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Publication trends and global productivity about the anterior cruciate ligament: a bibliometric analysis between 1980-2021

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ABSTRACT

Aim: Due to anatomic, biomechanical, kinematic, biological and clinical data obtained as a result of many studies related to treatment and rehabilitation of injuries to the anterior cruciate ligament (ACL), among the most studied anatomic structures in the human body, the literature is continuously being updated and improved. In this study, the aim was to holistically analyze scientific articles about the ACL published between 1980 and 2021 using a variety of statistical methods.

Material and Method: Articles published from 1980 to 2021 about the ACL were obtained from the Web of Science (WoS) database and analyzed using statistical methods and bibliometric approaches. To identify trend topics and global cooperation, and to complete citation analysis, network visualization maps were used. The exponential smoothing predictor was used to predict the number of articles that will be published in the next 5 years. Spearman's correlation coefficient was used for correlation research.

Results: A total of 11,077 publications were identified. Of these publications, 9101 (82.1%) were articles. The top 3 countries contributing most to the literature were the USA (3894, 42.7%), Japan (879, 9.6%) and Germany (616, 6.7%). The top 3 active organizations were Pennsylvania Commonwealth System of Higher Education (n=468), University of Pittsburgh (440), and University of California system (279). The top 3 journals publishing most articles were the American Journal of Sports Medicine (n=1614), Knee Surgery Sports Traumatology Arthroscopy (1418), and Arthroscopy: The Journal of Arthroscopic and Related Surgery (915). The most effective journal according to mean number of citations per article was the Journal of Bone and Joint Surgery (average citation per document: 80.7). The most active author was Freddie H. Fu (n=278, from University of Pittsburgh).

Conclusion: In this comprehensive bibliometric research about the topic of ACL, with a trend toward increasing publication numbers in recent years, the summary information for 9101 articles published between 1980 and 2021 was shared. According to analysis results to determine trend topics, the keywords studied in recent years include return to sport, ACL injury, anterolateral ligament, pivot shift, quadriceps strength, KOOS, ACL tear, ACL repair, meniscal repair, knee ligaments, tibial slope, posterior tibial slope, return to play, adolescent, graft failure and lateral meniscus.

Keywords: Anterior cruciate ligament, ACL, bibliometric analysis, trends, injuries, global cooperation

INTRODUCTION

The anterior cruciate ligament (ACL) is the structure limiting the forward translation of the tibia and providing rotational stability of the knee in both the frontal and transverse planes (1). The ligament, with a strong fibrous structure, assists in controlling movement by limiting the mobility of the knee joint. The ACL is one of the four main ligaments in the knee and provides 85% of anterior tibial displacement limitation in knee flexion from 30 degrees to 90 degrees (2). In the body, the ACL is more susceptible to injury due to its structural properties and is one of the most studied injuries related to sports surgery in orthopedics (3). Most ACL tears are the result of a contact-free mechanism, like sudden direction changes causing the knee to turn inward (4). Sportswomen with increased dynamic valgus and high abduction loads are at higher risk in terms of ACL injury. During a landing task, knee movements and knee load are determinants of the ACL injury risk of sportswomen (5).

Biomechanical changes after ACL injury are associated with cartilage degeneration and progressive knee joint osteoarthritis development (6). ACL reconstructive surgery is recommended to ensure knee joint stability and return to function after ACL injury (1). Even if

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conservative treatment is applied to chosen patients in the general population, as a result of the inability to obtain the desired results from cases undergoing primary repair, currently the gold standard treatment for ACL injury in athletic individuals has emerged as ACL reconstruction surgery. The most frequently used autografts for ACL reconstruction are the bone patellar tendon bone (BPTB), hamstring tendon (HT) and quadriceps tendon (QT) (7). Though a variety of grafts and techniques have been defined for ACL reconstruction, currently the most popular methods are arthroscopic repairs using hamstring tendon and patellar tendon autografts (8). However, the optimal graft tissue selection for ACL reconstruction is still controversial (9,10). A meta-analysis study by Freedman et al. (9) determined that patellar tendon autografts had significantly lower graft failure rates compared to hamstring tendon autografts, better static knee stability and higher patient satisfaction. Additionally, they reported that anterior knee pain was higher in patellar tendon autograft reconstructions. The results of a meta-analysis study performed by Xie et al. (11) stated that ACL reconstruction with BPTB autografts may be superior to four-strand hamstring tendon (4SHT) autografts in sustaining rotational stability of the knee joint and higher activity levels of patients. They concluded that there was insufficient evidence to determine which of the two types of grafts were significantly superior for ACL reconstruction (10). In recent years, though there is increasing interest in biological agents focusing on platelet-rich plasma (PRP) and mesenchymal stem cells for conservative treatment for ACL tears, the evidence of benefit is still inadequate.

