Pathogenesis and Treatment of the Anterior Cruciate Ligament Injury in Athletes: A Systematic Review

Ebrahim Piri [a], Amir Ali Jafarnezhadgero [a]*, Yaghoub Panahi [a]

a Department of Sports Biomechanics, Faculty of Educational Sciences and Psychology, University of Mohaghegh Ardabili, Ardabil, Iran

* ***Corresponding author***: Amir Ali Jafarnezhadgero, Department of Sports Biomechanics, Faculty of Educational Sciences and Psychology, University of Mohaghegh Ardabili, Ardabil, Iran. ***E-mail***: amiralijafarnezhad@gmail.com

Submitted: 2023-04-11; **Accepted**: 2023-06-08; **Doi:** https: doi.org.10.22037.jcpr.v8i3.46084

Abstract

Introduction: Anterior cruciate ligament (ACL) tears are a common sports injury, the incidence of which is increasing due to the population's increased participation in sports activities. ACL tears can lead to serious knee complications, including cartilage damage, meniscus tears, and osteoarthritis. This systematic review aimed to examine the pathogenesis and treatment of ACL injuris in athletes. **Materials and Methods:** Five electronic databases, Medline, Scopus, PubMed, Embase, and Cochrane, were comprehensively searched to identify published articles from January 1994 to October 2024 related to treatments of ACL rupture. According to the PICOS, the eligibility criteria were: *1*) The samples were athletes who experienced ACL injury and 2) Studies were published in English language. The modified version of the Downs and Black checklist was used to assess the methodological quality of the included articles. **Results:** Findings demonstrated that the rate of ACL injury for basketball and handball players ranged from 4.1 to 5. Furthermore, the rates for soccer players are slightly lower, ranging from 2.3 to 2.5. Alpine skiing in high school has an injury rate of 3.1. In contrast, lacrosse, ice hockey, and Military training have rates of 1.4, 2.0, and 2.7 respectively. **Conclusions:** Based on findings it can be conclude that basketball and handball players have higher rates of ACL injuries, especially at the collegiate level.

Keywords: Anterior Cruciate Ligament; Injury; Pathogenesis; Treatment

***Please cite this paper as*:** Piri E, Jafarnezhadgero AA, Panahi Y. Pathogenesis and Treatment of the Anterior Cruciate Ligament Injury in Athletes: A Systematic Review. J Clin Physio Res. 2023; 8(3): e91. Doi: *https:.doi.org.10.22037.jcpr.v8i3.46084*

Introduction

Anterior cruciate ligament (ACL) is a key structure inside the knee joint connecting the femur and tibia. Statistics show that ACL injury reaches 200,000 people in the United States annually, with this number increasing each year (1). Among the factors that contribute to the stability of the knee joint during activities that involve rapid changes in direction, jumping, and rotation, the ACL plays a critical role (2). Moreover, the ACL contributes to knee rotational stability in both frontal and transverse planes due to its specific orientation (3). The ACL has been the focus of many biomechanical/anatomical studies and is among the most frequently studied structures of the human musculoskeletal system over the past decades (4). Injuries related to the ACL are one of the most common and devastating sports related knee injuries participation (5). These injuries can cause joint effusion, altered motion, muscle weakness, and decreased functional performance, potentially resulting in a missed season for athletes, especially young athletes (5). ACL injuries are also associated with long-term clinical squeal that include meniscal tears, choral lesions, and an increased risk of early onset post-traumatic osteoarthritis (OA) (6). For a long time, the ACL was thought to have a poor healing capacity and a very high failure rate (40% to 100%) even after surgical repair using sutures. (7). The unsatisfactory outcomes of the ACL primary repair have led to the unanimous abandonment of suture repair and widespread adoption of ACL reconstruction. ACL reconstruction has remained the gold standard of care for ACL injuries, especially for young athletes who aim to return to high-level sporting activities (8). However, current surgical treatment of ACL injury is costly, with different outcomes, and is associated with a high risk of post-traumatic OA within two decades of injury (9). While few athletes are able to resume sports at the same level without surgery (5), surgical reconstruction is also not always successful at returning patients to their pre injury activity level (10). Furthermore, those athletes who successfully return to their professional sport are at high risk of a second knee injury (11), with notably less favorable outcomes (11).

