Rehabilitation and Return to Play After Anatomic Anterior Cruciate Ligament Reconstruction

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KEYWORDS

• Anterior cruciate ligament • Surgery • Knee • Rehabilitation

KEY POINTS

- Anterior cruciate ligament (ACL) reconstruction is one of the most common orthopedic surgical procedures.
- Evidence-based rehabilitation after ACL reconstruction is important to permit the individual to return to their previous level of activity and to minimize the risk for reinjury or injury to the contralateral knee.
- Rehabilitation after ACL reconstruction should consider control of postoperative pain and swelling, protection of the healing graft, restoration of full range of motion symmetric to the contralateral knee, strengthening of the muscles that stabilize the knee, hip, and trunk, enhancing neuromuscular control, and a gradual progression to functional activities that are required for return to sports.
- Recent advances towards anatomic ACL reconstruction, which focuses on restoring normal anatomy and function of the ACL, have important implications for rehabilitation.

INTRODUCTION

Rehabilitation after anterior cruciate ligament (ACL) reconstruction has evolved over the past 20 years and continues to advance rapidly. The evolution in rehabilitation after ACL reconstruction is in part a result of the development of different surgical procedures that address ACL injuries. In particular, recent efforts to anatomically reconstruct the ACL, which is defined as the functional restoration of the ACL to its native dimensions, collagen orientation, and insertion sites[1] is an important consideration for postoperative rehabilitation. Anatomic ACL reconstruction may result in a more

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rapid return of range of motion (ROM); however, the in situ forces in an anatomically placed graft are greater (comparable with the native ACL) than those in a nonanatomically placed graft (less force than the native ACL as a result of nonanatomic position of the graft).[2] As a result, rehabilitation and return to sport after anatomic ACL reconstruction may need to be progressed slower than after traditional, nonanatomic ACL reconstruction.

Other factors that have influenced advances in rehabilitation after ACL reconstruction include our understanding of the importance of early motion, prevention of joint stiffness, development of neuromuscular control, and the influence of the trunk and hips on function of the knee has greatly influenced the evolution of ACL rehabilitation. However, despite the advances in surgery and rehabilitation, the optimal rehabilitation program is still debatable and depends on the surgical procedure to reconstruct the ACL, concomitant surgical procedures that were performed, the individual's previous level of activity and fitness, response to surgery and rehabilitation, and desired activity level after surgery.

The safety and speed of returning patients to activity and sports after ACL reconstruction depends on the rehabilitation protocol. Initial protocols for ACL rehabilitation favored immobilization and only limited protected motion. Based on the observed problems with joint stiffness, more aggressive accelerated protocols that allowed early full ROM and immediate weight bearing became more widely accepted.[3–5] A randomized clinical trial conducted by Beynnon and colleagues[6] reported that no adverse effects were associated with accelerated versus traditional nonaccelerated rehabilitation in patients who underwent bone-patellar tendon-bone ACL reconstruction. In a recent systematic review, Wright and colleagues[7] evaluated studies that investigated accelerated rehabilitation. In addition to the randomized trial conducted by Beynnon and colleagues,[6] the systematic review identified 1 other study that reported no significant differences between a 6-month or 8-month rehabilitation program at 12 months.

The progression of rehabilitation after ACL reconstruction is affected by several factors. These factors include whether the surgical procedure was anatomic or nonanatomic, graft type, the presence of associated injuries (eg, meniscus tear, multiple ligament injury, chondral damage), and individual patient variation. Several goals remain constant for rehabilitation after ACL reconstruction regardless of the surgical procedure. Emphasis is placed on early ROM, preservation of quadriceps function, and progression of functional activities and not exceeding the limits of the involved tissue healing properties.

In this article, the rehabilitation program after (anatomic) ACL reconstruction is divided into 3 phases:

- Early postoperative stage
- Strengthening and neuromuscular control stage
- Return to activity and sports stage.

