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Mini Review

Pre and Post Surgery Preparation for Anterior Cruciate Ligament Reconstruction in Adult Patient

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Abstract

Introduction: Anterior cruciate ligament (ACL) injuries are among the most common knee injuries, particularly in athletes involved in high-impact sports. These injuries frequently result in knee instability, meniscal tears, and osteoarthritis if left untreated. ACL reconstruction is a widely performed surgical procedure designed to restore knee stability, reduce the risk of secondary injuries, and support individuals in returning to their prior activity levels. This literature review aims to provide an insight on the preoperative and postoperative preparation for ACL reconstruction in achieving optimal surgical outcomes.

Preoperative Preparation for ACL Reconstruction: Preoperative preparation, or prehabilitation, aims to reduce knee joint effusion, restore full active and passive range of motion, and achieve quadriceps strength symmetry. These steps help establish a strong foundation for recovery and minimize complications.

Postoperative Preparation for ACL Reconstruction: Postoperative rehabilitation employs a phased, criterion-based approach focusing on pain management, range of motion restoration, muscular strength rebuilding, and neuromuscular control enhancement. Rehabilitation programs are tailored to individual needs, with progress monitored through measurable benchmarks.

Conclusion: The management of ACL injuries requires a systematic, evidence-based approach that combines advanced surgical techniques, like ACL reconstruction, with personalized rehabilitation plans.Collaboration among physicians, physical therapists, and patients is vital to ensure effective recovery and a safe return to sports or daily activities. Despite advancements in surgical and rehabilitative techniques, further research is needed to standardize protocols and improve long-term outcomes.

Keywords: Rehabilitation, Prehabilitation, Knee, ACL Injuries

Introduction

Anterior cruciate ligament (ACL) injuries are among the most common knee injuries, frequently affecting one of the two primary ligaments responsible for stabilizing the knee joint. The ACL plays a critical role in maintaining knee stability by preventing anterior translation of the tibia and controlling rotational movements.[1,2] ACL injuries account for nearly half of all knee injuries, with an annual incidence in the United States estimated at approximately 1 in 3,500 individuals. Most countries, including European countries, United States, and New Zealand reported an annual incidence rate of 0,03-0,04% for the general population, and an annual incidence rate of 0,15-3,67% for professional athletes.[3] Around 400,000 ACL reconstruction procedures are performed each year in the United States alone, although these numbers may be underreported due to the lack of standardized surveillance systems.[4]

ACL injuries predominantly occur in athletes, especially those participating in high-impact sports such as football, soccer, and basketball. Most injuries arise from non-contact mechanisms, such as sudden pivoting or cutting movements, which result in the tibia shifting forward while the knee is slightly flexed and in valgus alignment. Contact injuries, such as direct blows to the lateral side of the knee, are also a common cause of ACL ruptures.[1,5]

Recurrent knee instability following ACL injuries can lead to significant complications, including meniscal tears and osteoarthritis. Acute ACL ruptures are often

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associated with other intra-articular injuries, such as lateral meniscus damage, which is present in over half of acute cases.[1,6] Chronic cases, on the other hand, are more likely to involve medial meniscus injuries. These associated injuries highlight the complexity of ACL damage and emphasize the need for prompt and effective management.[6]

The treatment of ACL injuries requires an individualized approach, with both surgical and non-surgical options available.[6] Surgical reconstruction is a widely used method, particularly for complete ACL ruptures in young, active individuals or older, physically demanding patients. The primary objectives of ACL reconstruction are to restore the anatomical structure of the ligament, enhance anterior and rotational stability, and reduce the risk of secondary meniscal or cartilage injuries. The procedure also aims to restore knee stability while preserving a full active range of motion (ROM).[1,2,7] Given the vital role of the ACL in maintaining functional knee stability, comprehensive preoperative and postoperative preparations are essential to optimize surgical outcomes and facilitate successful recovery. This literature review aims to provide an insight on the role of preoperative and postoperative preparation for ACL reconstruction in achieving optimal surgical outcomes.

