Trends in Publications on the Anterior Cruciate Ligament Over the Past 40 Years on PubMed

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Background: The anterior cruciate ligament (ACL) is the most commonly operated ligament of the knee. Details on the top journals, universities, and authors on the topic would be helpful to identify the sources of information for clinical and research queries as well as to observe trends for future research and identify universities/authors of particular interest for training or to follow their research.

Purpose: To consolidate information from PubMed on the ACL from 1979 to 2018, spanning 40 years.

Study Design: Cross-sectional study.

Methods: A search of the PubMed database was conducted for the ACL, and 18,696 articles published over the past 40 years were analyzed for further details. These details included the number of publications per year, top 10 journals publishing on the ACL, top 10 first authors publishing articles on the ACL, and number of articles published with specific keywords. Data were also sought from the Scopus database regarding the top universities and countries publishing on the ACL. The coauthorship of articles and co-occurrence of terms in titles were also analyzed using VOSviewer.

Results: There was a steady increase in the yearly average number of publications from 1979 to 2018. The top journal and top author publishing on the ACL were *The American Journal of Sports Medicine* and Freddie H. Fu, respectively. The most articles published by a first author were by K. Donald Shelbourne. Time-based links of Dr Fu to other authors were represented as VOSviewer output. Most occurrences of specific keywords in the title were also studied and listed. The United States was the most published country, and 8 of the top 10 universities that published were from this country.

Conclusion: There has been a steady increase in the number of articles published in PubMed since 1979. It appears that interest on the topic of the ACL has not decreased or stabilized but rather increased significantly over the past few years. This article quantifies the increased interest and could act as a baseline for future studies to compare.

Keywords: anterior cruciate ligament; ACL; publication; PubMed; database search; data mining; knee

PubMed (www.ncbi.nlm.nih.gov/pubmed) was started in 1996 as an experimental database by the National Center for Biotechnology Information (NCBI) at the National Library of Medicine, US National Institutes of Health, and was officially made free via MEDLINE access by June 1997. Literature searches before this included searches through Index Medicus, which was a quarterly publication. What used to be a quarterly update of literature in Index Medicus has been converted to almost daily updating with the inception of PubMed.

The anterior cruciate ligament (ACL) is the most commonly studied ligament in the knee. Publications on this topic run into the thousands, and yet, there is no study that has looked into the literature from PubMed to provide an overall picture on the trends of publications on this topic. It is often confusing for the beginner to find good sources of information on the ACL. In this study, results on the ACL...
from PubMed using a search strategy were analyzed to find journal publication details about the topic in the literature. This study aimed to consolidate knowledge in PubMed from 1979 to 2018, spanning 40 years.

METHODS

The following search strategy was used: terms used to search in PubMed were “anterior cruciate ligament”[MeSH] OR “anterior cruciate ligament injuries”[MeSH] OR “(ACL AND knee)”. The search resulted in a total of 19,060 articles from 1948 to 2019. Only completed years were included, and hence, articles from 2019 (n = 231) were excluded. This resulted in 18,829 articles. Further, articles before 1979 were excluded, including only those published in the past 40 years. There were only 133 articles published before 1979. This resulted in 18,696 articles. These articles were included for analysis.

All types of studies were included: human and animal studies including experiments, case reports, and meta-analyses. No filters were used, as all types of articles were sought in all languages on this topic.

In comparison with other databases, the search term “anterior cruciate ligament” resulted in a total of 43,100 articles from Semantic Scholar, 13,652 articles from Web of Science, 32,624 articles from EBSCO databases (consisting of CINAHL Plus with Full Text; MEDLINE with Full Text; PsycINFO; Psychology and Behavioral Sciences Collection; Health Business Elite; Biomedical Reference Collection: Comprehensive Edition; Library, Information Science and Technology Abstracts; and eBook Collection [EBSCOhost]), and 26,686 articles from Scopus. The Scopus database was queried to obtain the top 10 countries and universities publishing on this topic as well as the top 10 cited articles on the ACL.

Excel (Office 365 for Mac; Microsoft) was used to create a database, and demographics and data generated from PubMed were loaded and analyzed using this software. VOSviewer11 software (version 1.6.10 8; Leiden University) was used to study coauthorship and the co-occurrence of terms.

RESULTS

Figure 1 shows the yearly distribution of publications. The average number of published articles per year was 467. The average year-by-year increase in the number of publications was 34.72. The study period was also divided into publications before 1996 (before the start of PubMed) and 1996 and after. The yearly average number of published articles was 80.5 before 1996 and 731.8 from 1996 onward, and the yearly incremental increase in publications was 7 before 1996 and 51 from 1996 onward. Thus, there has been a substantial increase in the number of articles published since the inception of PubMed. Since 1979, nine years had negative increment values.