The incidence of ACL injuries is increasing due to the rapid increase from past to present in the numbers of people of every age playing sports. An incidence study by Mall et al. (3) in the United States stated that the incidence of ACL injuries significantly increased from 1994 to 2006, especially among women, those younger than 20 years of age and older than 40 years of age. In this study, the ACL injury incidence in the United States of America was 32.9 per 100,000 in 1994 and 43.5 per 100,000 in 2006. Every sportswoman is predicted to have nearly 10% ACL injury risk during their whole middle school and high school careers (12).

Bibliometrics is the statistical analysis of certain characteristics of publications such as author, subject, cited author, publication information, cited sources (13,14). Meta-analysis is a statistical analysis that combines the results of more than one scientific study (9,10,12). Bibliometric analysis and meta-analysis rely on quantitative techniques and can therefore reduce interpretation bias. Meta-analysis focuses on summarizing empirical evidence by analyzing the strength of effects and relationships between variables (9,10,12). In contrast, bibliometric analysis summarizes and maps the bibliometric and intellectual structure of a field by analyzing the social and structural relationships between different research components (e.g. authors, countries, institutions, topics). Therefore, well-done bibliometric studies provide scientists with a one-stop overview (13,14).

In parallel with the increasing number of publications in the literature, bibliometric research has been performed about many topics in the medical field (13-16). In addition to ACL injuries involving high health services use and high costs in financial terms, they lead to destructive outcomes for patient activity levels and quality of life. The literature is continuously updating and developing due to anatomic, biomechanical, kinematic, biological and clinical data obtained as a result of many studies related to treatment and rehabilitation of injuries to the ACL, one of the most studied anatomic structures in the human body. In this study, the aim was to holistically analyze scientific articles published about the ACL from 1980 to 2021 using a variety of bibliometric and statistical methods.

MATERIAL AND METHOD

Search Strategy

The Web of Science Core Collection (WoS by Clarivate Analytics) database was used for literature screening. The research period was determined to cover 1980 to 2021 (access date: 01.04.2022). As a result of publication screening using different keywords related to the ACL, all publications with statements related to ACL in the title were accessed. In order for the researchers to be able to access similar documents (research findings may change according to different access dates), repeatability codes were (Title=("ACL") or Title=("anterior cruciate ligament*") Refined by: Research area: (Orthopedics), Document Types: (Article), Timespan: 1980-2021). For this type of study ethics committee approval is not required. All procedures were carried out in accordance with the ethical rules and the principles.

Statistical Analysis

The exponential smoothing predictor in the Microsoft Office Excel program was used to predict the number of publications in future years according to previous publication trends. A website (https://app.datawrapper.de) was used to draw the world map. The VOSviewer (Version 1.6.16, Leiden University's Centre for Science and Technology Studies, Leiden, Netherlands) program was used to visualize bibliometric networks and for citation analysis (17). Statistical analyses were completed with the SPSS (version 22.00, SPSS Inc.,

Chicago, IL, USA, License: Hitit University) program. The fit of data to normal distribution was tested with the Shapiro-Wilks test. With the aim of assessing the correlation between global publication productivity about ACL and economic strength of countries, the correlation between the number of articles produced by countries with some markers of economic development (gross domestic product (GDP), gross domestic product per capita (GDP per capita) and human development index(HDI)) were investigated with the Spearman correlation coefficient (data obtained from the World Bank) (18). Statistical significance of a relationship was accepted as $p < 0.05$.

RESULTS

As a result of literature screening, a total of 17,343 publications published about ACL between 1980 and 2021 were found in the WoS database. Of these publications, only 11,077 studies published in the orthopedics research field were included in the study. The distribution of these studies according to publication categories were articles (9101, 82.1%), review articles (619, 5.8%), meeting abstracts (350, 3.6%), letters (320, 2.8%), proceedings papers (274, 2.4%) and the remainder were other publication types (editorial materials, early access, notes, book chapters, news items, corrections, additions, discussions, bibliographies, biographical items, books, book reviews). Bibliometric analyses were completed on 9101 publications in the article publication category from among the total of 11,077 publications. Of these articles, 97.5% (n=8880) were in English and the remainder were published in other languages (French (n=88), German (81), Czech (27), Russian (13), Turkish (7), Italian (2), Portuguese (2), Slovak (1)). Nearly all articles were included in the SCI-Expanded (n=8295, 91.1%) and Emerging Sources Citation Index (ESCI) (781, 8.5%) (the few remaining articles were indexed in the Social Sciences Citation Index (SSCI), Book Citation Index – Science (BKCI-S) and Conference Proceedings Citation Index – Science (CPCI-S)).

Development of Publications According to Year

The distribution of article numbers according to year is shown in **Figure 1**. The prediction values related to the results of the exponential smoothing prediction model used to estimate the number of articles that will be published in 2022 and later are shown in **Figure 1**. According to the estimation model results, it is predicted there will be 755 articles (confidence interval (CI) 705-806) published about ACL in 2022 and 966 (CI%: 897-1035) published in 2026 (**Figure 1**).

