

Epidemiology, Diagnosis and Reconstruction of Anterior Cruciate Ligament Injury

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Abstract. Both female athletes and physically active persons are susceptible to anterior cruciate ligament (ACL) rupture, a common sports-related injury. The ACL is structurally complex and is considered to be an important proprioceptor, as well as limiting tibial translation. The standard test for ACL tears is magnetic resonance imaging (MRI); however, there is currently no suitable method to accurately determine the severity of the injury. Numerous factors, including gender, muscle strength, and exercise habits, are linked to the causes of ACL tears. ACL tears prevent athletes from playing sports in the near future. They could eventually develop psychological problems, chronic knee disease, and blocked nerve signals, all of which would lower their post-ACL repair return numbers and performance. Reconstruction and recovery are the two stages of ACL treatment, and the therapy plan should be tailored to each patient's unique needs. Athletes' leg muscles should be strengthened as the primary means of preventing ACL injuries, but venues and coaches should also be taken into account.

Keywords: Anterior Cruciate Ligament Injury; ligament reconstruction; rehabilitation.

1. Introduction

In sports like volleyball, basketball, soccer, and other contact sports where players must twist and rotate their bodies, anterior cruciate ligament (ACL) injuries are a common but severe sports injury. According to statistics, this injury affects about 200,000 Americans annually, with a prevalence rate of 84/100,000, and 100,000 of those cases require ACL reconstruction. Even after reconstruction, there is a significant social cost to the patient, with the average cost of undergoing reconstructive surgery amounting to \$38,121 and the average cost of subsequent rehabilitation amounting to \$88,538 [1]. After ACL tearing, the patient experiences severe pain and weakness in the knee. For professional athletes, the ACL may greatly affect their performance. Some well-known soccer and basketball players have had to end their careers because of ACL tears. Therefore, the knowledge of ACL is very important. This paper will analyze and summarize the causes of ligament tears, their possible consequences, treatments and preventive measures.

2. Anatomical Structure and Function

The anterior-lateral (PL) and anterior-medial (AM) bundles are believed to be present in the densely packed connective tissue that makes up the anterior cruciate ligament (ACL), one of the pairs of cruciate ligaments in the human knee. It is situated anterior to the posterior cruciate ligament. ACL function is critical to human movement: On the one hand, it is innervated by the posterior articular nerve, and this mechanoreceptor is essential for proprioception, which is the ability to react differently to various pressures [2]. On the other hand, the ACL's greater toughness, elasticity, and its connection to the femur and tibia allow it to regulate tibial motion and prevent extreme tibial motion. Its two ends join the anterior horn of the medial meniscus at the tibia's intercondylar eminence, where they are attached anteriorly. One end unfolds in the shape of a fan on the inside surface of the lateral femoral condyle, travels obliquely through the intercondylar fossa, and inserts into the middle of the intercondylar region [3]. When the knee is impacted or twisted, the anterior tibial ligament (ACL) provides 87% of the total binding force at 30° and 85% at 90° of knee flexion, thereby limiting

anterior tibial translation. In conclusion, it can be said that the ACL is critical for maintaining normal human activity because it affects tibial modulation and neurofeedback [4].

3. Diagnostic

The most common test for ACL rupture is the use of Magnetic Resonance Imaging (MRI), where direct signs such as disrupted continuity of the ligament and deviation from its anatomical position, wavy cracks, etc., are observed in the patient's knee. An additional indirect result of the ligament rupture is an apparent "bone contusion" of the lateral femoral condyle and posterior lateral tibia. Recently Volokhina et al. described two possible MRI images after ACL tears, the "gap" sign and the "footprint" sign: the "footprint" denotes an increase in signal at the stop of the posterior lateral tibial fascicle, which may be connected to an ACL tear; the "gap" sign, which is present at the lateral femoral condyle and proximal femur, indicates a tear of the posterior lateral femoral fascicle. While the diagnosis of localized ACL tears can be made with some help from these two markers, it is still difficult to identify and predict the precise extent of ACL tears. None of the 12 tests, including MRI, showed great superiority, and MRI became less reliable in detecting the extent of partial tears, with an accuracy of only 25% to 53% [5,6].

