

# ACL Rehabilitation Progression: Where Are We Now?

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## Abstract

**Purpose of Review** With the increase of publications available to the rehabilitation specialist, there is a need to identify a progression to safely progress the patient through their post-operative ACL reconstruction rehabilitation program. Rehabilitation after ACL reconstruction should follow an evidence-based functional progression with graded increase in difficulty in activities.

**Recent Findings** Clinicians should be discouraged not to use strict time frames and protocols when treating patients following ACL reconstruction. Rather, guidelines should be followed that allow the rehabilitation specialists to progress the patient as improvements in strength, edema, proprioception, pain, and range of motion are demonstrated. Prior to returning to sport, specific objective quantitative and qualitative criteria should be met. The time from surgery should not be the only consideration.

**Summary** The rehabilitation specialist needs to take into account tissue healing, any concomitant procedures, patellofemoral joint forces, and the goals of the patient in crafting a structured rehabilitation program. Achieving symmetrical full knee extension, decreasing knee joint effusion, and quadriceps activation early in the rehabilitation process set the stage for a safe progression. Weight bearing is begun immediately following surgery to promote knee extension and hinder quadriceps inhibition. As the patient progresses through their rehabilitative course, the rehabilitation specialist

should continually challenge the patient as is appropriate based upon their goals, their levels of strength, amount of healing, and the performance of the given task.

**Keywords** Knee · Cruciate · Rehabilitation · Progression · Guideline · Criteria

## Introduction

Over 200,000 anterior cruciate ligament (ACL) injuries occur in the USA annually [1]. It is estimated that more than half of these injuries undergo surgical reconstruction [2]. Following ACL reconstruction (ACLR), under the direction of the orthopedic surgeon, the rehabilitation specialist is charged with the responsibility of returning the patient to their pre-injury level of function. Post-operative rehabilitation programs have changed dramatically over the past couple of decades. Strict protocols based on time elapsed from surgery have been replaced by criteria based guidelines (Table 1). These guidelines follow a progression where selective criteria are met prior to advancement in the program. This paper will discuss the progression of rehabilitation following ACL reconstruction.

A functional progression was defined by Kegerreis [3] as an ordered sequence of activities enabling the acquisition or reacquisition of skills required for the safe and effective performance of athletic endeavors. In other words, the patient needs to master a simple activity before advancing to a more demanding activity. Programs are individualized, where some patients will be ready to advance sooner than others. Biological factors such as graft revascularization and maturation as well as fixation techniques are also considered to ensure a safe progression through the ACLR rehabilitation program.

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**Table 1** Anterior cruciate ligament (BTB) rehabilitation guideline

Post-operative phase I (weeks 0–2)

Goals:

- Emphasis on full passive extension
- Control post-operative pain/swelling
- Range of motion 0° → 90°
- Early progressive weight bearing
- Prevent quadriceps inhibition
- Independence in home therapeutic exercise program

Precautions:

- Avoid active knee extension 40° → 0°
- Avoid ambulation without brace locked at 0°
- Avoid heat application
- Avoid prolonged standing/walking

Treatment strategies:

- Towel extensions, prone hangs, etc.
- Quadriceps re-education (quad sets with EMS or EMG)
- Progressive weight bearing
- PWB → WBAT (patella tendon) with brace locked at 0° with crutches
- Patella mobilization
- Active flexion/active-assisted extension 90° → 0° exercise
- SLR's (all planes)
- Brace locked at 0° for SLR (supine)
- Short crank ergometry
- Hip progressive resisted exercises
- Proprioception board/balance system (bilateral weight bearing)
- Leg press (bilateral/80° → 5° arc) (if ROM >90°)
- Upper extremity cardiovascular exercises as tolerated
- Cryotherapy
- Home therapeutic exercise program: evaluation based
- Emphasize patient compliance to home therapeutic exercise program and weight bearing precautions/progression

Criteria for advancement:

- Ability to SLR without quadricep lag
- ROM 0° → 90°
- Demonstrate ability to unilateral (involved extremity) weight bear without pain

Post-operative phase 2 (weeks 2–6)

Goals:

- ROM 0° → 130°
- Good patella mobility
- Minimal swelling
- Restore normal gait (non-antalgic)
- Ascend 8" stairs with good control without pain

Precautions:

- Avoid descending stairs reciprocally until adequate quadriceps control and lower extremity alignment
- Avoid pain with therapeutic exercise and functional activities

Treatment strategies:

- Progressive weight bearing/WBAT (patella tendon) with crutches brace opened 0° → 50°, if good quadriceps control (good quad set/ability to SLR without lag or pain)
- D/C crutches when gait is non-antalgic
- Brace changed to MD preference (OTS brace, patella sleeve, etc.)
- Standard ergometry (if knee ROM >115°)
- Leg press (90° → 0° arc)
- AAROM exercises
- Mini squats/weight shifts
- Proprioception training: prop board/balance system/contralateral Theraband exercises
- Initiate forward step-up program
- Stairmaster
- Aquaciser (gait training) if incision benign
- SLR's (progressive resistance)
- Hamstring/calf flexibility exercises
- Hip/hamstring PRE
- Core stabilization exercises
- Retrograde incline treadmill ambulation
- Active knee extension to 40°
- Home therapeutic exercise program: Individualized

Criteria for advancement:

- ROM 0° → 125°

**Table 1** (continued)

- Normal gait pattern
- Demonstrate ability to ascend 8" step
- Good patella mobility

Post-operative phase 3 (weeks 6–14)

Goals:

- Restore Full ROM
- Demonstrate ability to descend 8" stairs with good leg control without pain
- Improve ADL endurance
- Improve lower extremity flexibility
- Protect patellofemoral joint

Precautions:

- Avoid pain with therapeutic exercise and functional activities
- Avoid running and sport activity till adequate strength development and MD clearance

Treatment strategies:

- Progress squat program
- Initiate step down program
- Leg press
- Lunges
- Isometric → isotonic knee extensions 90° → 40°
- Advanced proprioception training (perturbations)
- Agility exercises (sport cord)
- Retrograde treadmill ambulation/running
- Quadriceps stretching
- KT 1000 knee ligament arthrometer exam at 3months
- Home therapeutic exercise program: evaluation based

Criteria for advancement:

- ROM to WNL
- Ability to descend 8" stairs with good leg control/alignment without pain
- Functional progression pending KT1000 and functional assessment

Post-operative phase 4 (weeks 14–22)

Goals:

- Demonstrate ability to run pain free
- Maximize strength and flexibility as to meet demands of activities of daily living
- Isokinetic test ≥85% limb symmetry

Precautions:

- Avoid pain with therapeutic exercise and functional activities
- Avoid sport activity till adequate strength development and MD clearance

Treatment strategies:

- Start forward running (treadmill) program when 8" step down satisfactory
- Continue LE strengthening and flexibility programs
- Advance agility program/sport specific
- Start plyometric program when strength base sufficient
- Isotonic knee extension (full arc/pain and crepitus free)
- Isokinetic training (fast → moderate velocities)
- Home therapeutic exercise program: Individualized

Criteria for advancement:

- Symptom-free running
- Isokinetic test ≥85% limb symmetry
- Lack of apprehension with plyometric and agility activities to date

Post-operative phase 5—return to sport (weeks 22–?)

Goals:

- Lack of apprehension with sport specific movements
- Maximize strength and flexibility as to meet demands of individual's sport activity
- Isokinetic test ≥90% limb symmetry
- Hop test ≥90% limb symmetry
- Acceptable quality movement assessment