Of the 18,696 ACL publications in PubMed during the past 40 years, 26 articles were published in 1979, compared with 1380 articles published in the year 2018 alone.

Journals

Figure 2 shows the top 10 journals publishing on the ACL. A total of 1,112 journals have published on the given search terms from 1979 to 2018. Of these, 28 journals belong to veterinary sciences (includes the term “vet” in the journal title), which have published 545 articles on the ACL. Of these veterinary articles, 317 were about cranial cruciate ligament injuries. Studies on animals were included because basic science studies of the ACL are conducted on animals. The American Journal of Sports Medicine was the leading publisher on this topic, with 1960 articles published from 1979 to 2018. The top 5 journals published 34%, while the top 3 journals (The American Journal of Sports Medicine; Knee Surgery, Sports Traumatology, Arthroscopy; and Arthroscopy) published 29% of all articles on the ACL in the study period.
Authors

There were a total of 41,936 unique authors, of whom 507 wrote more than 15 publications, 986 wrote more than 10 publications, and 2822 wrote more than 5 publications. Among the first authors as listed on studies, 31 authors wrote ≥20 publications, 61 wrote ≥15 publications, 145 wrote ≥10 articles, and 624 wrote ≥5 articles. Thirty-four articles did not have any authors listed; COR4. Author Freddie H. Fu has published the most number with 378 articles, which is 2% of all articles published on this topic.

Figure 3 shows the top 10 authors with the most publications when listed as the first author, as well as the number of publications when they are listed as one of the authors from 1979 to 2018. Figure 4 shows the top 10 authors reporting on the ACL from 1979 to 2018 (regardless of author order).

Figure 5 shows output from VOSviewer for all authors. Figure 6 shows an example of links to Dr Fu, author who published the most number of articles on the ACL.

Most Cited/Important Articles

Table 1 lists the titles of the top 10 most cited articles from Scopus for the ACL.

Keywords

Figure 7 shows the frequently occurring keywords related to the ACL from 2000 to 2015. While terms including animals and enzyme fatty acids related to basic sciences appear prominent toward 2000, terms such as “plyometrics,” “physical education,” “kinematics,” “fluoroscopy,” “registries,” and “return to play” figure more prominently toward 2015.

A clinically relevant keyword search was conducted from the titles of all articles on the ACL, and the results are presented in Table 2. The terms included types of grafts used, complications, types of procedures (eg, double-bundle reconstruction/repair of ACL), and types of studies performed.

Language

Figure 8 shows the top 10 languages of publications in PubMed. English was the predominant language, followed by German, Chinese, French, and Italian. The total number of articles for this group was 18,784 on PubMed from 1979 to 2018.

Timeline Trends of ACL Techniques and Types of Studies

Figure 9 shows the type of grafts used for ACL reconstruction found by analyzing article titles. While the patellar tendon was more popular in the early 1990s, the hamstring tendon appeared more frequently starting in the late 1990s and steadily increased, with more than 75 articles from 2017 to 2018. The patellar tendon plateaued at between 20 and 40 articles in the 1990s. Double-bundle reconstruction had an interesting timeline, with a rapid increase in publications from 2005 to a peak of 60 per year in 2011; that trend has been decreasing, with only 25 publications in 2018. The anterolateral ligament started appearing in 2013 with 2 publications, increasing to 57 in 2017 and 41 in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018. Allografts have seen a slow and steady increase, starting at 1 article in 1985 to 11 in 1996; it witnessed a dip in 2018.
Figure 5. VOSviewer output for all authors. The more prominent and more significant the author, the bigger the circle; and the more frequent the occurrence of the name, the greater number of publications. Color coding indicates that the publications were more frequent around 2010 and between 2010 and 2015, and color coding of the linked author indicates the predominant year of the link.

Figure 6. VOSviewer output for Fu FH with links to other authors.
with 85 in 2018. Studies of high quality (with higher levels of evidence), including systematic reviews, meta-analyses, and randomized studies, showed an increasing trend in the past 5 years. Randomized controlled trials started appearing in the literature starting in 1985 and ending with 39 studies published in 2018. However, meta-analyses and systematic reviews first appeared in the literature in 2002 and 2001, respectively, and have shown an increasing trend since. Case reports have plateaued at 10 to 15 a year since 2001.