4. Pathogenesis

ACL ruptures usually occur during noncontact or direct impact, with 70% to 80% of these cases being noncontact ACL tears. Most of these injuries occur during landing, while cutting, and sudden deceleration. When the knee is suddenly internally rotated, the tibia and femur move in opposite directions and extra pressure is placed on the ACL, causing a tear in the ligament. Sports like skiing, basketball, soccer, and volleyball that demand a lot of knee movement for support are more likely to cause this condition. When an ACL tear occurs in direct impact the ACL is subjected to strong valgus stress and may produce medial meniscus and medial collateral ligament injuries. Additionally, research indicates that the incidence of ACL injuries among female soccer players is three times greater than that of male soccer players [7]. This means that females experience ACL ruptures far more frequently than males. This situation is due to the weaker muscle strength and exercise habits of females. The strength of the hamstrings and hip adductors is crucial for maintaining physical stability when participating in sports, however, females tend to use their quadriceps rather than hamstrings for deceleration during sports, and the lack of strength in the hip adductors results in female athletes not being able to adequately counteract knee abduction loads. In terms of locomotor habits, female athletes typically present a greater knee valgus angle during landing and rotation, while the tibia externally rotates the foot internally and the ACL produces a substantial twist. In addition, intrinsic factors such as anatomical mutations, past medical history, BMI, and hormonal status as well as extrinsic factors such as competition environment, equipment, and type of competition may be associated with ACL tears [4].

5. Consequence

ACL injuries can be ranked from grade 1 (least severe) to grade 3 (most severe) based on the extent of rupture, according to the American Academy of Orthopaedic Surgeons (AAOS): A grade 1 injury is characterized by a minimally injured ligament that is still able to stabilize the knee joint; a grade 2 injury is characterized by a laxity of the ligament, sometimes known as a partial ligamentous rupture; and grade 3 injury is defined as complete tears of the ligament, where the ligament is torn in half or detached from the femur, resulting in knee instability [8]. Unfortunately most cases fall into the category of third-degree ACL injuries, where the ACL is completely disconnected. The subsequent consequences are analyzed based on a grade III ACL break.

5.1. Short Term Consequence

When an ACL ruptures, there is a noticeable popping sound, excruciating knee pain, a misaligned kneecap, a brief loss of mobility, and two to three months of recovery time following ACL reconstruction.

5.2. Nerve Signal Blockage

As an important mechanoreceptor in the human body, ACL rupture results in the inability of the knee to accurately regulate and detect tension, knee internal rotation angle, acceleration, and direction of movement during exercise and provide timely feedback. One study reported that 53% of patients with ACL rupture have proprioceptive deficits [9]. This may alter the spinal and supraspinal motor control, leading to altered movement habits, such as an increased probability of dynamic knee valgus [10]. Also, inappropriate movement habits due to ACL tears may lead to re-injury of the ACL, with some findings stating that 12% of people who sustained an initial ACL injury were re-injured over the next 5 years [11]. Blockade of nerve signals may also lead to Arthrogenic Muscle Inhibition (AMI), where the muscles surrounding the injured joint receive persistent inhibition and damage. In cases of ACL rupture, it is the quadriceps muscle that is most severely affected. The quadriceps muscle is unable to receive signals from the severed neurons, which further weakens it. It has been shown that in patients between two months and two years after an ACL injury, the quadriceps muscle decreases in volume (21% decrease) and symmetry (17% asymmetry). There are also concomitant problems associated with quadriceps weakening, including excessive hamstring excitation and SIGNIFICANT atrophy of the semitendinosus and gracilis [12].

5.3. Chronic Sequelae Distress

ACL injury leads to a series of chronic sequelae. The most common problem is chronic knee osteoarthritis, which occurs in more than 90% of patients with ACL injury. It is caused by damage to the cartilage of the knee joint from external forces and the inability of the ACL to organize the tibial translation. After reconstruction of the patient's ACL, the patient's knee joint has increased fluid volume, bone marrow edema, and morphologic changes in the cartilage, resulting in a more fragile joint. Of the 35 patients under investigation, 28 instances (80%) had articular cartilage injuries in the posterior lateral tibial plateau, and 33 cases (94.3%) had injuries in the lateral femoral condyle [13]. These cartilage changes may exacerbate the pressure on the meniscus and posterior cruciate ligament, leading to subsequent injury.

5.4. Psychological Disorders

The psychological impact of ACL injury on patients is one of the factors that cannot be ignored, especially for professional athletes. ACL injury usually causes irreversible psychological shadows on professional athletes, as well as a decrease in self-confidence compared to the previous period, fear of not being able to return to the pre-surgery level, and anxiety or even fear of sports. In a statistic of 62 athletes with ACL injuries, 47% ended their athletic careers, with 24% of them reporting that they were not confident in their performance, and the psychological scores of ACL patients were significantly lower than those of normal athletes in the experiment [14]. Even if the athlete is confident and returns to play, according to the previous article 12% will still experience another ligament tear. This situation may exacerbate the athlete's psychological burden and induce more serious psychological disorders.