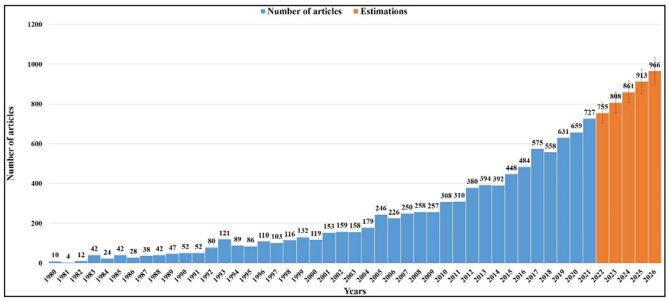

Figure 1. Bar chart showing the distribution of articles published about ACL by year and forecasts for the number of articles in the next 5 years

Active Countries

The distribution of article numbers according to country is shown in **Figure 2**. The top 20 countries publishing most articles were identified to be USA (3894, 42.7%), Japan (879, 9.6%), Germany (616, 6.7%), UK (489, 5.3%), France (417, 4.5%), South Korea (407, 4.4%), Sweden (388, 4.2%), Italy (382, 4.1%), Australia (380, 4.1%), China (352, 3.8), Canada (334, 3.6%), Switzerland (184, 2.0%), Norway (178, 1.9%), Netherlands (175, 1.9%), Turkey (167, 1.8%), Brazil (159, 1.7%), Austria (144, 1.5%), India (144, 1.5%), Spain (128, 1.4%), and Greece (123, 1.3%).

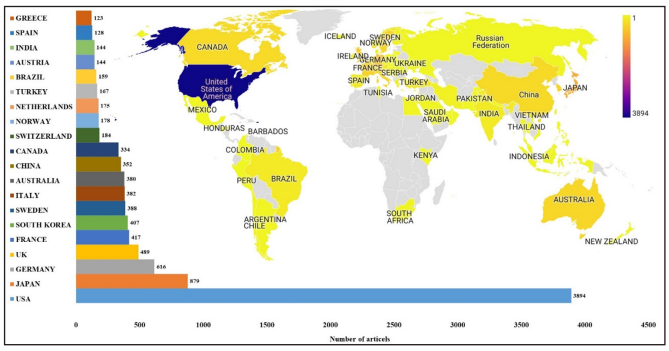

Figure 2. Global productivity world map showing the distribution of published articles about ACL by country and bar chart showing the top 20 most active countries

Cluster analysis was performed on the 50 countries producing at least 10 articles and with international cooperation between authors from among the 89 countries publishing articles about ACL and the results are shown in **Figure 3a.** According to the cluster analysis results, 9 different clusters related to international cooperation were identified (Cluster 1: Belgium, Czech Republic, England (in UK), India, New Zealand, Scotland, South Africa, United Arab Emirates, Wales. Cluster 2: Austria, Germany, Israel, Luxembourg, Netherlands, Poland, Russia. Cluster 3: Iran, Japan, Malaysia, South Korea, Taiwan, Thailand, USA. Cluster 4: Egypt, Greece, Kuwait, Qatar, Saudi Arabia, Turkey. Cluster 5: Canada, Denmark, Finland, Norway, Slovenia, Sweden. Cluster 6: Argentina, Brazil, Chile, Italy, Portugal, Spain. Cluster 7: Australia, China, Singapore. Cluster 8: Croatia, France, Ireland. Cluster 9: Serbia, Switzerland). Additionally,

the total link strength scores showing the collaborative power of the 50 countries were calculated and according to these scores the international collaboration density map is shown in **Figure 3b** (top 20 countries with highest scores USA=1055, Germany=366, England (in UK)=308, Sweden=282, Australia=267, Italy=246, France=236, Canada=215, Japan=191, Switzerland=164, Netherlands=137, Norway=133, Austria=130, Brazil=114, Greece=84, China=83, South Korea=78, Belgium=74, Luxembourg=72, Denmark=60).