**DISCUSSION**

PubMed is an excellent resource for information on research undertaken in the past in medicine, and with the advent of data mining tools, current and future research trends can be mined from the available data. Until 2014, PubMed used to be updated 5 times a week. However, since June 2014, updating is being done daily. It is freely available to all. It has helped speed up literature searches and publications from a few weeks/months to a few days in some cases. The problem of literature searches also has been simplified, as such searches were previously conducted in the library of an institution that had access to Index Medicus for all years; thus, there were limitations on space and time for conducting literature searches. Currently, searches can be conducted on PubMed and other databases even outside working hours, in the comfort of our homes, in a few seconds with an internet connection. There have also been technological advances in the process of

**TABLE 1**

| Article                                                                 | No. of Citations |
|------------------------------------------------------------------------|------------------|
| Knee Injury and Osteoarthritis Outcome Score (KOOS): Development of a Self-administered Outcome Measure | 1486             |
| Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes: A Prospective Study | 1373             |
| Two- to 9-Year Outcome After Autologous Chondrocyte Transplantation of the Knee | 1098             |
| The Long-term Consequence of Anterior Cruciate Ligament and Meniscus Injuries: Osteoarthritis | 1070             |
| The Cruciate Ligaments of the Knee Joint: Anatomical, Functional and Experimental Analysis | 1050             |
| Knee Injury Patterns Among Men and Women in Collegiate Basketball and Soccer: NCAA Data and Review of Literature | 1047             |
| Biomechanical Analysis of Human Ligament Grafts Used in Knee-Ligament Repairs and Reconstructions | 1012             |
| Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives | 959              |
| Fate of the ACL-Injured Patient: A Prospective Outcome Study | 881              |
| Accelerated Rehabilitation After Anterior Cruciate Ligament Reconstruction | 847              |

**Figure 7.** Most frequently occurring keywords related to the anterior cruciate ligament (ACL) in PubMed.
submitting articles to journals and reviewing, editing, and publishing that have sped up the publication process multifold; hence the proliferation of the number of journals to take the increased load of reporting.

The number of publications on the ACL has been increasing, especially since PubMed was introduced. This number was about 26 in 1979, increasing to more than 500 per year by 2005 and crossing 1000 per year by 2015. It took almost 60 years from 1948 to cross 500 per year but only 10 years (2005–2015) to increase from 500 to 1000 publications per year. In the past 10 years alone (2009–2018), 10,070 articles were published, constituting 54% of the total number of articles published on the topic.

Although there were publications before 1979, these were not included in this study, as in most of the years, the number of publications was less than 10 per year, and there were some years without any publications (the average from 1948 to 1978 was 5.54 per year). The first publication on the ACL was in 1948.

Table 2

| Keyword                                      | n (%) | Keyword                                      | n (%) |
|----------------------------------------------|-------|----------------------------------------------|-------|
| Reconstruction                               | 6595  | Pivot shift                                  | 81    |
| Arthroscop(y/ic)                             | 1191  | Ganglion                                     | 69    |
| Hamstrings                                   | 955   | Posterolateral corner/PLC                    | 68    |
| Patellar tendon                              | 788   | Double bundle                                | 64    |
| Review (all types)                           | 618   | PCL                                          | 62    |
| Repair                                       | 578   | Infection                                    | 61    |
| Athle(t/e/ic/ics)                            | 548   | Randomised                                   | 50    |
| Kinematic                                     | 499   | Congenital & absen(t/ce)                     | 49    |
| Allograft                                     | 447   | Return to play                               | 42    |
| Quadriceps                                   | 386   | Cyclops                                      | 41    |
| Randomized studies (includes prospective + RCTs) | 353   | Multiligament/multi-ligament                  | 41    |
| Systematic review                            | 348   | Mucoid degeneration                          | 36    |
| Revision                                      | 290   | Segond                                       | 42    |
| Interference                                 | 289   | Registry/registries (32/8)                   | 40    |
| Case report                                  | 241   | Case series                                  | 29    |
| Risk factor                                  | 185   | Accelerated                                  | 22    |
| Complication                                 | 163   | Notchplasty                                  | 21    |
| Meta-analysis                                | 161   | BPTB                                         | 20    |
| Anterolateral ligament                       | 148   | PRP/platelet rich plasma                     | 18    |
| Dislocation                                  | 139   | BTB                                          | 10    |
| RCT/(randomised/randomized) controlled trial  | 122   | Plyometric                                   | 7     |
| Paediatric/pediatric                         | 104   | Day case                                     | 5     |

*Keywords from titles of articles: BPTB, bone–patellar tendon–bone; BTB, bone–patellar tendon–bone; PCL, posterior cruciate ligament; PLC, posterolateral corner; PRP, platelet-rich plasma; RCT, randomized controlled trial.*

Figure 8. Top 10 languages for anterior cruciate ligament (ACL) publications.

Figure 9. Graft types used in anterior cruciate ligament reconstruction (ACLR) over the past 40 years, based on analysis of article titles. ALL, anterolateral ligament.
Although there have been a large number of articles on the topic of the ACL published since 1979, mining the data on the ACL in PubMed produced useful information about good sources of publications on this topic, including authors/journals that could be followed. The strength of their association with other authors could potentially indicate coworkers, common research interests, and collaborative studies. The increasing number of publications in recent years indicates continually increased interest on this topic.

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