EARLY POSTOPERATIVE STAGE (FIRST 4–6 WEEKS AFTER SURGERY)

The main goals of this stage (**Table 1**) are to control pain and swelling, protect the healing graft, minimize the effects of immobilization, obtain full passive and active extension of the knee symmetric to the noninvolved knee, achieve 100° to 120° of knee flexion, preserve quadriceps muscle function, restore the ability to perform a straight-leg raise (SLR) without a quadriceps lag, progression to full weight bearing, and achieve normal gait. To progress to the next stage, an individual should be able to walk normally without crutches or gait deviation; have full passive knee extension

Table 1
Summary of the primary goals for each stage of rehabilitation after anatomic ACL reconstruction

Early Postoperative	Strengthening and Neuromuscular Control	Return to Activity and Sports
Controlling pain and edema Protecting the healing graft Minimizing the effects of immobilization Obtaining full passive and active extension of the knee symmetric to the noninvolved knee Achieving 100° to 120° of knee flexion Preserving quadriceps muscle function Restore the ability to perform straight-leg raise without a quadriceps lag Progression to full weight bearing Achieving normal gait	Progression of strengthening Neuromuscular control Improving balance Preparation for the return to activity and sports stage	Complete the entire functional rehabilitation spectrum Make a full return to the patient's previous level of daily, occupational and athletic activity, and sport participation

symmetric to the noninvolved knee, and 100° to 120° of knee flexion; have no evidence of an extensor lag, and minimal effusion or other signs of active inflammation (Table 2).

Controlling pain and swelling is one of the most important goals in the early postoperative rehabilitation stage after ACL reconstruction. Reducing pain and swelling leads to improved ROM and quadriceps function and reduces the risk of limited ROM and contracture, which could later cause gait abnormalities and delay in the progression to the next stage. Control of pain and swelling can be achieved by following the ICE (ice, compression, and elevation) principle. A combination of these techniques results in better outcomes. Cryotherapy has been found to cause significant decrease in

Table 2
Summary of the critical milestones for progression of rehabilitation after anatomic ACL reconstruction

Early Postoperative	Strengthening and Neuromuscular Control	Return to Activity and Sports
Patients should be able to walk normally without crutches or gait deviation Have full passive knee extension symmetric to the noninvolved knee Have at least 100°–120° of knee flexion Have no evidence of an extensor lag Have minimal effusion or other signs of active inflammation	Patients should have no difficulty with daily activities Should tolerate all strength and flexibility exercises without evidence of joint pain or inflammation Should be able to jog 3.2 km (2 miles) (if possible previous to injury) and tolerate submaximal multidirectional functional activities	Patients should achieve a quadriceps index of 85% or greater Have satisfied all the previous criteria (appropriate ROM, strength, proprioception, and endurance) for functional progression Able to tolerate full-effort sprinting, cutting, pivoting, jumping, and hopping drills

postoperative pain.[8] In some challenging cases, nonsteroidal antiinflammatory drugs may be prescribed to control postoperative swelling and inflammation.

To protect the graft early after surgery, crutches and a postoperative brace are used. Patients typically ambulate with axillary crutches weight bearing as tolerated (WBAT), with knee brace locked in full extension for 1 week. After 1 week, unless the patient has a concomitant meniscus repair, the brace can be unlocked for ambulation. If the patient had a meniscus repair, the brace should remain locked in extension for ambulation for 4 to 6 weeks to reduce shear stresses on healing meniscus during ambulation.[9] The brace is continued until the patient has comfortably achieved at least 100° to 120° of knee flexion.

