Volume 7, Number 2, August 2024

THE JOURNAL OF INDONESIAN ORTHOPAEDIC & TRAUMATOLOGY

journal homepage: http://journal.indonesia-orthopaedic.org

Literature Review

Returning to Sport After Anterior Cruciate Ligament Reconstruction in Active Non-Athlete Individual: A Literature Review

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Article Info :

Article History :
Submission: March 7, 2024
Revision: June 24, 2024
Accepted: July 28, 2024

Keywords :
Anterior cruciate ligament
Anterior cruciate ligament injury
Anterior cruciate ligament reconstruction
Conservative and accelerated protocol
Return to sport

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Abstract

Anterior cruciate ligament (ACL) tears frequently occur as sports injuries, particularly in active young individuals. ACL reconstruction is a standard treatment for active individuals seeking to return to sports. Prehabilitation and post-operative rehabilitation therapy play crucial roles in strengthening the quadriceps and hamstrings before ACL reconstruction, facilitating the healing process, and enabling a return to sports at the pre-injury level. However, determining the appropriate time to resume sports activities after the injury is a complex and multifaceted decision-making process. Many criteria are considered for returning to sport after ACL reconstruction. Most surgeons suggest that individuals return to sports after nine months, with a limb symmetry index greater than >90% symmetry LSI criteria in hop tests and individuals exhibiting greater psychological readiness were more likely to return to sports.

Introduction

An anterior cruciate ligament (ACL) was crucial for knee stabilization. It is responsible for supporting dynamic-static stability and coordinating knee joint movements. The anterior cruciate ligament (ACL) experiences the highest injury frequency among all knee ligaments. Injury to the ACL severely impacts knee mobility and balance, leading to diminished sensory feedback and compromised knee joint function and stability.[1] ACL rupture stands out as one of the prevalent sports injuries among active young individuals, with 3.000 people suffering from ACL injury annually in the USA.[2,3] The age group most affected is individuals between 15 and 25.[4] Rehabilitation following ACL reconstruction plays a crucial role in restoring knee function and stability.[3] Returning to sports earlier will increase the risk of re-injury.[5] In contrast, a delayed return to sport may influence motivation and psychological readiness.[6]

After an ACL reconstruction, many patients expect to return to the pre-injury level of sports involving jumping, pivoting, and cutting.[7,8] However, a recent study reported that only 65% of patients return to their pre-injury level of sports, and males are more likely to return to sports than females.[8] Several studies have evaluated return-to-sport (RTS) criteria after an ACL reconstruction.[6,8-11] However, RTS decisions are complex, and many factors may influence the decisions.[10]

ACL ANATOMY AND THE MECHANISM OF INJURY

The ACL is one of the most important of the knee ligaments, which consists of 2 significant bundles: the posterolateral (PL) bundle and the anteromedial (AM) bundle (Figure 1). Both bundles originate on the posteromedial side of the lateral femoral condyle and are inserted on a region just anterior to the intercondylar tibial eminence.[12] The ACL plays a crucial role in knee joint stability, primarily restraining anterior translation of the tibia relative to the femur. Research has demonstrated that with the knee flexed from 20 to 90 degrees, there is an increase in tension on

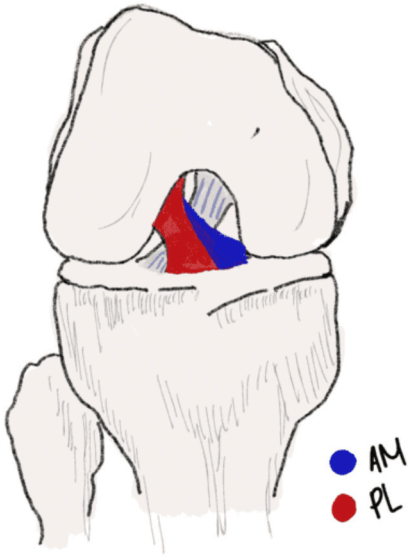

Figure 1. Illustration of a standard ACL consisting of 2 bundles (anteromedial and posterolateral

The anteromedial bundle of the ACL. In contrast, tension in the posterolateral bundle increases when the knee is extended.[12,13]

The mechanism of ACL tear injury can be categorized into two main types: contact and non-contact. Non-contact injuries to the ACL among athletes consistently demonstrate a specific knee flexion angle ranging from 30 degrees to full extension at the time of injury.[14,15] The rotation of the tibia plays a pivotal role in the non-contact ACL injury mechanism, with the lower leg experiencing either internal or external twisting relative to the femur. Tibial rotation exacerbates the strain on the ACL, with internal tibial torque resulting in more significant strain than external tibial torque. Rapid deceleration or landing actions are often considered provocative factors in non-contact ACL injuries occurring during soccer.[14] Boden et al. documented that landing motions frequently result in varus or valgus collapse of the knee, leading to subsequent ACL failure, with varus angulation imposing a tremendous strain on the ACL than the valgus.[15]

ACL injuries resulting from direct contact typically occur due to the application of an excessive valgus force on the knee. In soccer, this force is commonly inflicted by an opponent striking the lateral aspect of the player's leg, often during a slide tackle[14] (Figure 2).

