals with IF ≥10 (British Journal of Sports Medicine, Sports Medicine), 4 [7,31-33] in journals with 5 ≤ IF < 10 (American Journal of Sports Medicine, Cochrane Database of Systematic Reviews, Acta Physiologica) and 3 [34-36] in journals with 3 ≤ IF < 5 (Knee Surgery Sports Traumatology Arthroscopy, Journal of Orthopaedic & Sports Physical Therapy).

Table 3 showed the 10 most-cited papers on exercise and tendinopathy study with the highest citation frequency. The top 10 papers accounted for 11.7% (2691) of all citations. The article by Cook et al [28] with the title “Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy” published in 2009 in the British Journal of Sports Medicine was the most frequently cited (442 citations). Among the top 10 articles, 3 [28-30] in journals with IF ≥10 (British Journal of Sports Medicine, Sports Medicine), 4 [7,31-33] in journals with 5 ≤ IF < 10 (American Journal of Sports Medicine, Cochrane Database of Systematic Reviews, Acta Physiologica) and 3 [34-36] in journals with 3 ≤ IF < 5 (Knee Surgery Sports Traumatology Arthroscopy, Journal of Orthopaedic & Sports Physical Therapy).

Table 2. The top 10 authors, co-cited authors, and co-cited references on exercise and tendinopathy research.

| Authors          | Published articles | Co-cited authors | Cited times | Co-cited references | Cited times |
|------------------|--------------------|------------------|-------------|--------------------|-------------|
| Malliaras P      | 32                 | Alfredson H      | 290         | Beyer R, 2015, Am J Sport Med, V43, P1704 | 41          |
| Cook JL          | 26                 | Cook JL          | 252         | Ohberg L, 2004, Brit J Sport Med, V38, P8 | 32          |
| Zwerver J        | 25                 | Khan KM          | 196         | Roos EM, 2004, Scand J Med Sci Sport, V14, P286 | 30          |
| Alfredson H      | 23                 | Maffulli N       | 189         | Rio E, 2015, Brit J Sport Med, V49, P0 | 29          |
| Cook J           | 21                 | Ohberg L         | 169         | Young MA, 2005, Brit J Sport Med, V39, P102 | 28          |
| Maffulli N       | 18                 | Malliaras P      | 136         | Purdam CR, 2004, Brit J Sport Med, V38, P395 | 28          |
| Kjaer M          | 17                 | Silbernagel KG   | 116         | Jonsson P, 2005, Brit J Sport Med, V39, P847 | 27          |
| Magnusson SP     | 17                 | Kannus P         | 116         | Fahlstrom M, 2003, Knee Surg Sport Tra, V11, P327 | 26          |
| Langberg H       | 16                 | Lian OB          | 111         | Lian OB, 2005, Am J Sport Med, V33, P561 | 25          |
| Van Den Akker-Scheek I | 16             | Jonsson P        | 105         | Malliaras P, 2013, Sports Med, V43, P267 | 24          |
Discussion

Global Trends on Exercise and Tendinopathy Research

Our bibliometric analysis presents a systematic overview on exercise and tendinopathy with every related article from WoS between 2001 and 2020. In the past 20 years, there was a significant worldwide increase in the number of published articles, showing that exercise and tendinopathy is attracting broad attention from researchers and offers abundant information for further study. The number of papers had steadily risen since 2001, and the percentage of published articles between 2005 and 2007 had noticeable growth. Among the 5 research periods, 2017-2020 had the most papers (295), and 2005-2008 had the most citations (6686) and the highest H-index value (48). These findings indicated that the published papers on exercise and tendinopathy between 2005-2008 have good quality.