5.5. Low Rate of Return to Sport

Combined with the above points, ACL injuries have an extremely serious impact on professional athletes, both in terms of physical deficits and psychological fears. The two may have combined to cause a decline in performance and a permanent change to the athletic career of the majority of recovering athletes. Surveys have shown that 35% of athletes who undergo anterior cruciate ligament

repair (ACLR) experience a decline in performance within two years of the procedure, and this percentage increases over time, with more than 50% of athletes not performing as well as they did prior to the procedure within five years of the surgery [15]. In addition, less than 50% will return to sport at one year after ACL reconstruction, less than 65% will return to sport at two years, and 24% of patients will have a change in their sport habits or even 11% will no longer play sport.

6. Reconstruction and Rehabilitation

Regaining full range of motion (ROM) for the knee, restoring muscle strength and proprioception, and achieving good functional stability of the ACL are the general objectives of ACL treatment. Based on these aims, the overall treatment of the ACL can be divided into two phases, the first one being the reconstruction of the ACL ligament: the aim of this phase is to repair the ACL anatomically by different methods so that the structure meets the expected function of the ACL. However, due to the complexity of the ACL and the potential knock-on effects of the injury, ACL reconstruction is very challenging and should take into account a variety of factors, including but not limited to the patient's age, level of exercise, and daily activities. According to the consideration of comprehensive factors, ACL reconstruction can be mainly categorized into conservative treatment and surgical treatment, but currently most patients receive surgical treatment. The second stage is the rehabilitation of ACL: this stage mainly enables patients to restore the function of knee ligaments through postoperative rehabilitation exercises. However, similar to ACL reconstruction, specific rehabilitation exercises need to be developed dependent on the specific degree of joint injury, concomitant disease, the success of the ACL reconstruction, and the patient's own progress, and a large number of factors need to be taken into account to ensure that the patient achieves an optimal level of rehabilitation. The following section analyzes the advantages and disadvantages of common approaches to ACL reconstruction and rehabilitation, respectively.

6.1. Reconstruction

The most common treatment currently used in the general population or in athletes involves autografting, i.e. transplanting one's own tendon to replace the structural function of the ACL. This has the benefit of establishing a biological fixation from bone to bone, which enables the athlete to return to competition status quickly. On the other hand, it may cause instability in muscle function. The procedure involves a longitudinal incision from the patella's center to the tibial tuberosity. The deep fascia is sliced to expose the patellar tendon, and then the bone plugs of the patella (20 mm in length) and tibia (30 mm in length) with a breadth of 10 mm are retrieved. During harvesting, the knee was flexed to keep the tendon fibers straight when under tension. Bone cutting was then performed using a vibrating saw. Oblique cuts are typically made on elite athletes in order to prevent aberrant strains and the potential for patellar fractures. Using a Howell tibial guide, a hole is drilled while the knee is fully extended to create the tibial tunnel. With the knee flexed 90 degrees, the femoral tunnel is drilled through the tibial tunnel with the goal of reaching the anatomic ACL insertion point's center. The graft is implanted through the tunnel with an X-shaped button at the patellar bone plug and two sutures at the tibial bone plug. Onto the lateral femoral cortex, the buttons were inverted. To relieve the graft stress, the knee was repeatedly flexed and extended. At 20° of knee flexion, it was secured in the tibial tunnel with an absorbable interference screw at a tension of 80N. Additionally in the presence of significant anterior external rotation instability, additional lateral surgery is performed to enhance knee stability [9].

Age is an important factor influencing the means of reconstruction. Because of their immature skeleton and the tibial epiphysis, which is crucial to a child's growth, being damaged during ACL reconstruction can result in premature closure of the bone, leg length discrepancies, and angular deformities, children under the age of 12 are not candidates for conventional surgical reconstruction [16]. One approach is to attach the popliteus muscle to the goosefoot, over the tibialis anterior, across the anterior horn of the meniscus, and over-the-top to a femur groove that has already had treatment.