ACL RECONSTRUCTION

Surgery is still the gold start of treatment for ACL surgery where it can reinstate stability and reduce the risk of progressive knee degeneration and instability.[4] Early surgical intervention may expedite the return to work or sports; conversely, delayed ACL reconstruction could lead to postponed early rehabilitation due to heightened muscle atrophy and diminished strength.[16] ACL reconstruction was traditionally performed by the open method. Arthroscopic ACL reconstruction has become a standard procedure. Initially, arthroscopic ACL reconstruction utilized a two-incision technique involving drilling the femoral bone tunnel from outside. Subsequently, a one-incision technique became prevalent, where the femoral bone tunnel was drilled from the inside out, passing through the tibial tunnel.[17]

PRE-OPERATIVE REHABILITATION PROGRAMS

Several studies have shown that patients with a full extension range of motion (ROM) before ACL reconstruction will reduce the chance of postoperative complications such as arthrofibrosis.[18,19] Furthermore, a deficit in quadriceps strength of 20% or more indicates a significant strength deficit until two years after ACL reconstructions.[20] These previous findings can be avoided with pre-operative rehabilitation, known as prehabilitation.[21] Prehabilitation programs are often performed to prepare the knee for reconstruction surgery, improve rehabilitation outcomes, reduce the risk of pivot shift episodes, which can often cause progressive joint damage, and enhance recovery after reconstruction.[22] Several studies suggest that individuals should achieve 90% of their quadriceps and hamstring strength and capacity for hopping on the injured leg compared to the uninjured leg before undergoing ACL reconstruction surgery.[23,24] A study reported the relevance of pre-operative rehabilitation (prehabilitation) programs to improve RTS rates and two years of self-reported knee function.[25] Shaarani et al. reported that a 6-week progressive prehabilitation program for patients undergoing ACL reconstruction, with a 12-week follow-up, led to improved knee function based on the single-legged hop test and self-reported knee function.[20] There are various rehabilitation protocols; however, stretching, balance exercises, and muscle strengthening, focusing on the quadriceps and hamstring muscles, are commonly

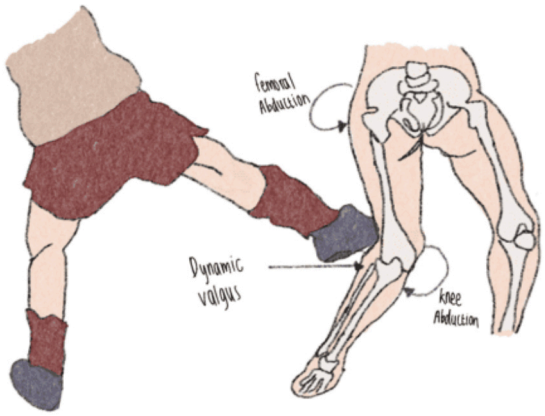

Figure 2. Illustration of the mechanism of the injury which leads to a valgus load.

included.[21] Furthermore, several studies reported high compliance and tolerance for participants with early stages of ACL injury.[20,26] Recently, a systematic review reported that prehabilitation improves quadriceps strength and single-leg hop scores three months after ACL reconstruction compared with no prehabilitation. However, the studies included needed more high-quality evidence due to a high risk of bias.[27]

POSTOPERATIVE REHABILITATION PROGRAMS

Post-reconstruction rehabilitation therapy is imperative for facilitating knee function healing and returning to sport to the pre-injury level.[21] However, the collaboration between the surgeon and physical therapist is crucial in tailoring the postoperative rehabilitation program to each patient's specific needs and conditions. Factors such as the surgical technique used, the type of graft, the presence of meniscal injuries, cartilage damage, ligamentous injuries, and any surgery-related complications all play a role in determining the appropriate rehabilitation approach. This individualized and collaborative approach helps optimize the recovery and outcomes for patients undergoing rehabilitation after ACL reconstruction.[28]