Based on the number of papers on exercise and tendinopathy research, the top 20 journals accounted for 53.33% (457 publications) for all publication output. British Journal of Sports Medicine was the most productive journal (68 publications, 7.93%), followed by Scandinavian Journal of Medicine & Science in Sports (48 publications, 5.60%) and American Journal of Sports Medicine (36 publications, 4.20%). The high number of citations per paper demonstrated that the British Journal of Sports Medicine had superior academic quality and was the undisputed main journal publishing exercise and tendinopathy research. British Journal of Sports Medicine had the highest value of IF (13.800). Among the top 20 journals with IF >10 (British Journal of Sports Medicine, IF: 13.800), 8 had 1 ≤ IF <3, 9 had 3 ≤ IF <5, and 2 had 5 ≤ IF <10. The mean IF of the top 20 journals was 4.074, revealing that publishing relational papers in high-IF journals is relatively challenging.

Based on the quantity of selected publications on exercise and tendinopathy studies, the USA led (219), followed by Australia (147) and England (120). Among the top 10 countries, there were 5 European countries, 3 American countries, and 2 Asia-Pacific countries. Figure 6A shows that the cooperation between countries was expansive. We found that 1064 different institutions contributed to 857 articles on exercise and tendinopathy from 2001 to 2020. According to the number of papers, the top 10 institutions included 4 in Australia, 2 in England, and 1 in Denmark, 1 from the Netherlands, 1 from Canada, and 1 from Sweden. These results show that the USA, Australia, and England were the leading countries in exercise and tendinopathy research. The top 10 institutions accounted for 36.99% (317 publications) of all publications, which demonstrates they...
had considerable research achievements. However, cooperation was not obvious among institutions compared with the collaboration among countries.

Research Focuses on Exercise and Tendinopathy Research

In the last 2 decades, as shown in Figure 4, Sport Sciences was the most popular research area on exercise and tendinopathy in terms of the subject categories (512), followed by Orthopedics (280), Rehabilitation (161), and Physiology (66). The top 10 productive subject categories were Sport Sciences, Orthopedics, Rehabilitation, Physiology, Engineering Biomedical, Surgery, Medicine General Internal, Neurosciences, Rheumatology, and Radiology Nuclear Medicine Medical Imaging. In our comprehensive analysis of the number of articles, citations, citations per paper, and the H-index value, we found that the first 3 subject categories (Sport Sciences, Orthopedics, Rehabilitation) accounted for more than 18% of all articles, and the H-index of all 3 categories exceeded 30, denoting that had excellent quality and were regarded as the main subjects in exercise tendinopathy research. As shown in the co-citation map of references, “eccentric exercises” was labeled as the first cluster #0, followed by “jumpers’ knee” #1 and “eccentric exercises” #2. Exercise therapy is an indispensable part of the

Figure 9. The keywords with the strongest citation bursts of publications on exercise and tendinopathy research. (CiteSpace 5.8.R3, Drexel University, Philadelphia, USA).
non-surgical management of tendinopathy [8,37]. For example, Van et al [38] compared the effect of different treatment interventions for patellar tendinopathy, which indicated eccentric training offered the highest chances of medical improvement in patients with patellar tendinopathy. However, a systematic review by Murphy et al [39] showed that heavy eccentric calf training (HECT) may be better than traditional physiotherapy, while HECT may be inferior to other exercise treatments for Achilles tendinopathy. Therefore, it is necessary to formulate individualized exercise therapy based on the type of pathological changes, functional status, and preferences of patients with tendinopathy. Based on the analysis of keywords, the outcomes showed that the top 31 keywords used since 2001 were: “tendinitis,” “ultrasonography,” and “etiology.”