Since its proposal and partial implementation in the 1990s, the approach known as iliotibial band physeal-sparing reconstruction has resulted in patients with generally good ACL function in the postoperative period, no leg length differences, and just two occurrences of graft failure. Nevertheless, even though this grafting method stabilizes the knee, it cannot fully restore anteroposterior translation at flexion angles of 30° or higher. An alternative method is the partial transphyseal procedure, wherein the graft is often inserted via the olecranon's tibial tunnel and thereafter secured in the metaphyseal tunnel or the femur in an over-the-top position. This method has less impact on the epiphysis than the partial transphyseal technique. The procedure should also be tailored to the sport in which the patient is involved and the individual characteristics of the patient.

6.2. Rehabilitation

The rehabilitation phase is extremely important for patients with ACL tears. Appropriate rehabilitation can help the patient to return to sport more quickly and avoid subsequent and consequential injuries caused by ACL. According to the international journal of sports physical therapy, the rehabilitation process can be divided into 4 cycles according to different purposes: the first cycle is 0-6 weeks in length, the main purpose is to protect the repaired ACL, activate the quadriceps muscle, restore the range of motion of the knee joint ROM and clear the knee joint effusion. Patients need to perform soft tissue massage, tendon stretching, up and down stairs, one-legged balance standing and other processes; the second cycle is 7-14 weeks long, mainly focusing on muscle endurance enhancement, especially the recovery of key muscle groups such as quadriceps, this is because ACL injury will lead to the atrophy of the type 1 muscle fibers, the exercises include Wall squat holds, TRX squats, resisted lateral steps, etc.; The third cycle lasts for 15-21 weeks, and the main goal is to build muscle strength, specifically for type II A and B muscle fibers, which is characterized by increased loads and decreased repetitions compared to the muscular endurance phase, with exercises such as Weighted reverse, single leg squat to target, etc.; The patient can initially run with 70% of the weight in a pool at chest level and lower the water level as needed to run with 100% of the weight; the fourth cycle lasts for 22 weeks or more. The purpose of this phase is to combine and improve muscle strength, speed and agility, so that the patient can fully restore the level of exercise, the exercises in this phase include Front Squat, Burpees, Abdominal crunch Isometric hold and other exercise. It should be noted that the patient should be diagnosed at this time in order to avoid re-tearing of ACL [17].

7. Precaution

Given the severity and widespread nature of ACL injuries, ACL injury prevention is necessary. ACL injuries are caused by a variety of circumstances, including intra-patient issues including weak muscles, unsteady gait, and insufficient ligament flexibility. To address these causes, the current conventional mean of prevention is neuromuscular training (NMT), which includes strength training, balance exercises, and stretching to manipulate muscle activation or imbalances, etc [18]. This technique works well to avoid ACL damage. Muscle cluster strengthening exercises, such as the one-legged knee squat, pelvic lift, two-legged knee squat, etc., are comparable to the third cycle of the rehabilitation phase, with each set lasting an average of 15 minutes [19]. Balance exercises are also frequently used as a means of prevention, specifically single-legged, double-legged stance activities, which have been suggested by most studies to enhance proprioception and thus reduce the mechanics associated with ACL injuries. However static stretching, despite being generally recognized as not being able to hold fast to skeletal muscle injuries, it is still used as a frequently mentioned preventive tool as the method may be related to the reduction of ligament injuries [20]. Also improvements for some external factors can reduce the probability of ACL injury. Coach training should be enhanced to ensure that coaches are professionally knowledgeable about the sport and can properly and reasonably plan for their players; improvements can also be made to the playing field by adding resilient layers, such as rubber cushioning or artificial turf infill, under the surface of the playing field.

These layers can provide additional cushioning and shock absorption to reduce the impact on the ACL during sports.

8. Conclusion

ACL rupture is a common sport injury that places a significant economic burden on the healthcare system. We have established several therapeutic techniques for the diagnosis, treatment, and rehabilitation of ACL rupture as well as a basic understanding of the anatomical structure and function of the ACL through long-term anatomical and clinical studies. This article's goal is to go over the current mainstream techniques to diagnosis, therapy, and rehabilitation as well as the anatomy and physiology of ACL. However, due to the complexity of factors leading to ACL injury, most of the current treatments have side effects and shortcomings and need to be further refined and improved.

