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Postoperative Rehabilitation After Posterior Cruciate Ligament Reconstruction and Combined Posterior Cruciate Ligament Reconstruction-Posterior Lateral Corner Surgery

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The management of injuries to the posterior cruciate ligament (PCL) and the posterior lateral corner (PLC) of the knee, although relatively rare, presents a challenge to both orthopedic surgeons and rehabilitation specialists. Injuries to the PCL can occur in isolation or in combination with a PLC injury. Surgical intervention is often warranted with the goal of surgery to have a stable, well-aligned knee and to restore the preinjury kinematics of the knee joint. Principles guiding rehabilitation should be followed following a PCL reconstruction or a combined PCL-PLC surgery. Advancement through the rehabilitative course should be based on meeting set criteria while adhering to set time frames to allow sufficient healing. Therapeutic interventions, when introduced to the rehabilitation program, have sound evidence to support their inclusion. A functional progression is followed throughout the rehabilitative course. Criteria via objective and qualitative measures are used and should be met before allowing an athlete or patient to return to sport or normal activities of daily living. Compliance by a patient throughout the course of rehabilitation is vital in achieving a successful outcome. Oper Tech Sports Med ■■■■-■■■ © 2015 Elsevier Inc. All rights reserved.

KEYWORDS PCL, PLC, Surgery, Knee

Introduction

In the general population, injury to the posterior cruciate ligament (PCL) accounts for approximately 3% of all knee injuries.¹ In patients who present to trauma centers with knee injuries, the incidence is reported as high as 37%.² Isolated PCL injuries may occur at a rate of 40%.³

The most frequent mechanism of injury in isolated PCL tears is a direct blow on the anterior tibia with the knee in the flexed position,⁴ for example, motor vehicle accidents involving the knee hitting the dashboard. In athletics, the

most common mechanism of injury involves a fall on a flexed knee with the foot in a plantar flexed position.^{5,6} The PCL and posterior capsule can also be torn by a hyperextension mechanism.⁷

Most PCL injuries present with concurrent knee injuries, including those to the anterior cruciate ligament (ACL), medial collateral ligament, or posterolateral corner (PLC). Fanelli and Edson⁸ have reported that 62% of PCL injuries in a trauma setting involved a concomitant injury to the PLC.

PLC injuries that present in athletic traumas, motor vehicle accidents, and falls have been reported to account for 16% of knee ligament injuries.⁹ Common mechanisms leading to PLC injuries include a direct blow to the anteromedial aspect of the knee with the knee at or near full extension, contact and noncontact knee hyperextension injuries, valgus contact force applied to a flexed knee, and a severe tibial external rotation torque applied with the knee in flexion or in hyperextension.^{10,11}

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Management of isolated and combined PCL and PLC injuries often negate surgical intervention. This article discusses the current rehabilitation guidelines following surgical reconstruction of these structures.

Principles Guiding Rehabilitation

Communicate With the Surgeon

A successful outcome following surgery can only be facilitated by open communication between the rehabilitation specialist and the surgeon who performed the procedure(s). Surgical procedure performed, graft choice, and fixation method as well as isometric graft placement contribute to a safe postoperative rehabilitation guideline. PCL reconstructions may be performed using a variety of surgical techniques and graft substitutes. Traditional methods use a transtibial technique, whereas more recently, PCL reconstructions have used the posterior inlay technique as well as a 2–femoral tunnel (double bundle) procedure. Achilles tendon allograft (Fig. 1) and bone-patella-tendon-bone autografts are commonly used as graft substitutes.

Surgical treatment of the PLC can vary, depending on the structural involvement and the time frame of the procedure from the date of injury. However, the goals of the reconstruction are the same for all the procedures: to have a stable, well-aligned knee and to restore the preinjury kinematics of the knee joint. Anatomical reconstruction of the fibular collateral ligament, popliteus tendon, and popliteofibular ligament is recommended.¹²

Incorporate the Knowledge of the Basic Sciences

Understanding the anatomical properties and function of the involved structures (PCL and PLC) supports an evidence-based rationale in rehabilitation program design.