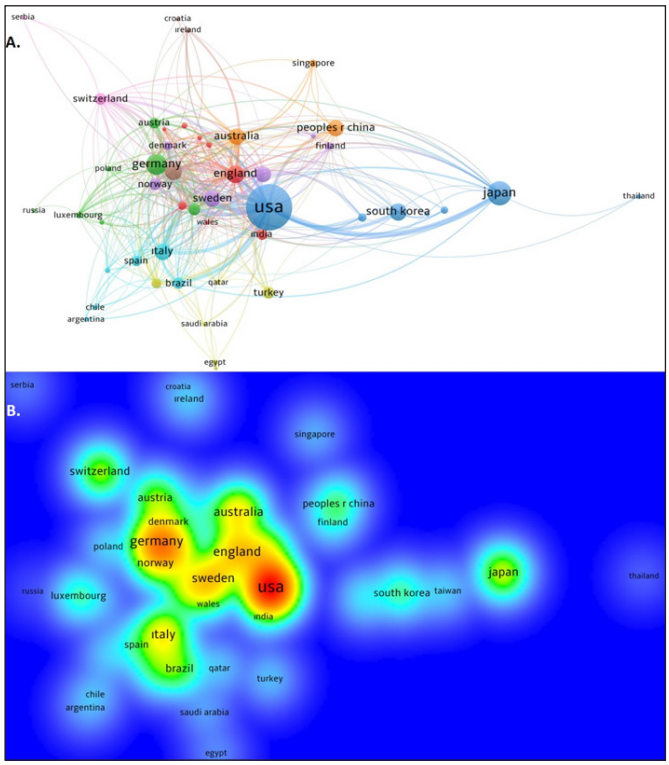

Figure 3. a. Network visualization map of cluster analysis showing cooperation between countries about ACL. Footnote: The color of the circle represents the cluster. The size of the circle indicates the number of articles. The larger the size of the circle, the more articles the country publishes. b. Density map showing the intensity of international cooperation between countries about ACL. Footnote: The strength of international cooperation score increases from blue to red (blue-green-yellow-red)

Correlation Analysis

Positive high level correlations were identified between the number of articles produced by countries with the GDP and HDI values, while there was a moderate level of statistically significant correlation with GDP per capita ($r=0.713$, $p<0.001$; $r=0.719$, $p<0.001$, $r=0.594$, $p<0.001$, respectively).

Active Authors

The top 15 authors actively publishing about ACL were identified to be Fu F.H. (n=278), Hewett T.E. (104), Spindler K.P. (102), Zaffagnini S. (98), Musahl V. (95), Bach B.R. (93), Engebretsen L. (92), Snyder-mackler L. (91), Fleming B.C. (84), Webster K.E. (81), Shino K. (76), Karlsson J. (75), Irrgang J.J. (74), Feller J.A. (73), and Yasuda K. (73)

Active Organizations

The top 20 most active organizations producing most articles about ACL were Pennsylvania Commonwealth System of Higher Education (n=468), University of Pittsburgh (440), University of California System (279), Harvard University (248), Hospital Special Surgery (238), Ohio State University (170), Mayo Clinic (134), Rush University (130), Cleveland Clinic Foundation (122), La Trobe University (121), Boston Children's Hospital (116), University of Vermont (107), Karolinska Institutet (106), Sahlgrenska University Hospital (105), University of Delaware (105), University of Oslo (105), Brown University (104), University of Michigan (102), University of Michigan System (102), and Vanderbilt University (102).

Active Journals

The 9101 articles about ACL were published in 119 different journals. The top 54 journals publishing 20 or more articles about the topic, the total citation number received by journals and the mean citation number per article are presented in **Table 1**.

Citation Analysis

The top 25 articles with most citations according to total citation number among the 9101 articles published about ACL are presented in **Table 2**. The final column in **Table 2** gives the mean citation number per year for the articles.

Co-citation Analysis

A total of 57,115 studies were identified in the reference sections of all 9101 articles published about ACL. Among these studies, the 9 studies with most co-citations and more than 350 citations were Tegner Lysholm (19) (Number of citations (NC):649), Lysholm Gillquist (20) (NC:510), Hefti et al. (21) (NC:484), Yagi et al. (22) (NC:454), Daniel et al. (23) (NC:445), Irrgang et al. (24) (NC:405), Lohmander et al. (25) (NC: 399), Noyes et al. (26) (NC:359), and Loh et al. (27) (NC: 353).

Trend topics

All of the 9101 articles about ACL used 7738 different keywords. **Table 3** shows 100 different keywords used in at least 33 different articles from among these keywords. The cluster network visualization map showing the cluster analysis results for these keywords is shown in **Figure 4**. The trend network visualization map completed to identify trend topics is shown in **Figure 5** and the citation network visualization map completed to reveal the topics receiving most citations is shown in **Figure 6**.

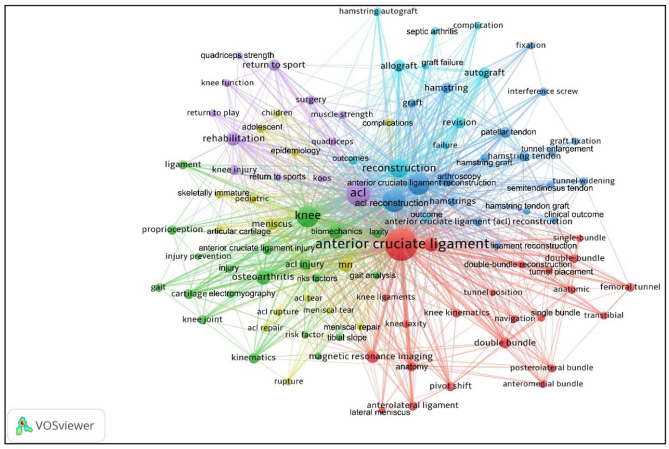

Figure 4. Network visualization map for cluster analysis based on keyword analysis performed to identify clustering of ACL topics from past to present. Footnote: The color of the circle represents the cluster. Keywords in the same cluster have the same color. The size of the circle indicates the number of uses of the keyword.