**Table 1** (continued)

Precautions:
<ul style="list-style-type: none"> <li>▪ Avoid pain with therapeutic exercise and functional activities</li> <li>▪ Avoid sport activity till adequate strength development and MD clearance</li> </ul>
Treatment strategies:
<ul style="list-style-type: none"> <li>▪ Continue to advance LE strengthening, flexibility, and agility programs</li> <li>▪ Advance plyometric program</li> <li>▪ Brace for sport activity (MD preference)</li> <li>▪ Monitor patient's activity level throughout course of rehabilitation</li> <li>▪ Reassess patient's complaint's (i.e., pain/swelling daily—adjust program accordingly)</li> <li>▪ Encourage compliance to home therapeutic exercise program</li> <li>▪ KT 1000 knee ligament arthrometer exam, isokinetic test, hop test(s), quality movement assessment at 6months</li> <li>▪ Home therapeutic exercise program: Individualized</li> </ul>
Criteria for discharge:
<ul style="list-style-type: none"> <li>▪ Isokinetic and functional hop test(s) <math>\geq 90\%</math> limb symmetry</li> <li>▪ Acceptable quality movement assessment</li> <li>▪ Lack of apprehension with sport specific movements</li> <li>▪ Flexibility to accepted levels of sport performance</li> <li>▪ Independence with gym program for maintenance and progression of therapeutic exercise program at discharge</li> </ul>

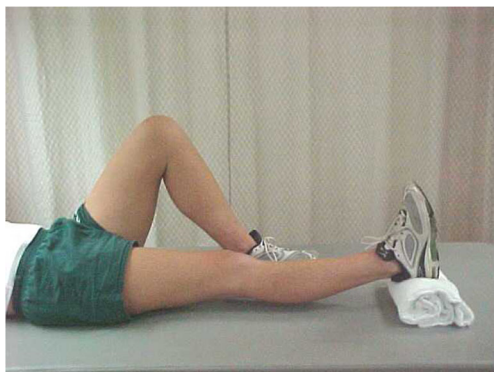
Adapted from “Anterior Cruciate Ligament Reconstruction” Cavanaugh JT, *Postsurgical Rehabilitation Guidelines for the Orthopedic Clinician* Cioppa-Mosca J, Cahill JB, Cavanaugh JT, Corradi-Scalise D, Rudnick H, Wolff AL, (eds) Elsevier Publishers pp.425–438, 2006

## Range of Motion

Following ACLR, achieving full knee extension range of motion (ROM) should be achieved as soon as possible. Extension loss results in abnormal joint arthrokinematics at both the tibiofemoral and patellofemoral joints. This in turn leads to abnormal articular cartilage contact pressures and quadriceps inhibition [4, 5, 6].

Achieving full extension should ideally be achieved preoperatively. McHugh, et al. [7] found that patients with knee extension loss were 5× more likely to have extension loss issues after surgery.

Treatment strategies employed to achieve full extension include low load prolonged stretching (Fig. 1) and calf



**Fig. 1** Passive low load prolonged stretching utilizing a rolled towel under the ankle



**Fig. 2** Active-assisted knee flexion/extension

stretching. Patellofemoral joint mobilizations in a superior direction are utilized to encourage extension ROM [8] Sleeping in a post-operative brace locked at 0° extension is utilized to encourage extension and discourage the formation of a flexion contracture during the night hours. Full extension is one of several important criteria to meet to safely progress the patient off their crutches after surgery.

ROM exercises to facilitate flexion begin immediately after ACLR. ROM flexion goals of 120° should be met 4 weeks following surgery and full symmetrical flexion achieved by 12 weeks. Treatment strategies begin with active-assisted ROM exercises off the side of a plinth or bed (Fig. 2). Treatment strategies employed to further progress gains in flexion ROM include wall slides, active-assisted ROM sitting or on a step, and one half moon movement on a stationary bicycle. A short crank ergometer (Fig. 3) is utilized allowing patients to cycle earlier in the rehabilitative process and thus facilitate gains in flexion ROM [9]. Fleming and colleagues [10] demonstrated relatively low ACL peak strain values in vivo during stationary cycling.



**Fig. 3** Short crank bicycle

Inferior-guided patellofemoral joint mobilizations are utilized to encourage gains in knee flexion [8]. When 120° of knee flexion is demonstrated, quadriceps stretching off the side of a plinth (Fig. 4) and eventually in a prone position is introduced to the patient's program. Soft tissue massage can be of particular benefit throughout the progression to restore full symmetrical flexion ROM.