### Table 3. The top 10 papers with the most citations on exercise and tendinopathy research.

| Title                                                                 | First author | Journal                                      | IF* (2020) | Year | Citations (WoS) | WoS** categories | Category ranking |
|-----------------------------------------------------------------------|--------------|----------------------------------------------|------------|------|-----------------|------------------|-----------------|
| Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy | Cook         | British Journal of Sports Medicine           | 13.800     | 2009 | 442             | Sport Sciences   | 1/85            |
| Prevalence of jumper’s knee among elite athletes from different sports – A cross-sectional study | Lian         | American Journal of Sports Medicine          | 6.202      | 2005 | 415             | Orthopedics; Sport Sciences | 1/82; 3/85       |
| What are the Main Running-Related Musculoskeletal Injuries? A Systematic Review | Lopes        | Sports Medicine                              | 11.136     | 2012 | 268             | Sport Sciences   | 2/85            |
| Superior short-term results with eccentric calf muscle training compared to concentric training in a randomized prospective multicenter study on patients with chronic Achilles tendinosis | Mafi         | Knee Surgery Sports Traumatology Arthroscopy | 4.342      | 2001 | 264             | Orthopedics; Sport Sciences; Surgery | 15/82; 15/85; 43/210 |
| Eccentric training in patients with chronic Achilles tendinosis: normalised tendon structure and decreased thickness at follow up | Ohberg       | British Journal of Sports Medicine           | 13.800     | 2004 | 262             | Sport Sciences   | 1/85            |
| Chronic Achilles tendon pain treated with eccentric calf-muscle training | Fahlstrom    | Knee Surgery Sports Traumatology Arthroscopy | 4.342      | 2003 | 212             | Orthopedics; Sport Sciences; Surgery | 15/82; 15/85; 43/210 |
| Exercise for women receiving adjuvant therapy for breast cancer       | Markes       | Cochrane Database of Systematic Reviews       | 9.266      | 2006 | 209             | Medicine, General & Internal | 10/165          |
| Eccentric muscle contractions: Their contribution to injury, prevention, rehabilitation, and sport | Lastayo      | Journal of Orthopaedic & Sports Physical Therapy | 4.751      | 2003 | 209             | Orthopedics; Rehabilitation; Sport Sciences | 10/82; 3/68; 11/85 |
| Eccentric loading, shock-wave treatment, or a wait-and-see policy for tendinopathy of the main body of tendo Achillis - A randomized controlled trial | Rompe        | American Journal of Sports Medicine          | 6.202      | 2007 | 206             | Orthopedics; Sport Sciences | 1/82; 3/85       |
| Region specific patellar tendon hypertrophy in humans following resistance training | Kongsgaard   | Acta Physiologica                            | 6.311      | 2007 | 204             | Physiology       | 8/81            |

IF – impact factor; WoS – Web of Science.
Keywords ending in 2020 were: “rehabilitation” (2017-2020), “rotator cuff tendinopathy” (2017-2020), “association” (2017-2020), “questionnaire” (2018-2020), “stiffness” (2018-2020), and “disability” (2018-2020). To date, global therapeutic exercise interventions for tendinopathy mainly include eccentric exercise, resistance training, isometric exercise, concentric exercise, static stretching exercises, and synthesis of multiple exercise modes [8,14,15,40]. Moreover, the mechanism and methods of exercise treatment of tendinopathy still need further research. As research covering exercise and tendinopathy has gradually shifted from phenomenon to mechanism over the past 20 years, we believe that more effective clinical interventions will be developed in the foreseeable future.

Strengths and Limitations

The current study is the first to summarize the global trends in exercise and tendinopathy for bibliometric analysis from SCI-Expanded of WoS between 2001 and 2020. The search strategy was not restricted to 1 scholarly journal to involve more related papers and obtain extensive data. As the results indicated, there were 194 different scholarly journals with 857 publications on exercise and tendinopathy research, such as the British Journal of Sports Medicine, Scandinavian Journal of Medicine & Science in Sports, and American Journal of Sports Medicine. Moreover, our bibliometric study not only included the annual publication outputs, citations, journals, and cooperations of countries/institutions, but also covered the co-citation analysis of references, analysis of keywords and authors, the H-index, and subject categories in WoS.

This bibliometric study has a few limitations. Firstly, we only used the SCI-Expanded WoS electronic database, and other relevant search databases were not retrieved and analyzed, such as Embase and Scopus. Moreover, we excluded all non-English articles. Although most relevant publications are in English, this limitation may have caused publication bias. Secondly, we did not conduct geospatial visualization with CiteSpace 5.8.R3 software. Thirdly, we cannot ensure that each paper was entirely relevant to the topic. However, we believe these findings offer a helpful and representative overview of exercise and tendinopathy research.