Rehabilitation following ACL reconstruction typically starts immediately after surgery and can continue for 9 to 12 months. Home-based rehabilitation programs can be a practical alternative for patients far from physical therapy centers or having difficulty scheduling frequent visits. Studies have shown that home-based programs can be as effective as supervised rehabilitation, particularly for patients with good compliance and motivation.[29] However, it's important to note that these programs may not be suitable for individuals participating in high-intensity sports, as they may require more specialized and closely monitored rehabilitation protocols to ensure optimal outcomes and prevent re-injury.[30] Grindem et al. reported that a comprehensive approach involving both rehabilitation and postoperative rehabilitation resulted in better self-reported knee function after a 2-year follow-up compared to postoperative rehabilitation only.[23]

Regardless of the surgical approach, postoperative rehabilitation is essential for a full recovery. Goals should align with the surgical technique to regulate strain on the healing ACL graft or repair. Repair techniques that minimize tissue damage may permit accelerated rehabilitation.[31,32] However, there has been no definitive consensus on postoperative rehabilitation. A recent study evaluated the Multicenter Orthopaedic Outcomes Network (MOON) guidelines and the Cavanaugh and Powers 2017 review to create the standard protocol after ACL reconstruction (Tables 1 and 2). However, any progression through phases is based on meeting functional criteria rather than the time since surgery. Some patients may be ready to advance sooner than the indicated time frame, while others may require more time.[33,34]

Table 1. Rehabilitation protocol after anterior cruciate ligament reconstruction

Bracing	**Week 0-3:** Surgeon dependent
Range of Motion	110° flexion by ~week 2 Full ROM should be achieved by ~week 6
Weightbearing	Immediate partial, progress to WBAT D/C crutches by ~week 2
Neuromuscular and Propriocaption	**Week 2-6:** Prop board/balance system/contralateral Theraband exercises
Exercises	**Week 4-6:** Light weights + sport cords **Week 2-6:** AAROM exercise, mini squats, weight shifts **Week 7-12:** Advance strengthening, hops, squats, straight line run **Week 13-16:** Aggressive strengthening, agility training, pylometrics
Run	**Week 7:** running training **Week 12-14:** running allowed
RTP	**Week 17-20:** sport-specific training **Week 24:** return to play

ROM, range of motion; WBAT, weight bearing as tolerated; D/C, discontinue; AAROM, Active Assisted Range of Motion

RE-INJURY RATE AFTER ACL RECONSTRUCTION

The rate of ACL re-injury following ACL reconstruction is approximately 15%.[35] Many risk factors might contribute to re-injury. Grindem et al. found that patients who returned to level I (jumping, pivoting, and intricate cutting) sports after ACL reconstruction had more than a fourfold increase in re-injury rates over two years. However, this rate decreased if an RTS occurred at least nine months or more after surgery, and having symmetrical quadriceps strength before RTS was crucial in reducing the re-injury rate.[36] Furthermore, re-injury was more frequent in younger individuals than 18 years old, and men had a greater risk of re-injury than women.[37,38]

CRITERIA OF RETURN TO SPORT AFTER ACL RECONSTRUCTION IN ACTIVE NON-ATHLETE INDIVIDUAL

Numerous criteria are utilized to assess whether an individual is suitable to return to sports (RTS) following ACL reconstruction: (1) time, (2) performance and functional test, and (3) psychological readiness.[39,40]

Phase 1 (weeks 0-2)	Phase 2 (weeks 2-6)	Phase 3 (weeks 7-12)	Phase 4 (weeks 13-16)	Phase 5 (weeks 17-20)
• Control post-operative pain/swelling • ROM: active flexion to 110° • Quadriceps control (20 SLR with no lag) • Weight bearing with crutches, should d/c before progressing	• Full ROM • Improve muscular strength functional in daily activities • Neuromuscular training to improve muscular control • Minimal pain • Satisfactory self-evaluation of knee function	• Maintain full ROM • Running and hopping without pain or swelling • Ascend 8" step without pain or deviation • Able to perform neuromuscular and strength exercises without difficulty	• Running patterns without difficulty at 75% speed • Jumping and contralateral hops without difficulty or instability • Satisfactory self-evaluation of knee function	• More than 85% normal contralateral strength and on-hop tests • Sport-specific training without pain, swelling, or difficulty • Isokinetic strength test(60°/sec) • Acceptable quality movement assessment (hop tests, vertical jump, deceleration shuffle test)

Table 2. Summary of rehabilitation goals.[34]