Anterior Cruciate Ligament (ACL) Injury

The anterior cruciate ligament (ACL) is a critical passive structure that stabilizes the knee by preventing anterior translation of the tibia relative to the femur and controlling rotational movements in the frontal and transverse planes. It consists of two bundles, the anteromedial (AM) and posterolateral (PL) bundles, named based on their tibial attachment sites.[8] These bundles work together to maintain knee stability, with the AM bundle being tauter during flexion and primarily resisting anterior tibial translation, providing approximately 85% of the ligament's stabilizing function. Meanwhile, the PL bundle tightens during extension, playing a key role in medial-lateral and rotational stability as a secondary restraint. This division of function underscores the importance of restoring both bundles during ACL reconstruction to achieve optimal knee stability.[1,9]

ACL injuries occur when the ligament is stretched or torn, compromising its stabilizing role. These injuries are commonly classified into direct contact, indirect contact, and non-contact mechanisms, with non-contact injuries being the most prevalent.[8] Non-contact ACL tears often result from internal forces during activities such as sudden deceleration, quick directional changes, pivoting, twisting, or improper landings after a jump. Direct trauma, such as a blow to the anterior tibia, can also cause ACL injuries.[1] These injuries frequently lead to knee instability, which can result in secondary complications like meniscal tears or early-onset osteoarthritis. Acute ACL ruptures often involve additional intra-articular injuries, with lateral meniscus tears observed in more than half of acute cases.[1,6]

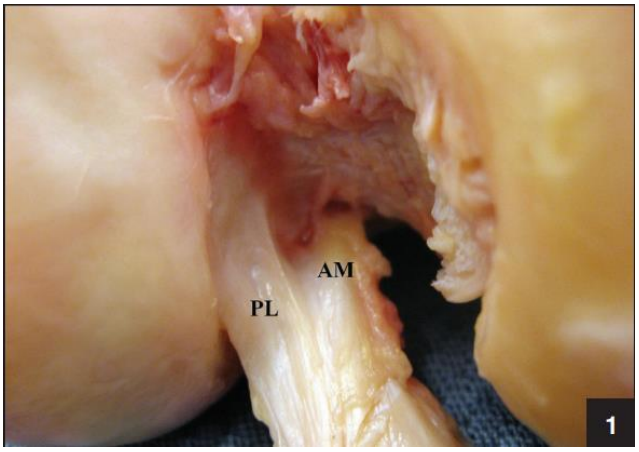


Figure 1. The Anatomy of Anterior Cruciate Ligament.[8]

Accurate diagnosis of ACL injuries combines clinical evaluation and imaging studies. Clinical assessments start with a thorough history, focusing on the mechanism of injury, reports of a "popping" sound during trauma, rapid knee swelling, and sensations of instability.[1,10] Physical examinations are integral, with

specific tests like the Lachman test, anterior drawer test, and pivot-shift test being used to assess knee stability. Among these, the Lachman test is the most sensitive and reliable, particularly in acute settings.[10,11] Imaging studies are essential for confirming the diagnosis and identifying associated injuries. Magnetic resonance imaging (MRI) is the gold standard, offering detailed visualization of the ACL and other intra-articular structures, such as the meniscus and cartilage. MRI can also differentiate between partial and complete ACL tears.[1,5] Effective diagnosis and identification of the mechanism of ACL injuries is crucial, as it not only guides appropriate management strategies but also determines the need for surgical intervention, such as ACL reconstruction, in cases of complete rupture or persistent instability.

Anterior Cruciate Ligament (ACL) Reconstruction

ACL reconstruction is a widely utilized surgical procedure aimed at restoring knee stability in patients with a complete ACL rupture, particularly those who are younger, active, or over 40 years old but maintain high physical activity demands. The primary goal of the surgery is to anatomically reconstruct the ACL to restore anterior and rotational stability, thereby reducing the risk of secondary injuries to the meniscus or articular cartilage. ACL reconstruction is also indicated in cases of partial ACL tears associated with functional instability or in pediatric patients where activity restriction is impractical.[12]

The surgery is most performed using minimally invasive arthroscopic techniques. Small incisions are made around the knee to harvest graft tissue, typically from the patellar tendon or hamstring tendons. A tunnel is created in the tibia and femur, through which the graft is threaded and positioned to mimic the original ACL. The graft is then securely fixed in place using screws, sutures, buttons, or other fixation devices, which are generally left permanently.[2,6]