Conclusions

This bibliometric study provides historical insights into the direction of exercise and tendinopathy research. Although the study has several methodological limitations, it adequately shows the worldwide trends in exercise and tendinopathy research. The number of papers has significantly increased in the past 20 years, and the number of publications each year increased from 8 in 2001 to 83 in 2020. The USA contributed the most publications, and the British Journal of Sports Medicine was the most influential journal on exercise and tendinopathy. The most popular subject category was Sport Sciences. In general, this bibliometric study provides a historical and scientific perspective on exercise and tendinopathy research, providing helpful information for researchers, funding agencies, and policymakers.

Acknowledgments

The authors thank Professor C. M. Chen for developing the free-to-use CiteSpace software.

Declaration of Figures’ Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

References:

1. Ackermann PW, Renström P. Tendinopathy in sport. Sports Health. 2012;4(3):193-201
2. Magnusson SP, Kong J, Almekinders LC. The pathogenesis of tendinopathy: Balancing the response to loading. Nat Rev Rheumatol. 2011;6(5):262-68
3. Maffulli N, Wong J, Almekinders LC. Types and epidemiology of tendinopathy. Clin Sports Med. 2003;22(4):675-92
4. Kettunen JA, Kvist M, Alaranta H, Kujala UM. Long-term prognosis for jumper’s knee in male athletes. A prospective follow-up study. Am J Sports Med. 2002;30(5):689-92
5. Lagas IF, Fokkema T, Bierma-Zeinstra S, et al. How many runners with new-onset Achilles tendinopathy develop persisting symptoms? A large prospective cohort study. Scand J Med Sci Sports. 2020;30(10):1939-48
6. Zwerer I, Bredeweg SW, van den Akker-Scheek I. Prevalence of jumper’s knee among nonelite athletes from different sports: A cross-sectional survey. Am J Sports Med. 2011;39(9):1984-88
7. Lian OB, Gegebreten L, Bahr R. Prevalence of jumper’s knee among elite athletes from different sports: A cross-sectional study. Am J Sports Med. 2005;33(4):561-67
8. van Ark M, Cook JL, Docking SI, et al. Do isometric and isotonic exercise programs reduce pain in athletes with patellar tendinopathy in-season? A randomised clinical trial. J Sci Med Sport. 2016;19(9):702-6
9. Stanis M, Juras G, Chmielowska D, et al. Extraarticular shock wave therapy for Achilles tendinopathy. Biomed Res Int. 2019;2019:3086910
10. Heinemeier KM, Øhlenschlæger TF, Mikkelsen UR, et al. Effects of anti-inflammatory (NSAID) treatment on human tendinopathic tissue. J Appl Physiol (1985). 2017;123(5):1397-405
11. Kaux JF, Croisier JL, Forthomme B, et al. Using platelet-rich plasma to treat jumper’s knees: Exploring the effect of a second closely-timed infiltration. J Sci Med Sport. 2016;19(3):200-4
12. Ruzzini L, Longo UG, Rizzello G, Denaro V. Stem cells and tendinopathy: State of the art from the basic science to clinical application. Muscles Ligaments Tendons J. 2012;2(3):235-38
13. Rio E, Kidgell DJ, Purdam C, et al. Isometric exercise induces analgesia and reduces inhibition in patellar tendinopathy. Br J Sports Med. 2015;49(19):1277-83
14. Peterson M, Butler S, Eriksson M, Svärdssund K. A randomized controlled trial of eccentric vs. concentric graded exercise in chronic tennis elbow (lateral elbow tendinopathy). Clin Rehabil. 2014;28(9):862-72
40. Dimitrios S, Pantelis M, Kalliopi S. Comparing the effects of eccentric training and static stretching exercises in the treatment of patellar tendinopathy. A controlled clinical trial. Clin J Sport Med. 2012;27(3):253-59