Restoration of ROM is also crucial in this stage. Achieving full extension symmetric to noninvolved knee and 100° to 120° of flexion is important in the early postoperative stage of rehabilitation. If the patient had a concomitant meniscus repair, they progress more slowly because knee flexion should be limited to less than 90° for 4 weeks after surgery. Failure to achieve these ranges may lead to gait abnormalities, patellofemoral pain, and in the long-term may contribute to degenerative joint disease. Activities to increase ROM after ACL reconstruction include the immediate initiation of heel slides, gastrocnemius and hamstring stretches, and passive, active-assisted, and active knee flexion exercises. Pedaling a stationary bicycle through a partial revolution progressing to a full revolution is also beneficial for restoring the range of knee flexion. A continuous passive motion (CPM) device may be used for select cases; however, 2 systematic reviews have shown no substantial advantage for the use of CPM except for a possible decrease in postoperative pain.[10,11] Patellar mobilization is used to maintain or increase patellar mobility. Inferior mobilization for the patella should be used if the patient has loss of passive flexion and decreased inferior patellar translation during mobility testing. Superior glide of the patella is important to ensure full active knee extension, which requires the quadriceps to pull the patella superiorly.

Preservation of quadriceps function in the early postoperative stage of rehabilitation after ACL reconstruction should be emphasized. Early initiation of isometric quadriceps setting exercises that result in superior translation of the patella are begun during the early rehabilitation period. SLR exercises are also initiated at this time. The ability to perform an SLR with the knee at the end range of full extension should be emphasized. The use of high-intensity electrical stimulation after ACL reconstruction has been shown to improve quadriceps strength,[12,13] gait,[13] and patient-reported outcomes.[12,14]

Activities that prepare the individual for progression to full weight bearing and ambulation, improving balance and postural control, and achieving normal gait should also be emphasized during this stage. Weight-shifting exercises should allow the individual to begin accommodating loads through the surgical knee and should be progressed to basic single-leg balance activities as tolerated. Gait training is performed as necessary to ensure that the individual uses a normal heel-toe gait and does not walk with a flexed knee during the midstance of gait.

Progression to full weight bearing and achieving a normal gait are necessary steps before progression to the strengthening and neuromuscular control stage. The patient initially starts walking WBAT with a postoperative rehabilitation brace and crutches, and later may progress to cane as necessary. Criteria for progression to ambulation without assistive devices includes minimal pain and swelling, full passive knee extension symmetric to the noninvolved side, ability to perform an SLR without a quadriceps lag, and demonstration of the ability to walk with a normal gait pattern without assistive devices.

As the patient continues to progress toward full weight-bearing status, therapeutic activities for all other muscles of the lower extremity should be advanced. Flexibility and strengthening exercises for the hip muscles, hamstring, gastrocnemius, and soleus muscles should be initiated and emphasized. SLR exercises in all planes of motion and use of a stationary bicycle with low resistance are advocated. However, individuals with a medial collateral ligament (MCL) injury or who underwent MCL repair should defer hip adduction exercises for 4 to 6 weeks after surgery, and those undergoing ACL reconstruction with a hamstring tendon or those who have undergone concomitant meniscus repair should defer resisted hamstring exercises until 6 weeks after surgery.

STRENGTHENING AND NEUROMUSCULAR CONTROL STAGE

The main goals during this stage of rehabilitation are continued progression of strengthening, neuromuscular control, balance activities, and preparation for the return to activity and sports stage (see **Table 1**).

Weight-bearing (closed kinetic chain [CKC]) and nonweight-bearing (open kinetic chain [OKC]) strengthening activities are initiated and progressed during this stage of rehabilitation. The effectiveness, safety, and functional implications of OKC versus CKC exercises have been discussed in the literature. Earlier protocols often emphasized early use of CKC exercises based on assumptions such as CKC activities being more functionally relevant and producing less graft strain secondary to joint compression and cocontraction of the quadriceps and hamstrings. It has been suggested that the OKC knee extension should be avoided because of increased ACL strain with extension in the range of 45° to full extension. However, evidence suggests that CKC and OKC activities produce similar levels of strain on the ACL and graft.[15,16] During OKC knee extension, the amount of strain increases as resistance is added, whereas ACL strain does not increase with increased loading of CKC activities. Patellofemoral contact stress increases between 45° and 20° of extension during OKC knee extension, and with increasing knee flexion during CKC activities. The effect of graft strain during OKC or CKC on graft healing is still unknown. A recent systematic review by Trees and colleagues[17] found no differences between groups using CKC and OKC exercises after ACL reconstruction in knee function, patellofemoral pain severe enough to restrict activity at 1 year, or knee laxity at 1 year. Although there is a debate in the literature regarding the advantages and disadvantages of nonweight-bearing and weight-bearing exercises, a review of available data suggests that a combination of both OKC and CKC exercises is helpful when appropriate precautions are taken to protect the healing graft and avoid excessive stress to the patellofemoral joint.[18–21] Also, the combination of these 2 exercises resulted in more frequent return to sport 2.5 years after ACL reconstruction compared with weight-bearing exercise only.[17]