Time

The time of RTS is one of the criteria that surgeons should consider in each individual. A scoping review found that 11 out of 88 studies reported that the time needed to RTS ranges between 6 to 12 months.[39] These findings align with the research conducted by Hildebrandt et al., which suggests that the RTS after ACL reconstruction should be postponed from the current 4- to 6-month period to at least nine months post-surgery.[12] In a similar study, Grindem et al. demonstrated that for each month the patient's RTS was delayed up to 9 months, there was a 51% decrease in the re-injury rate.[36] Additionally, a study reported a sevenfold increased risk of re-injury if athletes returned to the sport in less than nine months.[41]

Performance and functional test

Barber-Westin and Noyes discovered, through a survey of 211 expert surgeons who are members of the German Arthroscopic Association (AGA), that the criterion most commonly utilized regarding muscle strength is a cut-off value of >90% isokinetic strength compared to the contralateral side.[42,43] Alternatively, other parameters, such as a quadriceps index >90% and weighted leg extension >90%, may also be employed.[44]

Over 50% of clinicians in the United States utilize manual muscle testing to evaluate muscle strength.[45] However, this approach has several limitations, including poorly defined boundaries between grades "4" and "5".[46] Frequently, a limb symmetry index (LSI) is used, which is the ratio of the score of the involved limb score to that of the uninvolved limb score, expressed as a percentage. When returning to sports after ACL reconstruction, most surgeons consider an LSI greater than 90% acceptable for recreational and non-pivoting sports.[47] In addition to pivot, contact, and competitive athlete, an LSI >100% has been recommended.[13]

Another standard test used is the hop test. These tests are the single hop for distance, triple hop for distance, triple cross-over hop, and the 6-m timed hop (Figure 3).[48] The LSI >90% symmetry could be used as cutoff scores for hop tests. A study demonstrated that at six months post-surgery, performance on each of the four hop tests could predict the return to previous levels of sport at the 2-year mark.[49] Moreover, patients who scored >85% LSI in single hop for distance and triple hop for distance at the time of return to sport were more likely to resume their previous activity levels.[50]

In contrast, several studies have reported that athlete performance during these tests at six months post-surgery could not predict a return to sport 12 months after rehabilitation. Strength testing and subjective patient rating of function provided more relevant information in these cases.[51,52] A recent meta-analysis reported that symmetry in hop distance may not necessarily mean knee function is also symmetrical. Therefore, clinicians should rely on something other than the LSI to assess functional performance changes after ACL reconstruction, as it may lead to over-estimating functional improvement and neglecting potential worsening of contralateral limb function.[53]

Psychological Readiness

Besides physical impairments, an ACL injury also has a psychological impact. Psychological readiness is the most significant factor linked to returning to pre-injury activity.[52] Multiple studies have indicated that a significant proportion of athletes when questioned about resuming their prior sporting activities, expressed concerns regarding fear of new injury, re-injury, and lack of confidence in their knee.[54] Athletes who exhibited higher psychological readiness were more inclined to return to their pre-injury level, resume

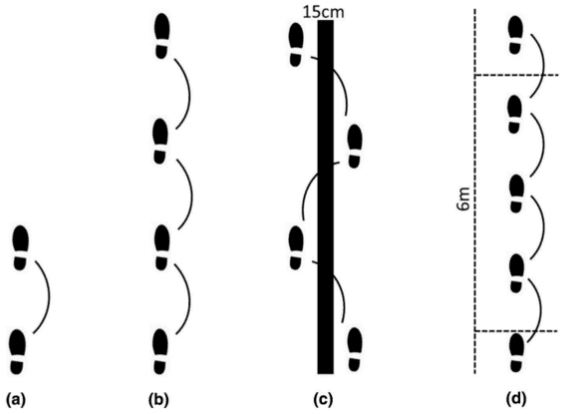

Figure 3. Depiction of the 4 single leg hop tests commonly used in return to sport protocols: a single hop for distance, b triple hop for distance, c cross-over hop for distance, d 6-m timed hop.[48]

sporting activities faster, and perceive better performance upon RTS.[54]

Conclusion

ACL reconstruction is essential to restore stability, minimize the risk of progressive knee degeneration and instability, and facilitate the return of individuals to sports and activities at a level comparable to their pre-injury state. However, rehabilitation plays a crucial role in achieving this outcome. The recommended rehabilitation following ACL reconstruction includes several key components: bracing, weight-bearing techniques, proprioceptive and neuromuscular training, various exercise methods, running, and sport-specific training. Several studies have indicated that the optimal timing for returning to sports activities after ACL reconstruction is within the first nine months following surgery with an LSI index greater than >90% symmetry in hop test and individuals with greater psychological readiness were more likely to return to sports.

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