Studies have consistently shown that female athletes are at a higher risk of ACL injury than male athletes, with a 1.5 times increased incidence and a 1.7times increased incidence of ACL injury compared to male athletes (12). Many external and internal factors may lead to ACL injuries. At present, ACL injury treatments are mainly divided into surgical treatments and non-surgical treatments. Non-surgical treatments, on the other hand, focus on rehabilitation through physical therapy, bracing, and neuromuscular training. These methods aim to strengthen the surrounding muscles, improve proprioception, and enhance joint stability, which can help athletes return to activity without invasive procedures. Non-surgical interventions are often recommended for individuals with partial tears, minimal instability, or those who do not engage in high-impact sports. Surgical treatment offers several advantages, including rapid postoperative recovery, reduced trauma, and fewer complications. However, it can only restore the anatomical structure, leaving some deficiencies (13), This systematic review aimed to examine the treatment of ACL injury in athletes.

Materials and Methods

The present study is a systematic review study that used PRISMA (Preferred Reporting Items for Systematic Reviews) guidelines in its writing process(14).

Eligibility criteria

According to the PICOS approach, the eligibility criteria were: (1) the samples of respondents consisted of were athletes; (2) athletes who experienced anterior cruciate ligament ACL injury and; (32) studies were written published in the English language.(15) (Table 1).

Databases and Search strategy

The following five databases were systematically searched from January 1994 to October 2024: MEDLINE, Scopus, PubMed, EMBASE, as well as the Cochrane Central Register of Controlled Trials (CENTRAL). The reference lists of published reviews and the identified studies were screened to find further potentially relevant papers.

The search syntax was created using the PICOS scheme and free-text keywords as well as medical subject headings (MeSH terms). Searched keywords were included in Table 2.

Searches were repeated using the keywords as MeSH terms as well. The search algorithm was intentionally general to maximize return. In addition to the online searches, the bibliographies of the included studies were reviewed to identify additional publications too. However, Articles related to injury epidemiology, mechanism, and surgical reconstruction were included as primary published works, as well as articles published after 1994. Duplicate articles were excluded. All in vivo and in vitro studies that focused on ACL repair following injury, not reconstruction, were considered. All titles resulting from the search criteria were reviewed and those that clearly referred to a topics other than the focus of the current review were excluded. All case reports and expert opinions were excluded too. Abstracts were also reviewed to confirm eligibility of the study. Finally, the full texts of eligible seven studies were included for final review.

Study selection

All titles and abstracts were reviewed by all authors of this study to identify potentially eligible studies according to the priori-defined inclusion and exclusion criteria. In case titles and abstracts did not provide sufficient information, full texts were examined. Any difference in the rating of the authors was resolved through discussion with a reviewer (SHM).

Quality Assessment of Included Articles

The methodological quality of the included studies was evaluated by the same author suing a modified version of the Downs and Black checklist for non-randomized controlled trials (16) (Table 3). The modified checklist includes 19 questions with eight reporting items (items 1, 2, 3, 4, 5, 6, 7, 10), two items for external validity (items 11 and 12), five items for internal validity (Bias) (items 14, 15, 16, 18, 20), three items for internal validity-confounding (items 21, 22, 25), and one item for power (item 27). The items were scored as 0 (“no” and “unable to determine”), and 1 (“yes”), except for item 5 for the principal confounders which was scored 0 (“no”), 1 (“partially”), 2 (“yes”). The overall quality score of each study was calculated based on a percentage of the maximum score (20). In cases where there were discrepancies in the authors’ rating of the quality scores, consensus was reached through discussion. Studies with quality scores of 75% or higher were considered as high quality studies, those with scores between 60% and 74% were considered as moderate quality, and those with scores of 60% or lower were categorized as low quality studies (17).

Data collection

One author (E.P.) extracted all relevant data according to the PICOS approach (population, study protocol, intervention, study design, and outcomes related) from the included articles. To reduce any errors in the extraction of data, all data were checked by the author (A.J.).