The PCL is the stronger and larger of the cruciate ligaments. The PCL is composed of 2 separate bundles: the anterolateral bundle and the posteromedial bundle. The anterolateral bundle is taut when the knee is flexed and the posteromedial bundle is taut when the knee is near extension.¹³ The anterolateral bundle is stronger and stiffer and has a higher ultimate load to failure than the posteromedial bundle.^{14,15}

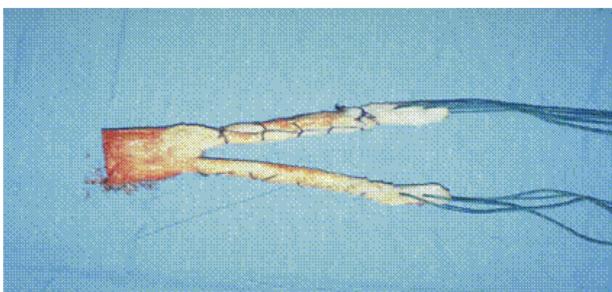


Figure 1 Split Achilles tendon allograft prepared for passage. (Photo courtesy: HSS Sports Medicine Service.) (Color version of figure is available online.)

The PCL has historically been considered a primary restraint to posterior tibial translation. More recent studies have also identified it as a secondary restraint to rotation, particularly between 90° and 120° of flexion.¹⁶

The posterolateral aspect of the knee is a 3-layered complex including the lateral collateral ligament, the popliteofibular ligament, and the popliteus tendon.¹⁷ The PLC has been shown to prevent posterior translation, varus rotation, and external rotation of the tibia.¹⁸

Follow a Functional Progression

A functional progression has been defined by Kegerreis¹⁹ as an ordered sequence of activities that enable the acquisition or reacquisition of skills required for the safe, effective performance of athletic endeavors. To ensure a safe progression, criteria need to be established, whereas a patient demonstrates the mastering of a simple activity before advancing to a more-demanding activity. In rehabilitating a knee following either a PCL or a combination PCL-PLC reconstruction, a rehabilitation specialist should use the following criteria when advancing a patient through the course of rehabilitation:

- Develop quadriceps control or progress range of motion (ROM)
- Establish a normal gait pattern
- Demonstrate the ability to ascend normal steps
- Demonstrate the ability to descend normal steps
- Initiate a running program (if appropriate)
- Initiate a plyometric, sports-specific training program (if appropriate)

Postoperatively, certain time frames need be followed to ensure proper healing. However, a rehabilitation specialist should be sure that certain criteria are indeed met before advancing a patient to more-demanding exercises or activities irrespective of the time elapsed since the operation. Hence, an assessment-based guideline is followed rather than a strict protocol based on the time from surgery. The time frames listed are guidelines to inform therapists and patients regarding what they can expect. Continual reassessment of a patient is vital to ensure a consistent and safe progression of the postoperative rehabilitation program.

Rehabilitation Following PCL Reconstruction

Postoperative Phase I (Postoperative Week 0-6)

Rehabilitation following PCL reconstruction can begin early postoperatively, although in many cases, we immobilize a patient for 4 weeks to allow for improved graft healing and to decrease the risk of laxity related to aggressive early motion (Table 1). Early motion has been shown to minimize the deleterious effects of immobilization, such as articular cartilage degeneration, excessive collagen formation, and pain.²⁰⁻²² Range-of-motion exercises are performed in the sitting

Table 1 Posterior Cruciate Ligament Reconstruction Guideline**Postoperative Phase I (Postoperative Week 0-6)****Goals**

- Control postoperative pain and swelling
- Range of motion $0^{\circ} \rightarrow 90^{\circ}$
- Prevent quadriceps inhibition
- Improve patella mobility
- Independence in home therapeutic exercise program

Precautions

- Avoid active knee flexion
- Avoid heat application
- Avoid ambulation without brace locked at 0°
- Avoid exceeding ROM and weight-bearing limitations
- Avoid pain with therapeutic exercise and functional activities