References

- [1] Mather RC 3rd, Koenig L, Dall TM, et al. Societal and economic impact of anterior cruciate ligament tear. *J. Bone Joint Surg. Am.* 2013; 95: 1751–9.
- [2] Sepúlveda, Fernando MD; Sánchez, Luis MD; Amy, Eduardo MD; Micheo, William MD, FACSM. Anterior Cruciate Ligament Injury: Return to Play, Function and Long-Term Considerations. *Current Sports Medicine Reports* 16(3): p 172-178, 5/6 2017.
- [3] Siegel L, Vandenakker-Albanese C, Siegel D. Anterior cruciate ligament injuries: anatomy, physiology, biomechanics, and management. *Clin J Sport Med.* 2012 Jul; 22(4): 349-55.
- [4] Acevedo RJ, Rivera-Vega A, Miranda G, Micheo W. Anterior cruciate ligament injury: identification of risk factors and prevention strategies. *Curr Sports Med Rep.* 2014 May-Jun; 13(3): 186-91.
- [5] Noyes FR. The function of the human anterior cruciate ligament and analysis of single- and double-bundle graft reconstructions. *Sports Health.* 2009 Jan;1(1):66-75.
- [6] Kohn L, Rembeck E, Rauch A. Verletzung des vorderen Kreuzbandes beim Erwachsenen: Diagnostik und Therapie [Anterior cruciate ligament injury in adults: Diagnostics and treatment]. *Orthopade.* 2020 Nov; 49(11): 1013-1028. German.
- [7] Prodromos CC, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. *Arthroscopy.* 2007 Dec; 23(12): 1320-1325.e6.
- [8] Courtney CA, Rine RM. Central somatosensory changes associated with improved dynamic balance in subjects with anterior cruciate ligament deficiency. *Gait Posture.* 2006 Oct; 24(2): 190-5.
- [9] Mariani, P.P., Cerullo, G., Iannella, G., Giacobbe, M. (2015). Anterior Cruciate Ligament (ACL) Lesions. In: Volpi, P. (eds) *Football Traumatology*. Springer, Cham.
- [10] Sanden, Nijhuis-van Der. "Return to Play after Anterior Cruciate Ligament Reconstruction in Pivoting Athletes." Melick, N. Van, 14 Mar. 2019. 17. Salmon L,
- [11] Russell V, Musgrove T, Pinczewski L, Refshauge K. Incidence and risk factors for graft rupture and contralateral rupture after anterior cruciate ligament reconstruction. *Arthroscopy.* 2005 Aug;21(8):948-57.
- [12] Pietrosimone, Brian, et al. "Arthrogenic muscle inhibition following anterior cruciate ligament injury." *Journal of Sport Rehabilitation* 31.6 (2022): 694-706.
- [13] Nishimori, M., Deie, M., Adachi, N., Kanaya, A., Nakamae, A., Motoyama, M., & Ochi, M. (2007). Articular cartilage injury of the posterior lateral tibial plateau associated with acute anterior cruciate ligament injury. *Knee Surgery, Sports Traumatology, Arthroscopy*, 16(3), 270–274.
- [14] Webster KE, Feller JA, Lambros C. Development and preliminary validation of a scale to measure the psychological impact of returning to sport following anterior cruciate ligament reconstruction surgery. *Phys Ther Sport.* 2008 Feb;9(1):9-15.

- [15] Engelen-van Melick N, van Cingel REH, van Tienen TG, Nijhuis-van der Sanden MWG. Functional performance 2-9 years after ACL reconstruction: cross-sectional comparison between athletes with bone-patellar tendon-bone, semitendinosus/gracilis and healthy controls. *Knee Surg Sports Traumatol Arthrosc.* 2017 May;25(5):1412-1423.
- [16] McConkey MO, Bonasia DE, Amendola A. Pediatric anterior cruciate ligament reconstruction. *Curr Rev Musculoskelet Med.* 2011 Jun;4(2):37-44.
- [17] Bousquet BA, O'Brien L, Singleton S, Beggs M. POST-OPERATIVE CRITERION BASED REHABILITATION OF ACL REPAIRS: A CLINICAL COMMENTARY. *Int J Sports Phys Ther.* 2018 Apr;13(2):293-305.
- [18] Petushek EJ, Sugimoto D, Stoolmiller M, Smith G, Myer GD. Evidence-Based Best-Practice Guidelines for Preventing Anterior Cruciate Ligament Injuries in Young Female Athletes: A Systematic Review and Meta-analysis. *Am J Sports Med.* 2019 Jun;47(7):1744-1753.
- [19] Taylor JB, Waxman JP, Richter SJ, Shultz SJ. Evaluation of the effectiveness of anterior cruciate ligament injury prevention programme training components: a systematic review and meta-analysis. *Br J Sports Med.* 2015 Jan;49(2):79-87.
- [20] Small K, Mc Naughton L, Matthews M. A systematic review into the efficacy of static stretching as part of a warm-up for the prevention of exercise-related injury. *Res Sports Med.* 2008;16(3):213-31.