Table 1. Participants, intervention, comparators, outcomes, and study design (PICOS) framework for study inclusion and exclusion criteria

Category	Inclusion	Exclusion
Participants	Individuals aged ≥20 years with ACL injuries	Individuals aged <20 years
Intervention	Not applicable	Not applicable
Comparator	Healthy adults	Healthy children or older adults
Outcome	Lower limbs kinematics and kinetics during transitional movements	Measures of lower limbs kinematics and kinetics during activities other than transitional movements (e.g., pedaling)
Study design	Case-control studies, case series, cohort studies, cross-sectional studies	All types of review studies (e.g., systematic reviews)

ACL, Anterior Cruciate Ligament

Table 2. Keywords used for the search (all databases).

	Search terms with Boolean operators AND, OR
1	Anterior Cruciate Ligament or Injury, ACL or Injury, Anterior Cruciate Ligament or Healing, ACL or Healing, Anterior Cruciate Ligament or Repair, ACL or Repair
	AND
2	Military training, Ice hockey, Lacrosse Handball, Alpine skiing, Soccer, Basketball

Table 3. Evaluation of the quality of the included articles by Downs and Black checklist.

Score of Black and Down	Included articles										
	Renstrom et al (18)	Arendt et al (19, 20)	Messina et al (21)	Renstrom et al (18)	Arendt et al (20)	Lindenfeld et al(22)	Stevenson et al (23)	Myklebust et al (24)	Renstrom et al (18)	Renstrom et al (18)	Gwinn et al (25)
1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	0	0	0	1	0	0
6	1	1	1	1	1	1	1	1	1	1	1
7	**1**	**0**	**1**	**0**	**0**	0	1	1	1	1	1
8	0	0	0	0	1	1	1	1	1	0	1
9	0	0	1	0	1	0	0	0	0	0	0
10	1	1	1	1	1	1	1	1	1	1	1
11	**1**	**1**	**1**	**1**	**1**	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	0	0	0	0	0
14	1	1	1	1	1	1	0	0	1	0	0
15	1	1	1	1	0	1	0	1	1	0	0
16	1	1	1	1	1	1	0	1	1	1	1
17	1	1	1	1	1	1	0	1	0	0	0
18	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1
21	0	0	1	1	1	0	0	0	1	1	1
22	1	1	1	1	1	1	1	0	1	1	1
23	1	1	1	1	1	1	1	1	0	0	0
24	0	0	1	0	1	0	1	1	0	0	0
25	1	0	1	1	1	0	0	0	1	0	0
26	0	0	0	0	0	0	0	0	0	0	0
27	4	3	5	4	5	4	2	3	4	2	3

Table 4. Gender-specific rates of ACL injury based on type of sports.

Authors	Sports	Level of competition	The rate of ACL injury (female/male)
Renstrom et al(18)	Basketball	Collegiate	3.3
Arendt et al(19, 20)	Basketball	Collegiate	4.1
Messina et al(21)	Basketball	High school	3.0
Renstrom et al(18)	Soccer	Collegiate	2.5
Arendt et al(20)	Soccer	Collegiate	2.3
Lindenfeld et al(22)	Soccer	Youth	3.0
Stevenson et al (23)	Alpine skiing	High school	3.1
Myklebust et al(24)	Handball	-	5.0
Renstrom et al(18)	Lacrosse	Collegiate	1.4
Renstrom et al(18)	Ice hockey	Collegiate	2.0
Gwinn et al(25)	Military training	Collegiate	2.7