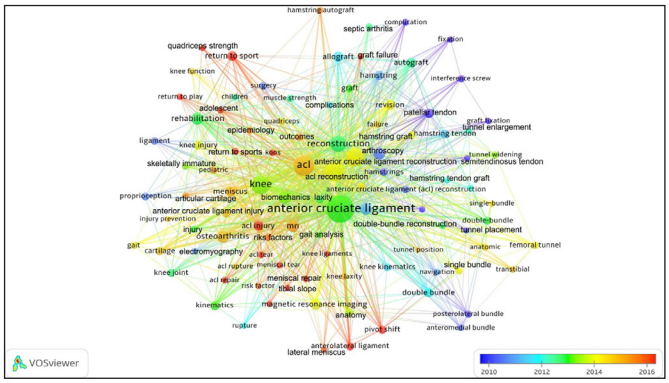

Figure 5. Network visualization map based on keyword analysis to identify past and current trends in ACL. Footnote: In the indicator given in the lower right corner of the figure, the topicality of the subject increases from blue to red (blue-green-yellow-red) over the years. The size of the circle indicates the number of uses of the keyword.

Table 1. The 54 most active journals that published more than 20 articles about anterior cruciate ligament (ACL)

Journals	NA	C	AC	Journals	NA	C	AC
American Journal of Sports Medicine	1614	108284	67.1	Journal of Pediatric Orthopaedics	51	1603	31.4
Knee Surgery Sports Traumatology Arthroscopy	1418	37836	26.7	Techniques in Orthopaedics	49	134	2.7
Arthroscopy: The Journal of Arthroscopic and Related Surgery	915	36671	40.1	Physician and Sports medicine	45	433	9.6
Knee	426	6478	15.2	Asia-Pacific Journal of Sport Medicine Arthroscopy Rehabilitation and Technology	43	108	2.5
Orthopaedic Journal of Sports Medicine	415	3482	8.4	Operative Techniques in Orthopaedics	43	417	9.7
Journal of Orthopaedic Research	357	14124	39.6	Orthopedic Clinics of North America	43	1611	37.5
Arthroscopy Techniques	235	1316	5.6	Journal of Orthopaedic Surgery and Research	42	230	5.5
Clinical Orthopaedics and Related Research	228	10871	47.7	European Journal of Orthopaedic Surgery and Traumatology	40	78	2.0
Archives of Orthopaedic and Trauma Surgery	217	3513	16.2	Journal of Orthopaedic Surgery	37	204	5.5
Journal of Bone and Joint Surgery (American Volume)	211	17030	80.7	Acta Orthopaedica et Traumatologica Turcica	36	319	8.9
Journal of Knee Surgery	185	1320	7.1	Muscles Ligaments and Tendons Journal	36	130	3.6
Arthroscopy	177	8100	45.8	International Journal of the Care of the Injured	30	491	16.4
Clinical Biomechanics	170	4566	26.9	Acta Chirurgiae Orthopaedicae et Traumatologiae Cechoslovaca	29	101	3.5
International Orthopaedics	156	3772	24.2	Journal of Experimental Orthopaedics	28	55	2.0
Orthopedics	135	2605	19.3	Journal of Orthopaedics	28	48	1.7
Journal of Orthopaedic & Sports Physical Therapy	129	6182	47.9	Acta Orthopaedica Belgica	27	252	9.3
Orthopaedics & Traumatology: Surgery & Research	100	1193	11.9	Clinics in Orthopedic Surgery	27	239	8.9
BMC Musculoskeletal Disorders	97	907	9.4	Physical Therapy	27	1960	72.6
Journal of Bone and Joint Surgery (British Volume)	97	6741	69.5	Current Reviews in Musculoskeletal Medicine	26	366	14.1
Osteoarthritis and Cartilage	90	3304	36.7	Current Orthopaedic Practice	25	40	1.6
Revue de Chirurgie Orthopedique et Reparatrice de l'Appareil Moteur	89	785	8.8	Journal of Orthopaedics and Traumatology	25	242	9.7
Clinical Journal of Sport Medicine	67	2697	40.3	Connective Tissue Research	24	326	13.6
Acta Orthopaedica Scandinavica	62	2071	33.4	Zeitschrift für Orthopädie und Unfallchirurgie	23	139	6.0
Gait & Posture	59	1172	19.9	Orthopade	22	182	8.3
Journal of Orthopaedic Science	54	822	15.2	Sportverletzung-Sportschaden	22	111	5.0
Indian Journal of Orthopaedics	54	250	4.6	Acta Ortopedica Brasileira	21	70	3.3
Skeletal Radiology	53	831	15.7	Bone & Joint Journal	20	449	22.5