39. Murphy MC, Travers MI, Chivers P, et al. Efficacy of heavy eccentric calf muscle training for treating mid-portion Achilles tendinopathy: A systematic review and meta-analysis. Br J Sports Med. 2019;53(17):1070-77

38. van Rijn D, van den Akker-Scheek I, Steunebrink M, et al. Comparison of eccentric training and static stretching exercises in the treatment of patellar tendinopathy. A randomized controlled trial. Clin J Sport Med. 2017;27(3):253-59

37. Rio E, van Ark M, Docking S, et al. Isometric contractions are more analgesic than isotonic contractions for patellar tendon pain: An in-season randomized controlled trial. Clin J Sport Med. 2019;29(3):181-87

36. LaStayo PC, Monson P, Lorentzon R, Alfredson H. Chronic Achilles tendon pain treated with eccentric calf-muscle training. Knee Surg Sports Traumatol Arthrosc. 2003;11(5):327-33

35. Fahlström M, Jonsson P, Kihlström M, et al. The beneficial effects of eccentric exercise in the management of lateral elbow tendinopathy: A systematic review and meta-analysis. J Clin Med. 2021;10(17):3968

34. Mafi N, Lorentzon R, Alfredson H. Superior short-term results with eccentric calf muscle training compared to concentric training in a randomized prospective multicenter study on patients with chronic Achilles tendinosis. Knee Surg Sports Traumatol Arthrosc. 2003;11(5):327-33

33. Kongsgaard M, Reitelseder S, Pedersen TG, et al. Region specific patellar tendon hypertrophy in humans following resistance training. Acta Physiol (Oxf). 2007;191(2):111-21

32. Rompe JD, Nafe B, Furia JP, Maffulli N. Eccentric loading, shock-wave treatment, or a wait-and-see policy for tendinopathy of the main body of tendon Achilles: A randomized controlled trial. Am J Sports Med. 2007;35(3):374-83

31. Markes M, Brockow T, Resch KL. Exercise for women receiving adjuvant therapy for breast cancer. Cochrane Database Syst Rev 2006;(4):CD005001

30. Rabello LM, van den Akker-Scheek I, Brink MS, et al. Association between clinical and imaging outcomes after therapeutic loading exercise in patients diagnosed with Achilles or patellar tendinopathy at short- and long-term follow-up: A systematic review. Clin J Sport Med. 2020;30(4):390-403

29. Ohberg L, Lorentzon R, Alfredson H. Eccentric training in patients with chronic Achilles tendinosis: Normalised tendon structure and decreased thickness at follow up. Br J Sports Med. 2004;38(1):8-11; discussion 11

28. Cook JL, Purdam CR. Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. Br J Sports Med. 2009;43(6):409-16

27. Liang YD, Li Y, Zhao J, et al. Study of acupuncture for low back pain in recent 20 years: A bibliometric analysis via CiteSpace. J Pain Res. 2017;10:951-64

26. Chen C, Hu Z, Liu S, Tseng H. Emerging trends in regenerative medicine: A scientometric analysis of global research from 1980 to 2018. J Clin Med. 2020;52(4):jim00052

25. Peng MS, Chen CC, Wang J et al. The top 100 most-cited papers in long-term follow-up: A systematic review. Clin J Sport Med. 2020;30(4):390-403

24. Bornmann L, Leydesdorff L. Scientometrics in a changing research landscape: A bibliometric analysis of the guiding themes of an emerging research field. Front Hum Neurosci. 2016;10:336

23. Yoon SY, Kim YW, Shin IS, et al. The beneficial effects of eccentric exercise to explain the clinical presentation of load-induced tendinopathy. Br J Sports Med. 2015;49(7):502-06

22. Thompson DF, Walker CK. A descriptive and historical review of bibliometrics with applications to medical sciences. Pharmacotherapy. 2015;35(6):551-59