To minimize strain on the healing graft, limited arc of motion between 90° and 60° for nonweight-bearing knee extension exercises for the first 3 months after surgery are recommended. After 3 to 4 months, we encourage OCK knee extension exercises through the full arc of motion as tolerated by the patellofemoral joint. OKC knee flexion can be performed to increase strength of the hamstrings, but is avoided for the first 4 to 6 weeks after surgery when a meniscus repair has been performed.

For the first 3 months after surgery, weight-bearing exercises between 0° and 60° are recommended to minimize complaints of patellofemoral symptoms. These exercises include for example wall slides, partial squats with symmetric weight distribution on both legs, weight-bearing terminal knee extension (with therapeutic tubing or other form of external resistance), and low-resistance, limited-arc leg press with a functional progression to step-up activities. Progressing from double-leg to single-leg extension activities aids in avoiding compensation using the nonsurgical extremity. After 3 to 4 months, the ROM for CKC exercises may be progressed to 75° to 90° of knee flexion. At this point during the rehabilitation program, CKC exercises may include double-leg and single-leg squats and leg press, lunges, and higher-level step-up/step-down exercises. As part of the strengthening progression, the eccentric component of exercises should be emphasized. Eccentric exercises have been found to be effective in increasing muscle strength and functional performance after ACL reconstruction.[22,23]

Activities and exercises emphasizing hip and lumbopelvic stabilization are also suggested. The role of appropriate hip abductor and external rotator strength has been described in the literature.[24,25] Weakness of the hip abductors and external rotators has been found to be associated with valgus collapse of the knee and noncontact ACL injuries.[26–28] Exercises including side-lying hip abduction and extension, lateral side support, resisted hip rotation, and lateral and diagonal walking against elastic bands for resistance are used to strengthen the hip abductors and external rotators. Weakness of the core trunk stabilizers has also been found to contribute to the risk of ACL injury. Therefore, rehabilitation after ACL reconstruction should include exercises that include activities that focus on transverse abdominus contraction, pelvic tilts, bridging, lateral side support, and activities that use the multifidus muscle group and paraspinal musculature. An advancement of these exercises with more functional approach is recommended.

Early in the strengthening and neuromuscular control stage, patients may begin to perform low-impact aerobic exercise. Appropriate activities include exercise on a stepper, pedaling a stationary bicycle ergometer, walking on an elliptical machine or treadmill, and aquatic jogging or swimming. As endurance activities are progressed, the patient should be monitored for the presence of swelling, pain, or other signs of inflammation.

As part of the functional progression, balance and perturbation activities should also be included. Two of the main impairments that patients may experience after ACL injury are lack of muscle strength and neuromuscular control of the lower extremity.[29] Evidence has shown that patients with ACL injury may develop an adaptive motor pattern and coping mechanism that cause biomechanical alterations, which increase dynamic stability and improve function of the knee.[30,31] Therefore, emphasis is placed on developing compensatory lower extremity muscle activity patterns that promote functional stability.