Treatment strategies

- Passive extension (pillow under calf)
- Quadriceps reeducation (Quad Sets with Electrical Muscle Stimulation (EMS) or Electromyography (EMG))
- Gait: weight-bearing TTWB with brace locked at 0° with crutches
- Progressive weight-bearing at week 2-6 to 75%
- Patella mobilization
- Active-assisted knee extension or passive flexion exercise (ROM $0^{\circ} \rightarrow 70^{\circ}$)
- Progress to 90° as tolerated, week 4-6
- SLRs (supine or prone) brace locked at 0°
- SLRs (all planes) or progressive resistance
- Multiple-angle quadriceps isometrics (ROM $60^{\circ} \rightarrow 20^{\circ}$)
- Leg press (ROM 60° - 0° arc) (bilaterally)
- Proximal (hip) strengthening PREs
- Proprioception training (bilateral weight-bearing)
- Hamstring or calf flexibility exercises
- Short-crank ergometry
- Cardiovascular exercises (UBE, Airdyne, etc) as tolerated
- Cryotherapy
- Emphasize patient compliance to home therapeutic exercise program and weight-bearing precautions

Criteria for advancement

- ROM $0^{\circ} \rightarrow 90^{\circ}$
- Ability to bear 75% weight on involved extremity
- Ability to SLR without quadriceps lag
- Continued improvement in patella mobility and proximal strength

PRE, progressive resistance exercise; TTWB, toe-touch weight-bearing; UBE, upper body exercise.

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position, with the goal of achieving 90° flexion at 6 weeks. If a patient has not achieved 90° flexion at 12 weeks, arthroscopic lysis of adhesions and manipulation under anesthesia should be performed. Subsequently, flexion ROM is advanced slowly as increased strain on the PCL occurs as the knee flexes, with maximum strain recorded at 100° .²³

The patient is taught to passively flex the involved knee with the support of the noninvolved extremity (eccentric quadriceps



Figure 2 Active-assisted knee range of motion. (Color version of figure is available online.)

contraction). The knee is then active assistively extended to 0° via concentric contractions of the bilateral quadriceps muscles (Fig. 2). Achieving full passive extension is seldom a complication following PCL reconstructive surgery, but it must be addressed and achieved in the early postoperative period to ensure proper patellofemoral mechanics. Extension ROM is facilitated by having a patient rest the involved calf on a pillow, allowing gravity to assist in regaining extension (Fig. 3). Patella mobilization is an important intervention during this phase, as flexion is restricted to protect the graft. Normal inferior glide of the patella is necessary for knee flexion²⁴ (Fig. 4).

As PCL graft healing times have been reported to be almost double the time of ACL graft healing, weight-bearing is initially limited and progresses slower than ACL reconstruction rehabilitation.²⁵⁻²⁷

Weight-bearing with crutches is restricted to toe-touch weight-bearing for the first 2 weeks. Weight-bearing is then gradually progressed to partial weight-bearing (50%) by 4 weeks and (75%) weight-bearing by 6 weeks. The brace is kept locked at 0° extension for ambulation during this period to minimize posterior tibial shear forces created by hamstrings activation. Morrison²⁸ reported a posterior tibiofemoral shear force of 0.4 times the body weight during level walking.

Quadriceps strengthening is a central component for PCL reconstruction programs, as the quadriceps serves as a

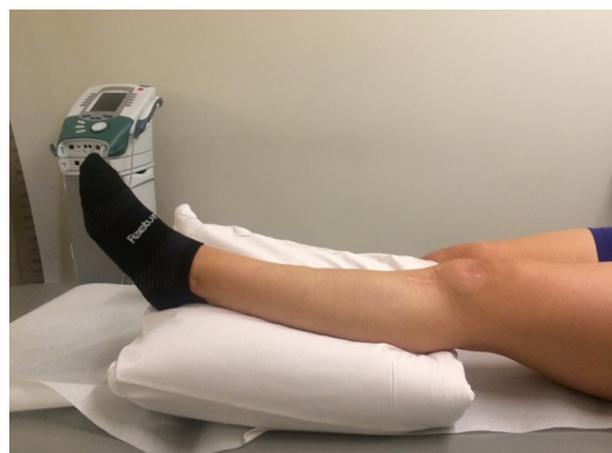


Figure 3 Passive extension with a pillow placed under the involved calf to promote extension. (Color version of figure is available online.)