21. Peng MS, Chen CC, Wang J et al. The top 100 most-cited papers in long-term follow-up: A systematic review. Clin J Sport Med. 2020;30(4):390-403

20. Lu K, Yu S, Yu M, et al. Bibliometric analysis of tumor immunotherapy studies. Med Sci Monit. 2018;24:3405-14

19. Miao Y, Liu R, Pu Y, Yin L. Trends in esophageal and esophagogastric junction cancer research from 2007 to 2016: A bibliometric analysis. Medicine (Baltimore). 2017;96(20):e9924

18. Wang R, Wang XM, Wang XQ. Exercise for low back pain: A bibliometric study of exercise and tendinopathy Zhu Y. et al: Expert Opin Biol Ther. 2012;12(5):593-608

17. Leefmann J, Levallois C, Hildt E. Neuroethics 1995-2012. A bibliometric analysis of the guiding themes of an emerging research field. Front Hum Neurosci. 2016;10:336

16. Thompson DF, Walker CK. A descriptive and historical review of bibliometrics with applications to medical sciences. Pharmacotherapy. 2015;35(6):551-59

15. Beyer R, Kongsgaard M, Hougs Kjær B, et al. Heavy slow resistance versus eccentric training as treatment for achilles tendinopathy: A randomized controlled trial. Am J Sports Med. 2015;43(7):1704-11

14. Thompson DF, Walker CK. A descriptive and historical review of bibliometrics with applications to medical sciences. Pharmacotherapy. 2015;35(6):551-59

13. Bornmann L, Leydesdorff L. Scientometrics in a changing research landscape: A bibliometric analysis of the guiding themes of an emerging research field. Front Hum Neurosci. 2016;10:336

12. Wang R, Wang XM, Wang XQ. Exercise for low back pain: A bibliometric analysis of global research from 1980 to 2018. J Rehabil Med. 2020;52(4):jim00052

11. Miao Y, Liu R, Pu Y, Yin L. Trends in esophageal and esophagogastric junction cancer research from 2007 to 2016: A bibliometric analysis. Medicine (Baltimore). 2017;96(20):e9924

10. Lu K, Yu S, Yu M, et al. Bibliometric analysis of tumor immunotherapy studies. Med Sci Monit. 2018;24:3405-14

9. Peng MS, Chen CC, Wang J et al. The top 100 most-cited papers in long-term follow-up: A systematic review. Clin J Sport Med. 2020;30(4):390-403

8. Bornmann L, Leydesdorff L. Scientometrics in a changing research landscape: A bibliometric analysis of the guiding themes of an emerging research field. Front Hum Neurosci. 2016;10:336

7. Liang YD, Li Y, Zhao J, et al. Study of acupuncture for low back pain in recent 20 years: A bibliometric analysis via CiteSpace. J Pain Res. 2017;10:951-64

6. Chen C, Hu Z, Liu S, Tseng H. Emerging trends in regenerative medicine: A scientometric analysis in CiteSpace. Expert Opin Biol Ther. 2012;12(5):593-608

5. Hirsch JE. An index to quantify an individual's scientific research output. Proc Natl Acad Sci USA. 2005;102(46):16569-72

4. Rabello LM, van den Akker-Scheek I, Brink MS, et al. Association between clinical and imaging outcomes after therapeutic loading exercise in patients diagnosed with Achilles or patellar tendinopathy at short- and long-term follow-up: A systematic review. Clin J Sport Med. 2020;30(4):390-403

3. Chen C, Hu Z, Liu S, Tseng H. Emerging trends in regenerative medicine: A scientometric analysis in CiteSpace. Expert Opin Biol Ther. 2012;12(5):593-608

2. Liang YD, Li Y, Zhao J, et al. Study of acupuncture for low back pain in recent 20 years: A bibliometric analysis via CiteSpace. J Pain Res. 2017;10:951-64

1. Cook JL, Purdam CR. Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. Br J Sports Med. 2009;43(6):409-16