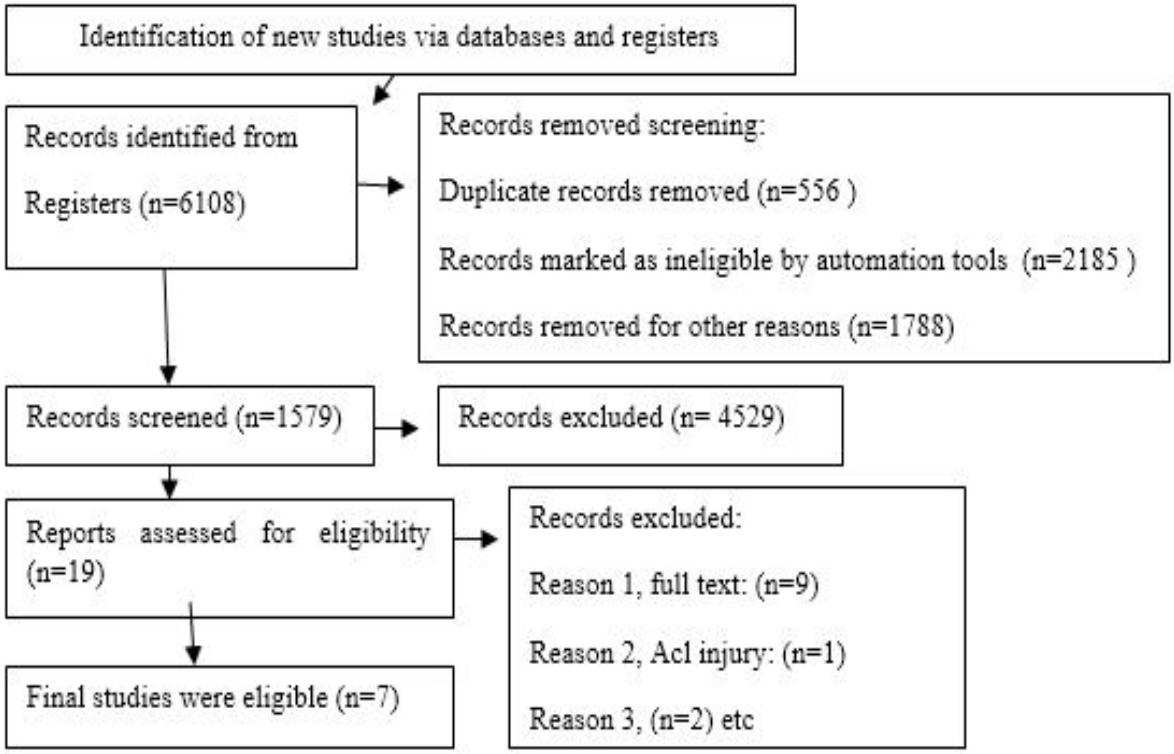

Figure 1. PRISMA 2020 flow diagram template for systematic reviews. The new design is adapted from flow diagrams proposed by Boers(26), Mayo-Wilson et al(27). and Stovold et al(28).

Results

The initial search identified 6,108 studies. After removing duplicate articles, 1,579 studies remained. Following the screening of titles and abstracts, 19 full texts were further considered. Finally, 7 studies were eligible to be included in this systematic review (18-25).The results of this review are shown in Table 4 and Figure 1.

ACL injuries based on different sports

A review of studies has shown significant differences in ACL injuries across sports. College basketball players face injury rates of 3.3 to 4.1, indicating significant vulnerability at the collegiate level. Meanwhile, football is slightly lower, with rates of 2.3 to 2.5 for college athletes and 3.0 for youth players, indicating risk among younger athletes. . Alpine skiing at the high school level shows a substantial injury rate of 3.1 due to

the sport's physical demands. Handball stands out with the highest reported injury rate at 5.0, indicating a significant risk during play. In contrast, lacrosse and ice hockey exhibit lower rates of 1.4 and 2.0, respectively. Notably, military training has an injury rate of 2.7, which could be due to the intense physical demands of personnel and the need for effective injury prevention and management strategies in dealing with high-risk environments (18-25).

Discussion

The differences in rates of ACL injury across various sports can be attributed to several factors, including the nature of the involved movements, the level of competition, the physical characteristics of the athletes, and the specific demands of each sports. The high rates of injury was related to basketball and handball with the rates of 3.3 to 4.1 and 5.0 respectively. These rates can be attributed to explosive movements and the need for agility, which increase the risk of ACL injuries during sudden stops or pivots natures of these sports (18, 24).The rates of injury for collegiate soccer players was 2.3 to 2.5 and for youth players was 3.0 which indicating a moderate risk level of ACL injury (18, 20, 22).The injury rate of 3.1 in high school alpine skiing is notable due to the high speeds and the need for precise control while navigating downhill. The combination of speed and the potential for falls contributes to the risk of ACL injuries (23). Lacrosse and ice hockey these sports have lower rates of injuris (1.4 and 2.0, respectively) likely because they involve less frequent rapid changes in direction and jumping compared to basketball and handball sports (18).