To maximize surgical success, patients must achieve a full range of motion preoperatively to minimize the risk of postoperative complications such as arthrofibrosis. Rehabilitation following reconstruction is critical for restoring knee function and achieving a successful return to sports. The timeline for resuming athletic activities depends on multiple factors, including the patient's demographic characteristics, functional recovery, and psychological readiness. In addition to ACL reconstruction, concurrent procedures may be performed to address associated injuries. Meniscal tears, often accompanying ACL injuries, may be repaired or treated with a meniscectomy, while damage to other knee ligaments can be repaired or reconstructed as necessary. These additional interventions contribute to improved overall knee function and long-term outcomes for the patient.[12]

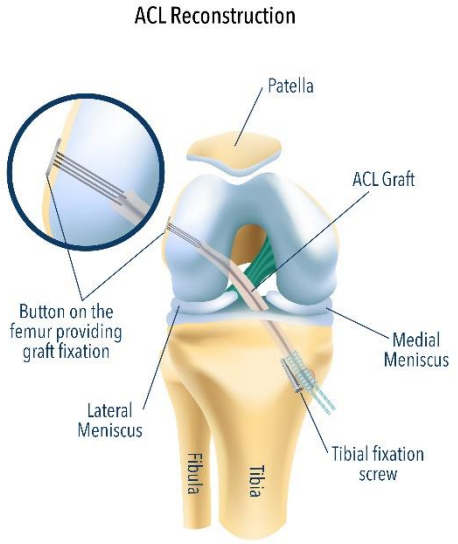


Figure 2. Anterior Cruciate Ligament Reconstruction.[7]

ACL reconstruction surgery has become a cornerstone in the management of ACL injuries, with advancements in techniques and graft options ensuring tailored approaches for individual patients. This personalized

care maximizes the chances of achieving both functional recovery and a return to previous activity levels.[12]

Pre-Operative Preparation for ACL Reconstruction

Anterior Cruciate Ligament (ACL) injuries are commonly encountered in athletic populations and often necessitate surgical intervention to restore knee stability and enable individuals to return to pre-injury activity levels.[12] Prehabilitation (PreHab) is an essential step in preparing patients for ACL reconstruction (ACLR) to improve postoperative outcomes. Patients who are physically and mentally prepared before surgery tend to experience better recovery. Factors such as optimism, self-efficacy, strong quadriceps muscles, and full passive knee extension have been linked to improved results after ACLR.[13–15] Preoperative rehabilitation has been shown to enhance patient-reported knee function and activity levels compared to minimal or no rehabilitation before surgery.These findings highlight the importance of preoperative rehabilitation, which has been associated with better postoperative patient-reported function and activity level compared to no or limited rehabilitation prior to ACLR.[16–18]

PreHab is a structured approach initiated immediately after the diagnosis of an ACL injury to optimize recovery and enhance surgical outcomes. The primary goals of PreHab are to reduce knee joint effusion, achieve full active and passive range of motion, and restore at least 90% quadriceps strength symmetry. These objectives are crucial for minimizing postoperative complications and establishing a strong foundation for effective rehabilitation and successful recovery.[12] PreHab is implemented through a phased strategy, starting with the acute phase, which focuses on managing joint effusion, regaining knee extension, and managing of pain. This phase incorporates active and passive range-of-motion exercises, such as quadriceps sets, straight leg raises, and heel slides, combined with pain management techniques like cryotherapy.[19]

Following the acute phase, the intermediate phase emphasizes improving dynamic knee stability through neuromuscular training and progressive muscle strength exercises. Activities such as balance training, agility drills, and plyometrics are introduced and gradually intensified. This progression moves from light-load, high-repetition exercises to heavier loads with fewer repetitions, using the "2+ principle" to guide load adjustments effectively. This phased and systematic approach ensures that patients achieve optimal physical readiness for ACL reconstruction and a smoother rehabilitation process.[12,19]

Table 1. Preoperative Rehabilitation of Anterior Cruciate Ligament Injury[12]