NA: Number of articles, C: Number of citation, AC: Average citation per document

Table 2. The top 25 most cited articles about ACL by total number of citations

No	Article	Author	Journal	PY	TC	AC
1	Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes	Hewett TE. et al.	American Journal of Sports Medicine	2005	1899	105.5
2	Mechanisms of anterior cruciate ligament injury	Boden BP. et al.	Orthopedics	2000	923	40.13
3	Fate of the ACL-injured patient: A prospective outcome study	Daniel DM. et al.	American Journal of Sports Medicine	1994	912	31.45
4	Injury mechanisms for anterior cruciate ligament injuries in team handball a systematic video analysis	Olsen OE. et al.	American Journal of Sports Medicine	2004	760	40
5	Tensile properties of the human femur-anterior cruciate ligament-tibia complex: the effects of specimen age and orientation	Woo SLY. et al.	American Journal of Sports Medicine	1991	700	21.88
6	Accelerated rehabilitation after anterior cruciate ligament reconstruction	Shelbourne KD. and Nitz P.	American Journal of Sports Medicine	1990	697	21.12
7	Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport	Paterno MV. et al.	American Journal of Sports Medicine	2010	693	53.31
8	Biomechanical analysis of an anatomic anterior cruciate ligament reconstruction	Yagi M. et al.	American Journal of Sports Medicine	2002	657	31.29
9	Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up	Mandelbaum BR. et al.	American Journal of Sports Medicine	2005	655	36.39
10	Mechanisms of anterior cruciate ligament injury in basketball: video analysis of 39 cases	Krosshaug T. et al.	American Journal of Sports Medicine	2007	647	40.44
11	Combined knee loading states that generate high anterior cruciate ligament forces	Markolf KL. et al.	Journal of Orthopaedic Research	1995	629	22.46
12	Abnormal lower-limb symmetry determined by function hop tests after anterior cruciate ligament rupture	Noyes FR. et al.	American Journal of Sports Medicine	1991	585	18.28
13	The synergistic action of the anterior cruciate ligament and thigh muscles in maintaining joint stability	Solomonow M. et al.	American Journal of Sports Medicine	1987	547	15.19
14	Prevention of anterior cruciate ligament injuries in female team handball players: A prospective intervention study over three seasons	Myklebust G. et al.	Clinical Journal of Sport Medicine	2003	523	26.15
15	Knee stability and graft function following anterior cruciate ligament reconstruction: Comparison between 11 o'clock and 10 o'clock femoral tunnel placement	Loh JC. et al.	Arthroscopy: The Journal of Arthroscopic & Related Surgery	2003	494	24.7
16	Abnormal rotational knee motion during running after anterior cruciate ligament reconstruction	Tashman S. et al.	American Journal of Sports Medicine	2004	492	25.89
17	Incidence and trends of anterior cruciate ligament reconstruction in the United States	Mall NA. et al.	American Journal of Sports Medicine	2014	472	52.44
18	Arthroscopic anterior cruciate ligament reconstruction: A metaanalysis comparing patellar tendon and hamstring tendon autografts	Freedman KB. et al.	American Journal of Sports Medicine	2003	467	23.35
19	A biomechanical comparison of different surgical techniques of graft fixation in anterior cruciate ligament reconstruction	Kurosaka M. et al.	American Journal of Sports Medicine	1987	461	12.81
20	Patellofemoral problems after anterior cruciate ligament reconstruction	Sachs RA. et al.	American Journal of Sports Medicine	1989	458	13.47
21	Functional anatomy of the anterior cruciate ligament. Fibre bundle actions related to ligament replacements and injuries	Amis AA. and Dawkins GP.	Journal of Bone and Joint Surgery: British Volume	1991	451	14.09
22	Instrumented measurement of anterior knee laxity in patients with acute anterior cruciate ligament disruption	Daniel DM. et al.	American Journal of Sports Medicine	1985	450	11.84
23	Mechanisms for noncontact anterior cruciate ligament injuries: knee joint kinematics in 10 injury situations from female team handball and basketball	Koga H. et al.	American Journal of Sports Medicine	2010	440	33.85
24	Distribution of in situ forces in the anterior cruciate ligament in response to rotatory loads	Gabriel MT. et al.	Journal of Orthopaedic Research	2004	430	22.63
25	A 10-year comparison of anterior cruciate ligament reconstructions with hamstring tendon and patellar tendon autograft: a controlled, prospective trial	Pinczewski LA. et al.	American Journal of Sports Medicine	2007	429	26.81