Due to increased intensity in training and competition at the collegiate level compared to youth or high school levels the rates of ACL injury tend to be higher. For instance, the rate of collegiate basketball injury reflects the higher stakes and more rigorous physical demands placed on athletes(29).The inherent characteristics of each sport play a crucial role in the risk of injury. For example, military training has the highest rate of reported injury at 2.7, reflecting the extreme physical demands and rigorous training regimens that participants endure. The intensity and variety of physical challenges faced during military training can lead to a higher incidence of ACL injuries(30).

Rick of the ACL Injury

Anatomical factors and ACL injury epidemiology

As one of the two main types of ligaments within the knee joint, the ACL can provide rotational and translational stability to the knee (31, 32). The high risk of injury along with the high rate of sports participation among women over the last three decades has led to a rapid rise in ACL injuries in females. ACL injuries are commonly associated with other joint injuries, especially meniscus injuries, and may lead to an 80% increased risk of early onset osteoarthritis after ten to fifteen years (33). In addition to pain, instability, and associated long-term squeal, ACL injury may affect the athletes' quality of life economically as well as socially (33). Moreover, patients who have suffered an ACL injury face long-term consequences that include lowered activity levels, high risk of injury, and long-term disability due to post-traumatic OA (33).

Q angle

The Quadriceps or Q-angle is an index of the vector for the combined pull of the extensor mechanisms and the patellar tendon (34). Athletes that suffer or have suffered from ACL injuries always have a quite larger Q angle than the athletes who do not have ACL injuries(35).The Q-angle measurement is widely used as an indicator of patella femoral dysfunction, including patella femoral pain syndrome (PFPS) and patella instability (36).

High Posterior Tibial inclination (PTS)

PTS is also a risk factor. In knees with ACL loss, tibial anterior displacement increased by 6 mm when PTS increased a 10°. Retrospective analysis shows that compared with the ACL-intact group, in the ACL-deficient group, the medial posterior tibial slope(MPTS) and lateral posterior tibial slope(LPTS) were significantly higher at 25%,50%, and75% (37). A systematic review study confirmed that increasing the PTS was related to the increased the risk of ACL transplant failure after reconstruction (38).The increase of PTSA is sometimes associated with the ACL degradation too.

The treatment of ACL injury

With the development of the arthroscopic surgery techniques, most of the patients would be likely to choose the surgical treatment, especially the people who are young and active. The surgical treatment has several advantages the post-operative recovery is fast, less traumatic, and has fewer complications (39).The most prevailing operative method of ACL injury is reconstructive surgery. The American Academy of Orthopedic Surgeons' 2016 guidelines for ACL injury management suggest arthroscopic reconstructive surgery for the vast majority of patients with ACL injuries (40). Reconstruction involves using grafts to create a new ligament. The success of the reconstruction can be influenced by factors such as ;timing of the surgery, ROM before surgery, the amount of swelling, and

the strength of the quadriceps(41). Although the reconstructed ACL cannot be completely restored to the original anatomical structure of the ACL, the grafts used for reconstruction must have characteristics that closely resemble the original ligament and also have minimal antigenic and biological properties (42).The limitation of this study is that it only examines the ACL injury of athletes and limited types of sports.

Conclusion

Based on the findings it can be suggested that basketball and handball have may higher rates of ACL injuries, especially at the collegiate level. It seems the differences in rates of ACL injury across various sports can be attributed to several factors, including the nature of the involved movements, the level of competition, the physical characteristics of the athletes, and the specific demands of each sports.

Acknowledgment
None

Ethical consideration
None.

Funding support
None.

Conflict of interest
None.

Authors' contributions
EP and YP: Supervision, data duration, formal analysis, investigation, and methodology, writing, original draft. AAJ: supervision, resources, and writing, original draft. All authors read and approved the final manuscript.