### Post-operative Weight Bearing

Weight bearing progression following ACLR is dictated by graft selection and surgeon preference. Advanced fixation techniques such as cancellous screw bone-to-bone fixation allow for immediate post-operative weight bearing. Following ACLR with an autologous bone-patellar tendon-bone (BTB) graft weight bearing is at first partial (50%) utilizing crutches and subsequently progressed to weight bearing as tolerated (WBAT) on successive days. This progression allows the knee joint to acclimate to increased loads. Ambulating in water, e.g., underwater treadmill (Fig. 5) can be utilized to gradually apply increased load through the knee joint and assist in the development of a normal gait pattern. Walking in chest-deep water results in a 60 to 75% reduction in weight bearing, while walking in waist-deep water results in a 40 to 50% reduction in weight bearing [11, 12].

A post-operative brace is initially locked at 0° for ambulation to protect the harvest site. The brace is opened when quadriceps control is demonstrated by the ability of the patient to straight leg raise (SLR) without a quadriceps lag or complaints of pain. Crutches are then discontinued upon meeting the criteria of demonstrating a normal non-antalgic gait.

A significant decrease in patellofemoral pain has been reported when an immediate progressive weight bearing guideline is utilized [13•]. ACLR's utilizing hamstring or allografts are progressed at a slower rate secondary to the decreased strength of soft tissue fixation and biological considerations, respectively. Weight bearing may be delayed following ACLR's with concomitant articular cartilage or meniscus repair procedures.



**Fig. 4** Quadriceps stretching off the side of a plinth



**Fig. 5** Underwater treadmill (Hudson Aquatic Systems LLC, Angola, IN)

### Strengthening

Re-establishing quadriceps control is an early goal of post-operative ACLR rehabilitation. Controlling post-operative effusion assists in discouraging quadriceps inhibition. Spencer et al. [14] identified that mechanoreceptors in the joint capsule respond to changes in tension and in turn inhibit motor nerves supplying the quadriceps muscles. Therapeutic interventions utilized include the use a commercial cold with compression device (Fig. 6), quadriceps setting with a towel under the knee, and weight bearing with the appropriate amount of load. Should a patient have difficulty eliciting a quadriceps contraction, a biofeedback unit or an electrical muscle stimulator can be used in conjunction with the quadriceps setting exercise to



**Fig. 6** Gameready cold/compression device

better facilitate a quadriceps contraction. Numerous studies [15–17] have demonstrated an earlier return of quadriceps strength after ACLR with the use of electrical stimulation. As quadriceps activation is demonstrated, a key observation in order to progress the patient is seeing the patient perform a straight leg raise without the assistance of the post-operative brace without any complaints of pain or quadriceps lag. When this criteria is met, the post-operative brace can be opened to allow normal knee range of motion during ambulation. Crutches are continued at this point until a non-analgesic gait is demonstrated. Closed kinetic chain exercises including leg press and squats inside a pain free arc of motion are introduced as these activities have been shown to minimize stress to the ACL [18–21, 22, 23]. Limited evidence now demonstrates that open kinetic chain (OKC) exercises inside a 90°–0° arc of motion may not compromise graft laxity.[24–26]. Mikkelsen et al., randomized 44 ACLR (BTB) patients to either a closed chain rehabilitation only program and a closed chain program that added open chain exercises 6 weeks post-operatively. At 6-month follow up, KT-1000 knee ligament arthrometer values showed no significant difference in knee laxity between the groups. A significant increase in quadriceps strength in the open chain group was also identified. With the demonstration of 0°–130° ROM, OKC exercise progression begins with multiangle quadriceps isometrics inside a 90°–40° arc of motion (Fig. 7). Isometric exercises are progressed to isotonic exercises using progressive resistance (PRE). At 3 months, post-operatively isotonic exercise is allowed throughout a full arc of motion and progressed to isokinetic exercises utilizing moderate-fast speeds. Throughout this progression, the rehabilitation specialist should closely monitor the patellofemoral joint for crepitus and complaints of pain.