Perturbation training techniques have been found to be effective in enhancing neuromuscular control in patients undergoing nonoperative treatment after ACL injury.[32] We believe that perturbation training techniques are also beneficial after ACL reconstruction. Such techniques include the use of a roller board and tilt board, with application of controlled perturbation forces, which are progressed to random perturbations over time (**Fig. 1**). These techniques can also be modified so that patients can experience the perturbations during performance of activity-related tasks, which may enhance carry-over of learned protective responses to functional performance situations. Several studies have shown that hamstring reaction time and functional ability were improved after training with these techniques.[33,34] Reflex activity of the hamstring muscles after a direct stress placed on the ACL has been found to be a critical factor for dynamic knee stabilization.[35]

Balance training progression guidelines have been described in the literature.[36–38] Initially, tasks should be introduced in a predictable fashion on a stable surface. Over time, balance activities should be progressed to more complex tasks, with minimal cues. Increased task complexity can be achieved by changing surface variability through the use of foam surfaces or a tilt board. Positional cues can be given

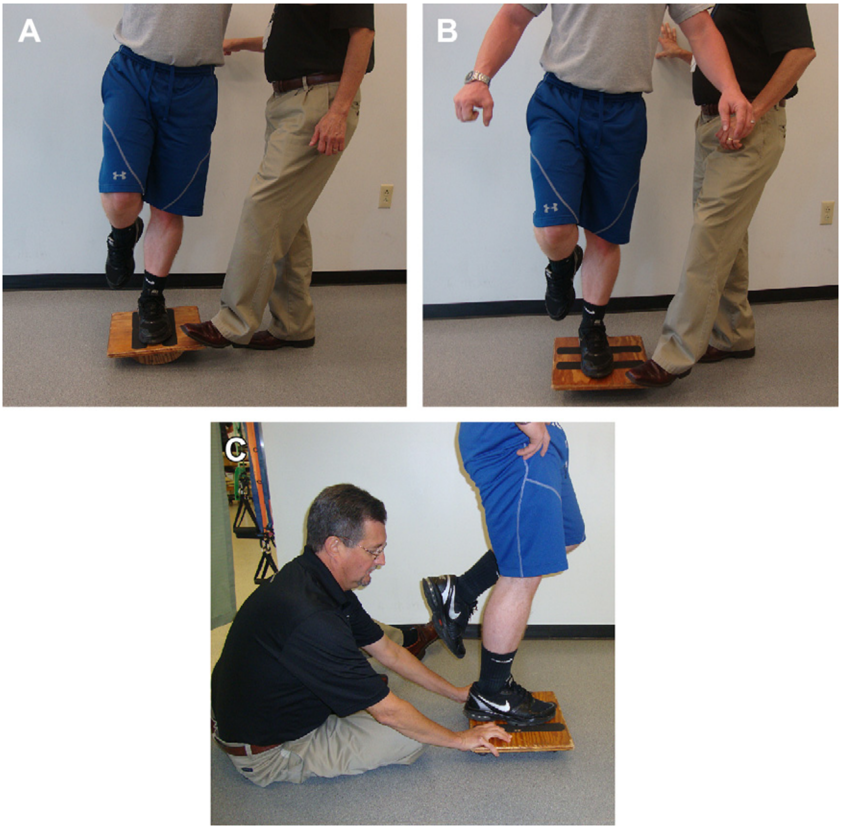

Fig. 1. Tilt board (*A* and *B*) and roller board (*C*) perturbations. Patient stands with operated leg over the tilt board or roller board. The therapist applies controlled perturbation forces that are progressed to random perturbations over time.

less often, and additional activities such as throwing and catching objects ensure an increase in task difficulty. Appropriate strength, ROM, and stability during basic perturbation and balance activities help ensure an adequate foundation on which more advanced functional activities can be built.

At the end of the strengthening and neuromuscular control stage, any residual strength and flexibility deficits that remain should be resolved. Progression with running may be initiated at this point, provided the patient meets specific strength requirements to advance with specific functional activities. Quadriceps strength should be assessed quantitatively. This assessment may include isometric testing with a hand-held dynamometer or isokinetic dynamometer, isokinetic testing, or a single-repetition maximum quadriceps strength test. Minimum quadriceps strength index values of 70% to 75% for running, 80% for submaximal agility training, and 85% for sport-specific skill training are recommended. In addition, to begin a jogging program, the patient should have full, pain-free ROM with no pain or swelling or evidence of patellofemoral symptoms and should be able to walk briskly for 15 minutes without gait deviations or symptoms.