References

1. Rodríguez-Merchán EC. Anterior cruciate ligament reconstruction: is biological augmentation beneficial? International Journal of Molecular Sciences. 2021;22(22):12566.
2. Kiapour AM, Wordeman SC, Paterno MV, Quatman CE, Levine JW, Goel VK, et al. Diagnostic value of knee arthrometry in the prediction of anterior cruciate ligament strain during landing. The American journal of sports medicine. 2014;42(2):312-9.
3. Quatman CE, Kiapour AM, Demetropoulos CK, Kiapour A, Wordeman SC, Levine JW, et al. Preferential loading of the ACL compared with the MCL during landing: a novel in sim approach yields the multiplanar mechanism of dynamic valgus during ACL injuries. The American journal of sports medicine. 2014;42(1):177-86.
4. Kiapour A, Murray M. Basic science of anterior cruciate ligament injury and repair. Bone & joint research. 2014;3(2):20-31.
5. Hewett TE, Di Stasi SL, Myer GD. Current concepts for injury prevention in athletes after anterior cruciate ligament reconstruction. The American journal of sports medicine. 2013;41(1):216-24.
6. Chu CR, Beynnon BD, Buckwalter JA, Garrett Jr WE, Katz JN, Rodeo SA, et al. Closing the Gap Between Bench and Bedside Research for Early Arthritis Therapies (EARTH) Report From the AOSSM/NIH U-13 Post–Joint Injury Osteoarthritis Conference II. The American journal of sports medicine. 2011;39(7):1569-78.
7. Strand T, Mølster A, Hordvik M, Krukhaug Y. Long-term follow-up after primary repair of the anterior cruciate ligament: clinical and radiological evaluation 15–23 years postoperatively. Archives of orthopaedic and trauma surgery. 2005;125:217-21.
8. Musahl V, Becker R, Fu FH, Karlsson J. New trends in ACL research. Springer; 2011. p. 1-3.
9. Murray JR, Lindh AM, Hogan NA, Trezies AJ, Hutchinson JW, Parish E, et al. Does anterior cruciate ligament reconstruction lead to degenerative Disease? Thirteen-Year results after bone–patellar tendon–bone autograft. The American journal of sports medicine. 2012;40(2):404-13.
10. Ardern CL, Webster KE, Taylor NF, Feller JA. Return to the preinjury level of competitive sport after anterior cruciate ligament reconstruction surgery: two-thirds of patients have not returned by 12 months after surgery. The American journal of sports medicine. 2011;39(3):538-43.
11. Shelbourne KD, Gray T, Haro M. Incidence of subsequent injury to either knee within 5 years after anterior cruciate ligament reconstruction with patellar tendon autograft. The American journal of sports medicine. 2009;37(2):246-51.
12. Montalvo AM, Schneider DK, Yut L, Webster KE, Beynnon B, Kocher MS, et al. "What's my risk of sustaining an ACL injury while playing sports?" A systematic review with meta-analysis. British journal of sports medicine. 2019;53(16):1003-12.
13. Group IOCPAIC, Ardern CL, Ekås G, Grindem H, Moksnes H, Anderson AF, et al. 2018 International Olympic Committee consensus statement on prevention, diagnosis, and management of pediatric anterior cruciate ligament injuries. Orthopaedic journal of sports medicine. 2018;6(3):2325967118759953.
14. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. International journal of surgery. 2021;88:105906.
15. Moher D, Liberati A, Tetzlaff J, Altman DG, Group* P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine. 2009;151(4):264-9.
16. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. Journal of epidemiology & community health. 1998;52(6):377-84.
17. Radzimski AO, Mündermann A, Sole G. Effect of footwear on the external knee adduction moment a systematic review. The knee. 2012;19(3):163-75.