PY: Publication year. TC: Total citation. AC: Average citations per year

Table 3. The 100 most frequently used keywords in articles about ACL

Keywords	Number of uses	Keywords	Number of uses	Keywords	Number of uses
anterior cruciate ligament	2522	outcomes	67	navigation	43
ACL	1037	double-bundle	66	return to play	43
ACL reconstruction	948	knee kinematics	66	ACL repair	42
Knee	824	anterior cruciate ligament (ACL) reconstruction	65	anteromedial bundle	42
anterior cruciate ligament reconstruction	820	hamstrings	65	complications	42
reconstruction	529	outcome	64	epidemiology	42
biomechanics	267	hamstring graft	62	failure	42
osteoarthritis	251	laxity	62	septic arthritis	42
anterior cruciate ligament (ACL)	243	ligament	61	single bundle	42
rehabilitation	230	risk factors	61	children	41
Arthroscopy	225	surgery	60	articular cartilage	40
MRI	205	gait	56	clinical outcome	40
magnetic resonance imaging	177	posterolateral bundle	55	tunnel enlargement	40
Meniscus	155	injury	54	ACL rupture	38
Allograft	145	tunnel widening	53	graft fixation	38
Revision	139	anatomic	51	rupture	38
return to sport	135	interference screw	51	risk factor	37
Autograft	125	muscle strength	51	fixation	36
ACL injury	123	pediatric	51	graft failure	36
Hamstring	123	KOOS	49	ligament reconstruction	36
patellar tendon	117	return to sports	49	tunnel placement	36
double bundle	110	double-bundle reconstruction	48	hamstring tendon graft	35
Kinematics	108	electromyography	48	meniscal tear	35
Anatomy	94	knee laxity	48	posterior tibial slope	35
anterior cruciate ligament injury	94	ACL tear	47	semitendinosus tendon	35
Cartilage	90	skeletally immature	47	lateral meniscus	34
hamstring tendon	86	gait analysis	46	quadriceps strength	34
knee injury	82	hamstring autograft	46	single-bundle	34
anterolateral ligament	79	adolescent	45	tibial slope	34
pivot shift	78	complication	45	injury prevention	33
proprioception	72	meniscal repair	44	knee ligaments	33
Graft	68	quadriceps	44	tunnel position	33
femoral tunnel	67	transtibial	44		
knee joint	67	knee function	43		

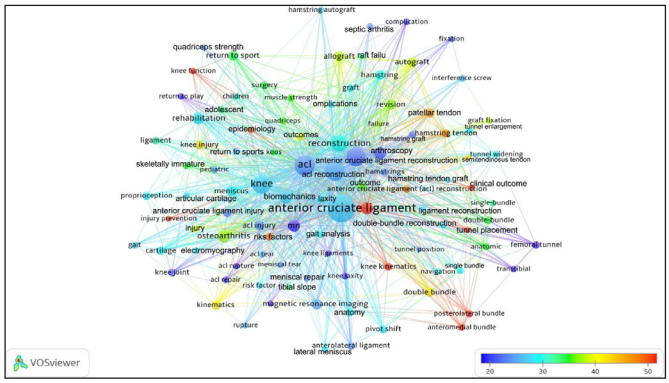

Figure 6. Network visualization map based on keyword analysis performed to identify the most cited topics about ACL. Footnote: In the indicator given in the lower right corner of the figure, the number of citations received by the topic increases from blue to red (blue-green-yellow-red). The size of the circle indicates the number of uses of the keyword.

DISCUSSION

When the article distribution about ACL between 1980 to 2021 is investigated, from 4-179 articles (mean 79 articles) were published from 1980 to 2004. From 2005-2014, from 226 to 394 articles were published (mean 302 articles). From 2015-2021, from 448-727 articles were published (mean 583 articles). The notable increasing trend beginning from 2010-2011 continued until 2021 and the number of articles published reached 727 in 2021. When prediction results for the next 5 years are assessed, it can be said the increasing trend for article numbers will continue.

When the publication distribution for global countries is investigated, 17 of the top 20 most active countries contributing to the literature for article productivity

about ACL were developed countries. Only 3 of the top 20 active countries (China, Brazil, Turkey) were developing countries, though all have large economies. There were high level positive correlations between the number of articles about ACL produced by countries with the GDP and HDI of the countries and a moderate statistically significant correlation with GDP per capita. When active countries are assessed along with development levels, article productivity in the literature about ACL is primarily affected by the economic size of countries and their development level.

When the density map created according to total collaboration between countries is assessed, the countries with highest collaboration were identified to be USA, Germany, England (in UK), Sweden, Australia, Italy, France, Canada, Japan, Switzerland, Netherlands, Norway, Austria and Brazil. When common author collaboration about ACL in countries is investigated, it appears that geographical adjacency affects international cooperation. Collaborations mainly occur between countries located in the same region (international collaboration clusters: (Croatia, France, Ireland), (Serbia, Switzerland), (Argentina, Brazil, Chile), (Italy, Portugal, Spain), (Canada, Denmark, Finland, Norway, Sweden), (Egypt, Greece, Kuwait, Qatar, Saudi Arabia, Turkey), (Japan, Malaysia, South Korea, Taiwan, Thailand), (Austria, Germany, Luxembourg, Netherlands, Poland), and (Belgium, Czech Republic, England (in UK), Scotland, Wales)).