When the patient meets these criteria, they can begin a jogging program. We recommend starting to run at a slow pace on a treadmill or over ground for 5 to 10 minutes every other day. The running program is gradually increased and progressed by 10% to 15% per week if the patient does not develop pain, swelling, or gait asymmetries. During this time, the patient can also be progressed to low-level submaximal (less than 50% effort) agility drills, including side-to-side shuffling, forward and backward running, and jumping and landing on both limbs simultaneously from distances less than 50% of the individual's height. These activities can be progressed to carioca drills and cone drills, which involve changing directions at various angles. Once proficiency of jogging and submaximal agility drills is shown, the patient should be evaluated to determine if they are a candidate for progressing toward a return to full activity and sport.

After successful completion of these activities, the individual should have no difficulty with daily activities. All strength and flexibility exercises should be tolerated without evidence of joint pain or inflammation. The patient should be able to jog 3.2 km (2 miles) (if possible previous to injury) and tolerate submaximal multidirectional functional activities (see **Table 2**).

RETURN TO ACTIVITY AND SPORTS STAGE

The final stage of rehabilitation after ACL reconstruction is the stage of returning to full activity and sports participation. The time to return to full activity and sport is variable and depends on several factors. Some of these factors are graft type, graft healing and maturation, the concomitant surgical procedures, individual patient tolerance for the activities, surgeon preferences, and the physical demands of the sport. The primary goals during this final stage (see **Table 1**) are to complete the entire functional rehabilitation spectrum and make a full return to the patient's previous level of daily, occupational, and athletic activity, and sports participation. During this stage of rehabilitation, emphasis is placed on a gradual increase in function that culminates in return to sport. Strengthening exercises through the full ROM and activities to enhance neuromuscular control are also continued to ensure full recovery and maintenance of strength and dynamic stability. Once the patient has achieved a quadriceps index of 85% or greater and has satisfied all the previous criteria (appropriate ROM, strength, proprioception, and endurance) for functional progression, they can begin full-effort sprinting, cutting, and plyometric activities. These activities may then be integrated into a sport-specific training program.

Plyometric activities should be prescribed in a manner that allows the patient to improve power and performance in relation to their sport and ensure an appropriate level of safety. Initially, activities focusing on landing and the appropriate attenuation of force through the lower extremity should be used. Such activities include double-leg jumping, single-leg jumping, and stepping off plyometric drill boxes. Activities can be made more challenging by changing height and distance of jump, time of drills, direction, and combining multiple tasks.

Once the patient is able to tolerate full-effort sprinting, cutting, pivoting, jumping, and hopping drills, return to sport can be considered (see **Table 2**). A functional brace may be considered for those individuals returning to strenuous sports. The use of a functional brace has been found to be beneficial in decreasing the risk of subsequent knee injury compared with not using them for patients with high-demand sports after ACL reconstruction.[39] However, the use of functional bracing after ACL reconstruction is still a source of debate. During this time, the patient can also be progressed to more specific sport-related exercises. Initially, training should begin with unopposed components of the individual's athletic activity. As the patient becomes proficient and can perform these tasks safely, speed and complexity should be increased. Opposition from other players should be introduced as tolerated. To return to full participation in sports, the patient should be progressed from partial return to practice to full return to practice, followed by return to competition.

SUMMARY

Rehabilitation after ACL reconstruction is one of the main factors that contributes to safe and full return of the individual to functional activities and sports participation after ACL injury. An appropriate rehabilitation program should reflect the advancement and changes in the surgical procedures of ACL reconstruction. There is no consensus in the literature regarding the optimal rehabilitation program and time to return to sports after ACL reconstruction. However, established rehabilitation guidelines for graft protection and functional progression should be followed.

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