18. Renstrom P, Ljungqvist A, Arendt E, Beynnon B, Fukubayashi T, Garrett W, et al. Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. British journal of sports medicine. 2008;42(6):394-412.
19. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. The American journal of sports medicine. 1995;23(6):694-701.
20. Arendt EA, Agel J, Dick R. Anterior cruciate ligament injury patterns among collegiate men and women. Journal of athletic training. 1999;34(2):86.
21. Messina DF, Farney WC, DeLee JC. The incidence of injury in Texas high school basketball. The American journal of sports medicine. 1999;27(3):294-9.
22. Lindenfeld TN, Schmitt DJ, Hendy MP, Mangine RE, Noyes FR. Incidence of injury in indoor soccer. The American journal of sports medicine. 1994;22(3):364-71.
23. Stevenson H, Webster J, Johnson R, Beynnon B. Gender differences in knee injury epidemiology among competitive alpine ski racers. The Iowa orthopaedic journal. 1998;18:64.
24. Myklebust G, Maehlum S, Holm I, Bahr R. A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball. Scandinavian journal of medicine & science in sports. 1998;8(3):149-53.
25. Gwinn DE, Wilckens JH, McDevitt ER, Ross G, Kao T-C. The relative incidence of anterior cruciate ligament injury in men and women at the United States Naval Academy. The American journal of sports medicine. 2000;28(1):98-102.
26. Boers M. Graphics and statistics for cardiology: designing effective tables for presentation and publication. Heart. 2018;104(3):192-200.
27. Mayo-Wilson E, Li T, Fusco N, Dickersin K, investigators M. Practical guidance for using multiple data sources in systematic reviews and meta-analyses (with examples from the MUDS study). Research synthesis methods. 2018;9(1):2-12.
28. Stovold E, Beecher D, Foxlee R, Noel-Storr A. Study flow diagrams in Cochrane systematic review updates: an adapted PRISMA flow diagram. Systematic reviews. 2014;3:1-5.
29. Beynnon BD, Vacek PM, Newell MK, Tourville TW, Smith HC, Shultz SJ, et al. The effects of level of competition, sport, and sex on the incidence of first-time noncontact anterior cruciate ligament injury. The American journal of sports medicine. 2014;42(8):1806-12.
30. Montalvo AM, Schneider DK, Webster KE, Yut L, Galloway MT, Heidt Jr RS, et al. Anterior cruciate ligament injury risk in sport: a systematic review and meta-analysis of injury incidence by sex and sport classification. Journal of athletic training. 2019;54(5):472-82.
31. Stone AV, Marx S, Conley CW. Management of partial tears of the anterior cruciate ligament: a review of the anatomy, diagnosis, and treatment. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2021;29(2):60-70.
32. Amis AA, Dawkins G. Functional anatomy of the anterior cruciate ligament. Fibre bundle actions related to ligament replacements and injuries. The Journal of Bone & Joint Surgery British Volume. 1991;73(2):260-7.
33. Mather III RC, Koenig L, Kocher MS, Dall TM, Gallo P, Scott DJ, et al. Societal and economic impact of anterior cruciate ligament tears. JBJS. 2013;95(19):1751-9.
34. Brattström H. Shape of the intercondylar groove normally and in recurrent dislocation of patella: a clinical and x-ray anatomical investigation. Acta Orthopaedica Scandinavica. 1964;35 (sup68):1-148.
35. Herrington L, Nester C. Q-angle undervalued? The relationship between Q-angle and medio-lateral position of the patella. Clinical biomechanics. 2004;19(10):1070-3.
36. Ando T, Hirose H, Hnoue M, Shino K, Doi T. A new method using computed tomographic scan to measure the rectus femoris-patellar tendon Q-angle comparison with conventional method. Clinical Orthopaedics and Related Research (1976-2007). 1993;289:213-9.
37. Hohmann E, Tetsworth K, Glatt V, Ngcelwane M, Keough N. Medial and lateral posterior tibial slope are independent risk factors for noncontact ACL injury in both men and women. Orthopaedic Journal of Sports Medicine. 2021;9(8):23259671211015940.
38. Liu Z, Jiang J, Yi Q, Teng Y, Liu X, He J, et al. An increased posterior tibial slope is associated with a higher risk of graft failure following ACL reconstruction: a systematic review. Knee Surgery, Sports Traumatology, Arthroscopy. 2022;30(7):2377-87.
39. Mallinos AD. INFLUENCE OF LIGAMENT LOCATIONS AND ACTIVITY PROFILES ON RISK OF KNEE INJURY IN ADOLESCENTS: Cleveland State University; 2023.
40. Marx RG, Yin K, Kaeding CC. AAOS appropriate use criteria: treatment of anterior cruciate ligament injuries. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2016;24(8):e84-e6.
41. Maestro A, Herruzo I, Varillas-Delgado D, Martín-Saborido C. Subjective assessment reported by patients shows differences between single-bundle and double-bundle anterior cruciate ligament reconstruction, systematic review and meta-analysis. Scientific Reports. 2021;11(1):15385.
42. Lin KM, Boyle C, Marom N, Marx RG. Graft selection in anterior cruciate ligament reconstruction. Sports medicine and arthroscopy review. 2020;28(2):41-8.