**Fig. 7** Isometric Knee Extension at 60° knee flexion

## Neuromuscular Training

After ACLR, surgery afferent information is altered, which results in a disruption in the pathway between the patient's center of gravity and base of support [27]. Improving neuromuscular reaction time to imposed loads enhances dynamic stabilization around the knee and thus protects the static reconstructed tissue from overstress or re-injury [28]. As soon as the patient achieves 50% weight bearing, neuromuscular/balance training is initiated on a dynamic balance system (Fig. 8) or proprioception device (foam cushion, rocker board, etc.). Balance activities are then increased progressively to include unilateral weight bearing, use of multiplanar support surfaces, and perturbation training [29]. Activities should attempt to eliminate or alter sensory information from the visual, vestibular, and somatosensory systems so as to challenge the other systems.

## Continued Progression

As range of motion and strength is demonstrated, the patient is instructed in a progressive step-up program, first mastering 6" steps advancing to normal stair height 8" steps. As further strength is demonstrated, a forward step down program is introduced (Fig. 9).



**Fig. 8** Dynamic balance system (Biodex Corporation, Shirley, NY)



**Fig. 9** Forward step down exercise off an 8" step

After 3 months post-op, if ROM is within normal limits and sufficient strength is demonstrated via a pain-free 8" step down without deviation, a running program is started. Backward running is preceded by forward running, as retrograde running has been shown to generate lower patellofemoral joint compression forces than forward running [30]. An Alter G treadmill (Alter G, Inc., Fremont, CA) (Fig. 10) is utilized to incrementally add load during a forward running progression. A running program is progressed with an emphasis on speed over shorter distances vs. slower distance running.



**Fig. 10** Unweighted treadmill (AlterG Inc., Fremont, CA)

Plyometric training is then incorporated only if full ROM, an adequate strength base and flexibility, is demonstrated. Plyometric training should follow a progression with its components of speed, intensity, load, volume, and frequency being monitored and progressed accordingly. Activities should begin with simple drills and advance to more complex exercises (e.g., double leg jumping vs. box drills). Agility and deceleratory training are important interventions to include in the later phases of rehabilitation in preparation for return to sport.

## Return to Sport

When to return to sport following ACLR is a controversial issue. Pinczewski et al. [31] reported that one in four patients undergoing an ACLR will suffer a second tear within 10 years of their first. Paterno et al. [32•] reported an incidence rate of a second ACL injury within 2 years after returning to sports was nearly 6× greater than healthy controls.

More and more surgeons and rehabilitation specialists are utilizing numerous forms of assessment in determining an athlete's readiness to return to play. Subjective rating scales, knee laxity testing, isokinetic testing, functional hop testing, balance testing, and qualitative movement assessment (Fig. 11) are utilized to provide evidence in the decision making process. Acceptable scores on these assessments are required to safely return the athlete to sport. Following discharge from a formal rehabilitation program, volume of athletic exposures needs to be modified.

Several studies have demonstrated deficits in muscular strength, kinesthetic sense, balance, and force attenuation 6 months to 2 years following reconstruction [32•, 33–35]. Return to sport 6 months following ACLR, therefore is no longer the expected norm.



**Fig. 11** Quality movement assessment of a single leg squat exercise

## Summary

Rehabilitation following ACL reconstruction has shifted from a paradigm based on protocols to a progression based program with gradient increases in difficulty. It is the rehabilitation specialist's responsibility to consider the forces placed on the healing ACL graft and patellofemoral contact pressures generated during specific exercises and activities. Early in the rehabilitative process, the focus needs to be on gaining full knee extension, decreasing edema, and developing quadriceps strength. Therapeutic exercises should progress in difficulty often being performed in a variety of positions and settings. Neuromuscular training should be implemented into the rehabilitation program as early as deemed appropriate and progressed accordingly throughout the rehabilitative process. ACLR rehabilitation progression should be based on objective criteria and not just time frames. In order to achieve a successful outcome the rehabilitation specialist must continually assess the patient and select exercises that challenge the patient properly. When the patient is ready to return to sports, objective criteria must be met in order to reduce the risk of further injury. This transition is now considered to take place at greater than 6 months. Exposure/volume to athletic activity needs to be controlled in the post-rehabilitation period.

## Compliance with Ethical Standards

**Conflict of Interest** Both authors declare that they have no conflict of interest.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors. Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

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