Figure 4 Inferior glide mobilization of the patella. (Color version of figure is available online.)

dynamic stabilizer in preventing posterior tibial translation.²⁹ Quadriceps sets (contraction with the knee in full extension) with an appropriate-sized towel under the knee allows for a quality, pain-free exercise for quadriceps reeducation. Electrical stimulation or biofeedback used in conjunction with this exercise is useful in deterring quadriceps inhibition and atrophy.^{30,31} Straight leg raising (SLR) is performed with the postoperative brace locked at 0° until sufficient quadriceps control is demonstrated, that is, ability to SLR without pain and quadriceps lag.

To further aid in lower extremity strength development, selected open kinetic chain (OKC) and closed kinetic chain (CKC) exercises are implemented in the program. Supported by research, these activities aim to build lower extremity strength without placing undue stress on the maturing graft substitute.³²⁻³⁵ OKC multiple-angle quadriceps isometrics inside a 60° → 30° arc of motion are used bilaterally with submaximal effort. As ROM improves, CKC leg press is introduced inside a 60° → 0° arc of motion. When ROM achieves 90° flexion, a short-crank ergometer is incorporated into the program to develop strength, ROM, and cardiovascular conditioning³⁶ (Fig. 5).

Neuromuscular training is initiated when 50% weight-bearing status is achieved. Balance training on a Biodex Balance System (Biodex Medical Systems Inc, Shirley, NY) is incorporated into the program to provide patients with visual feedback (Fig. 6).

Proximal (hip) strengthening is initiated with multiple-plane SLRs, progressing to a progressive resistance exercise regime using cuff weights. Isotonic exercise machines are added to further challenge the proximal musculature. Core stabilization exercises are introduced at a level considered appropriate for the individual. Flexibility exercises are performed for the hamstring and calf musculature.

Knee joint effusion and quadriceps inhibition are closely related.³⁷ Therefore, controlling postoperative swelling leads to a faster return of muscle function. To assist in meeting this goal, patients are encouraged to avoid prolonged standing, maintain proper weight-bearing restrictions, and apply some form of cryotherapy to the surgical knee several times per day based on

symptoms, for example, Game Ready Cold Therapy Compression System (CoolSystems, Inc Concord, CA) (Fig. 7).

Throughout phase 1, a patient's home therapeutic exercise program is continually updated. Compliance to this program and to instructed activity modifications is essential to ensure a safer progression to the next phase of the rehabilitation program.

Postoperative Phase 2 (Week 6-12)

The second phase of rehabilitation following PCL reconstruction is directed toward progressive improvement in knee



Figure 5 Short-crank ergometry. (Color version of figure is available online.)



Figure 6 Biodex balance system (Biodex Medical Systems Inc, Shirley, NY). (Color version of figure is available online.)

ROM, the normalization of gait, and improved ability to perform activities of daily living (ADL) (Table 2).

Active-assisted ROM exercises are performed with the goal of achieving 130° of flexion by the 12th postoperative week. As ROM improves to $110^\circ \rightarrow 115^\circ$, cycling is advanced to a standard 170-mm ergometer. At 6 weeks postoperatively, the postoperative brace is changed per MD preference (OTS-PCL brace, patella sleeve, etc), allowing active knee flexion.

Weight-bearing is gradually progressed, as tolerated, using crutches. Crutches are discontinued when a patient demonstrates a normal gait pattern. To assist patients in the transition off crutches, an underwater treadmill system is used (Fig. 8).