Rehabilitation Phase	Goal(s)	Exercise(s)
Acute Phase	No knee joint effusion, full active and passive range of motion, straight leg raise without lag	Active and passive range-of-motion exercises • Quadriceps sets • Active straight leg raise • Prone hang • Heel slides Management of effusion • Adjustment of loading Management of pain • Cryotherapy
Intermediate Phase	Control of terminal knee extension in weight-bearing positions, 80% quadriceps strength symmetry, 80% hop test symmetry with adequate movement quality	Neuromuscular training • Perturbation training • Balance training • Agility drills • Plyometrics Progressive muscle strength exercises • Progressive load training with “+2 principle”

Effective rehabilitation relies on collaboration between the physician, physical therapist, and patient. Referral to a skilled rehabilitation clinician is essential to develop a tailored exercise plan, with follow-up visits typically scheduled biweekly to monitor progress. Patients must have access to appropriate facilities to perform their prescribed exercises, which may need to be performed daily or several times per week. Clear communication between the physician and rehabilitation clinician is critical to ensure optimal care. Patients

should be referred back to the physician if new knee injuries, recurrent instability, or complications arise, such as failed meniscal repair or limited passive extension indicative of cyclops lesions.[12]

The benefits of PreHab extend beyond athletic populations, offering non-athletes an opportunity to improve knee function and consider conservative management options. Tailoring PreHab programs to individual needs ensures patients are well-prepared for surgery, experience fewer complications, and achieve better long-term outcomes, facilitating a successful return to desired activities.[12]

Post Operative Preparation for ACL Reconstruction

Postoperative preparation encompasses a structured approach to rehabilitation designed to optimize surgical outcomes and facilitate a safe return to daily activities or sports. This process involves progressive phases of physical therapy, with a focus on pain management, restoring range of motion, rebuilding muscular strength, and re-establishing neuromuscular control. Additionally, psychological preparation is increasingly recognized as a significant factor influencing adherence to rehabilitation protocols and overall recovery success.[20]

The current body of literature addressing criterion-based rehabilitation protocols following ACL reconstruction demonstrates significant variability and lack of consensus. Despite the abundance of research on ACL reconstruction, there remains no clear agreement regarding optimal strategies for weight-bearing, range of motion (ROM), or the initiation and progression of a structured strength training program, including running and return-to-sport activities. Then, in 2018, Brett et al. divided the criteria for post-operative ACL rehabilitation into four phases. The four phases are as follows:[20]

Phase 1: Protection, Range of Motion, and Muscle Initiation (0–6 Weeks)

First phase of postoperative rehabilitation following ACL reconstruction focuses on protecting the repaired ligament, restoring knee range of motion (ROM), initiating quadriceps activation, and managing joint effusion. This phase sets the foundation for successful progression through subsequent stages of rehabilitation. Patients are typically fitted with a postoperative hinged knee brace set to allow 0–90° of knee motion during gait activities for six weeks. Partial weight-bearing (PWB) ambulation is recommended immediately post-surgery, with a gradual progression to full weight-bearing by two weeks. Crutches are discontinued once patients achieve a non-antalgic gait and demonstrate the absence of extension lag during a straight leg raise.[21]

Restoring knee ROM is a critical component of phase 1, as it helps reduce postoperative complications and improves long-term outcomes. Passive ROM exercises, such as edge-of-table flexion and wall slides, are prioritized because they do not place undue stress on the reconstructed ligament. Patients are encouraged to progress their ROM based on pain tolerance, with >110° of passive knee flexion typically allowing them to initiate stationary cycling without resistance.[22] Tibiofemoral extension is supported through techniques like posteriorly directed femoral glides and external rotary mobilization. Establishing full passive patellofemoral motion through patellar mobilizations in superior/inferior and medial/lateral directions further ensures joint flexibility and minimizes adhesions, which could otherwise restrict knee mobility and increase joint contact pressures.[22–24]