We can recommend that authors who research and want to publish ACL should first pay attention to the top 14 journals in **Table 1** that publish the most articles on ACL. When citation analysis of the journals is assessed, the most effective journals according to mean citation numbers per article published were identified to be Journal of Bone and Joint Surgery (American Volume), Physical Therapy, Journal of Bone and Joint Surgery (British Volume), American Journal of Sports Medicine, Journal of Orthopaedic & Sports Physical Therapy, Clinical Orthopaedics and Related Research, Arthroscopy, Clinical Journal of Sport Medicine, Arthroscopy: The Journal of Arthroscopic and Related Surgery, Journal of Orthopaedic Research, Orthopedic Clinics of North America, Osteoarthritis and Cartilage, Acta Orthopaedica Scandinavica, Journal of Pediatric Orthopaedics and Acta Orthopaedica, in that order. Researchers who wish to publish studies receiving more citations are recommended to prioritize these journals.

When the analyzed articles are assessed according to total citation numbers, the study receiving most citations was identified as the study entitled "Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes" published by Hewett et al. (5) in the American Journal of Sports Medicine. The second most effective study was entitled "Mechanisms of anterior cruciate ligament injury", published by Boden et al. (28) in Orthopedics. The third most effective paper was published by Daniel et al. (23) in the American Journal of Sports Medicine entitled "Fate of the ACL-injured patient: A prospective outcome study". The fourth most effective study was published by Olsen et al. (29) in the American Journal of Sports Medicine entitled "Injury mechanisms for anterior cruciate ligament injuries in team handball a systematic video analysis". The fifth most effective study was entitled "Tensile properties of the human femur-anterior cruciate ligament-tibia complex: the effects of specimen age and orientation", published by Woo et al. (30) in the American Journal of Sports Medicine. When articles are assessed according to mean number of citations per year, the most effective study was the one by Hewett et al. (5). The second most effective study was by Paterno et al. (31) published in the American Journal of Sports Medicine and entitled "Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport" . The third, fourth and fifth most effective studies were by Mall et al. (3), Sanders et al. (32) and Paterno et al. (33) related to the incidence of ACL reconstruction . According to the co-citation numbers for all articles analyzed, the top articles were Tegner and Lysholm (19), Lysholm and Gillquist (20), Hefti et al. (21), Yagi et al. (22), Daniel et al. (23), Irrgang et al. (24), Lohmander et al. (25), Noyes et al. (26) and Loh et al. (27) We recommend that orthopedists interested in this topic firstly read these publications.

When analysis findings about keywords are assessed, the results of cluster analysis identified 6 clusters with different colors about ACL. The keywords receiving most citations were identified as knee kinematics, knee function, posterolateral bundle, anteromedial bundle, tunnel placement, clinical outcome, epidemiology, injury prevention, risk factors, anterior cruciate ligament (ACL) reconstruction, hamstring tendon, and patellar tendon. According to analysis results to identify trend topics, keywords studied in recent years were identified as return to sport, ACL injury, anterolateral ligament, pivot shift, quadriceps strength, KOOS, ACL tear, ACL repair, meniscal repair, knee ligaments, tibial slope, posterior tibial slope, return to play, adolescent, graft failure and lateral meniscus.

We did not encounter any bibliometric study as a result of literature screening about ACL. This comprehensive study is the first bibliometric research related to this topic, which is a strong point of this study. A limitation of the research is that only the WoS database was used for literature screening. Our reason for not choosing the

PubMed database is that citation and co-citation analyses cannot be performed in PubMed. The Scopus database was not chosen due to indexing journals with low impact factor. The WoS database indexes articles published in journals with higher impact factor compared to other databases (13-15).

CONCLUSION

This comprehensive bibliometric research about ACL, a topic with an increasing trend in article numbers in recent years, shares summary information about 9101 articles published from 1980-2021. The trend in the number of articles about ACL increasing every day will continue. Nearly half of the articles originated in the USA. According to analysis results to identify trend topics, the trend keywords studied in recent years were return to sport, ACL injury, anterolateral ligament, pivot shift, quadriceps strength, KOOS, ACL tear, ACL repair, meniscal repair, knee ligaments, tibial slope, posterior tibial slope, return to play, adolescent, graft failure and lateral meniscus. This article may provide better understanding about the historical literature about ACL for clinicians, scientist and surgeons and ideas for new studies to be designed by investigating research trends.

ETHICAL DECLARATIONS

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent: For this type of study formal consent is not required.

Referee Evaluation Process: Externally peer-reviewed.

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