Effusion management is essential during this phase, as excessive swelling can inhibit quadriceps activation, limit ROM, and hinder rehabilitation progress. Effusion typically peaks around the third postoperative day and subsides by the end of Phase 1 at six weeks. Techniques such as lymphedema massage, pneumatic compressive devices, elevation, and active muscle pumps from the quadriceps and calves are employed to reduce joint swelling. Rehabilitative specialists are also encouraged to gradually stress the tissues within their tolerance to prevent exacerbating effusion.[20,21]

Quadriceps atrophy is another common concern following ACL reconstruction and can impair knee extension and gait mechanics. Quadriceps training begins immediately post-surgery with isometric exercises performed in terminal knee extension. As tolerated, patients progress to short-arc open kinetic chain exercises, targeting 30° to full terminal extension. These exercises activate all quadriceps muscles effectively while minimizing strain on the ACL, comparable to closed kinetic chain squats. Progression to the next phase of rehabilitation requires achieving specific milestones, including near-symmetric ROM, swelling reduction, and restored quadriceps activation.[20,25]

Phase 2: Periodized Strength Development –

Muscular Endurance (7–14 Weeks)

After the protection phase, rehabilitation progresses to a structured strength development program focusing on muscular endurance, strength, and power. This phase addresses type 1 muscle fiber atrophy, commonly seen after ACL injuries due to arthrogenic inhibition where muscles surrounding a joint fail to activate properly. Type 1 fibers, known for their endurance capabilities, are targeted using low-intensity, high-repetition exercises to build a foundational endurance base. Rehabilitation programs typically incorporate light to moderate loads of less than 50% of the patient's one-repetition maximum (1RM), performed for more than 15 repetitions.[26] The American College of Sports Medicine (ACSM) guidelines recommend two to four sets per session, with rest periods under 90 seconds, allowing sufficient recovery and consistent progress.[27]

Quadriceps strengthening is a key focus during this phase, alongside major lower-limb muscle groups, as their function is critical for knee joint stability and effective rehabilitation. Exercises progress from bilateral (double-leg) to unilateral (single-leg) activities to enhance strength symmetry and neuromuscular control. Single-leg exercises, such as squats, are emphasized due to their predictive value for frontal plane kinematics and their relevance in return-to-sport assessments. Tools like the Y-Balance Test and single-leg squats from a 10-inch step allow clinicians to evaluate strength, stability, and trunk, hip, and knee alignment in the surgical limb. These objective measures track progress and help guide individualized rehabilitation strategies.[20]

Strength progression is monitored using metrics like the back squat and leg press relative to body weight, with specific benchmarks for males (1.25x body weight for 10 reps) and females (0.8x body weight for 10 reps). A quadriceps symmetry index of 80% compared to the non-surgical leg serves as an additional indicator of recovery. Incorporating endurance-based strength training 2–3 times per week, with at least 48 hours of rest between sessions, ensures optimal muscle adaptation without overloading the joint or soft tissues. This systematic approach lays the groundwork for advanced rehabilitation phases by restoring strength and functional stability in the affected limb.[20,28]

Phase 3: Periodized Strength Development – Muscular Strength (15–21 Weeks)

In Phase 3 of rehabilitation, the focus shifts from muscular endurance to regaining muscular strength through a structured, periodized program. This phase emphasizes the strengthening of type II muscle fibers, which are responsible for generating power and force. The exercise regimen involves moderate to heavy loads, ranging from 60–67% of the patient's one-repetition maximum (1RM), with repetitions and sets tailored to the patient's prior experience—typically 1–12 repetitions and 2–6 sets per session. Rest periods of 2–5 minutes between sets are recommended to ensure adequate recovery and optimal performance. Additionally, a "de-loading week" every four weeks, using 50–60% of resistance, allows for recovery of the muscles and soft tissues, minimizing the risk of overtraining.[20]

This phase also introduces a running progression for patients whose activities involve running. The initiation of running is based on strength benchmarks, such as achieving a quadriceps symmetry index of 90%, which correlates with normal jogging mechanics.[25] A staged running program begins with reduced weight-bearing on devices like the Alter-G treadmill or in water at chest depth. Gradual increases in weight-bearing are made by 5% per session, with clinical judgment guiding adjustments to minimize pain and swelling. Upon completing pain-free running for 20 minutes, agility drills are introduced at low intensity and single-plane movements, gradually increasing in intensity and complexity to prepare for multidirectional sports activities.[20]

Advancement from Phase 3 to Phase 4 is determined by objective criteria, including achieving 80% of the predicted 10-repetition maximum for back squats or leg presses, a quadriceps symmetry index of 90%, and a hamstring-to-quadriceps strength ratio of 60%. Other benchmarks include the Y-Balance Test (with a 4 cm difference or less between limbs), girth measurements within 1 cm of the non-surgical leg, and successful completion of the single-leg drop test, measured with an inertial measurement unit (IMU) to assess neuromuscular control. Meeting these criteria ensures the patient is prepared to return to practice and advance to the final phase of rehabilitation.[20]

Phase 4: Periodized Strength Development – Muscular Power, Speed, and Agility (22+ Weeks)

Phase 4 focuses on developing muscular power, speed, and agility to prepare the patient for a full return

to sport. Unlike traditional time-based models, this phase emphasizes a criterion-based approach, which incorporates objective measures to assess readiness for unrestricted activity. Rehabilitation in this phase is tailored to replicate the specific physical demands of the sport or activity, requiring the rehabilitative specialist to design personalized programs. Exercises in this phase include power development activities using 30% of the patient's repetition maximum for athletic performance or 75–90% of the patient's repetition maximum for enhancing movement speed and force production. These are typically performed in short, intense sessions to prevent fatigue and maximize effectiveness.[20,29]

The progression in Phase 4 includes continuing strength maintenance alongside activities that develop explosive power, agility, and speed. Indicators of readiness for sport include achieving a 90% or greater score on the 10-repetition maximum squat or leg press, maintaining symmetry in quadriceps strength and girth, and passing functional tests like the Y-Balance Test and Vail Sports Test. Additional assessments such as the single-leg hop and box drop tests are used to evaluate neuromuscular control and dynamic strength. Agility tests, including the modified T-test, further determine the patient's ability to tolerate sport-specific movements. The focus remains on optimizing performance while minimizing the risk of re-injury.[20]

Ultimately, the decision for return to unrestricted sports is collaborative, involving the patient, physician, and therapist. While the current approach combines evidence from reconstruction procedures and physiological healing timelines, there remains a need for further research to validate the effectiveness of these strategies in improving long-term outcomes. Nonetheless, this phase provides a structured framework to guide patients through the final stages of recovery and safely transition back to their desired activities.[20,30]

Conclusion

ACL injuries are common among athletes, often caused by non-contact actions like sudden pivots or improper landings.[8] One of the primary management options for ACL injuries, especially in cases of complete tears or significant instability, is surgical intervention in the form of ACL reconstruction. Preoperative and postoperative preparations in ACL reconstruction are crucial for achieving the best surgical outcomes.[1,5] Preoperative preparation, or prehabilitation, focuses on reducing swelling, restoring full range of motion, and improving quadriceps strength, while postoperative preparation involves a structured rehabilitation program designed to restore knee stability, rebuild strength, and improve overall function.[11,20]

In summary, managing ACL injuries effectively requires a systematic, evidence-based approach that combines advanced surgical techniques, like ACL reconstruction, with personalized rehabilitation plans. Collaboration between physicians, physical therapists, and patients is essential, with progress closely monitored through measurable benchmarks to ensure a smooth recovery and a safe return to activities.

Limitations OF This Study

This study has several limitations. First, it relies on previously published studies, which may introduce selection bias. Second, while it highlights the importance of preoperative and postoperative rehabilitation, it doesn't provide a comprehensive analysis of variations in rehabilitation protocols or their effectiveness long-term. Third, the review does not account for individual patient factors, such as age, sex, activity level, or psychological readiness, which can significantly influence recovery outcomes. Lastly, further research are needed to optimize prehabilitation and rehabilitation strategies and establish a standardized prehabilitation and rehabilitation protocols, ensuring improved long-term outcomes and minimizing the risk of re-injury. Future studies, including high-quality randomized controlled trials, are needed to establish standardized rehabilitation protocols and optimize long-term functional recovery after ACL reconstruction.

Conflict of Interest

The authors declare no conflicts of interest.

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