Gait sequencing is aided by the unloading properties of the water.^{38,39}

Strengthening programs are advanced with specific attention to the forces generated during therapeutic exercises. CKC leg press (Fig. 9), squats, and OKC knee extensions are performed inside a $0^\circ \rightarrow 60^\circ$ ROM. Wilk et al³⁵ demonstrated increased posterior forces with OKC knee extension, CKC squat, and leg press at flexion angles greater than 60° . Lutz et al³² demonstrated posterior shear forces during a CKC squat exercise, but the forces were significantly less than those produced during OKC knee flexion. Quadriceps strengthening is further developed by having the patient retrograde ambulate on a treadmill at progressive inclines.⁴⁰ Isolated OKC hamstring strengthening is avoided for the first 6 postoperative months. Toutoungi et al³³ calculated that during isokinetic or isometric flexion exercises, peak PCL loads occur at $\sim 90^\circ$ of knee flexion and that these loads may exceed 4 times the body weight. Careful attention must be given to the patellofemoral joint during strengthening exercises. Loaded arcs of motion that present with pain and crepitus should be avoided. Skyhar et al⁴¹ studied the effects of sectioning the PCL on medial compartment and patellofemoral contact pressures. The group reported a 16% increase in patellofemoral contact pressure when the PCL was sectioned, with the most significant increases occurring at 60° of knee flexion. As ROM and lower extremity muscle strength demonstrate improvement, functional activities such as graduated (4", 6", and 8") step-ups and step-downs are introduced to the program. The goals for this phase include having the patient demonstrate the ability to ascend an 8" step and descend a 6" step by the 12th postoperative week.

Neuromuscular control activities are used to aid in the development of dynamic stabilization. Balance activities are progressed to include unilateral weight-bearing on less-stable support surfaces (foam rollers, rocker boards, multiplanar surfaces, etc), contralateral elastic band exercises, and perturbation training. Improving neuromuscular reaction time is intended to enhance dynamic stabilization around the knee and thus protect the static reconstructed tissue from overstress or reinjury.^{42,43}



Figure 7 Game Ready cold therapy compression system (CoolSystems, Inc Concord, CA). (Color version of figure is available online.)

Table 2 Postoperative Phase II (Week 6-12)**Goals**

- ROM 0° → 130°
- Restore normal gait
- Demonstrate ability to ascend 8" stairs with good leg control without pain
- Demonstrate ability to descend 6" stairs with good leg control without pain
- Improve ADL endurance
- Improve lower extremity flexibility
- Protect patellofemoral joint

Precautions

- Avoid exceeding ROM limitations in therapeutic exercises
- Avoid resistive knee flexion exercises
- Avoid pain with therapeutic exercise and functional activities
- Monitor activity level (prolonged standing or walking)

Treatment strategies

- D/C crutches when gait is normal (week 6-8)
- Brace changed to MD preference (OTS brace, patella sleeve, unloader brace, etc)
- Standard ergometry (if knee ROM > 115°)
- Leg press or mini squats (ROM 60° → 0° arc)
- AAROM exercises
- Proprioception training: multiplanar support surfaces
- Progress to unilateral support or contralateral exercises (elastic band)
- Perturbation training
- Forward step-up program
- Underwater treadmill system or pool (gait training)
- Retrograde treadmill ambulation
- Active knee extension—PRE (OKC) 60° → 0° (*monitor patella symptoms*)
- NO active (OKC) hamstring exercises
- Initiate step-down program when appropriate
- Knee ligament arthrometer examination at 3 months

Criteria for advancement

- ROM 0° → 130°
- Normal gait pattern
- Demonstrate ability to ascend an 8" step
- Demonstrate ability to descend a 6" step
- Functional progression pending knee ligament arthrometer examination and functional assessment

AAROM, active assistive range of motion.

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Lower extremity flexibility exercises are continued with the addition of quadriceps stretching as the involved knee attains 120° of flexion. At 3 months postoperatively, a KT1000 knee ligament arthrometer test (MEDmetric Corporation, San Diego, CA) may be performed to document laxity (Fig. 10). These results and patient progress to date are communicated with the referring surgeon. Daily application of cryotherapy, compliance to home therapeutic exercises, and modification in ADL are emphasized.

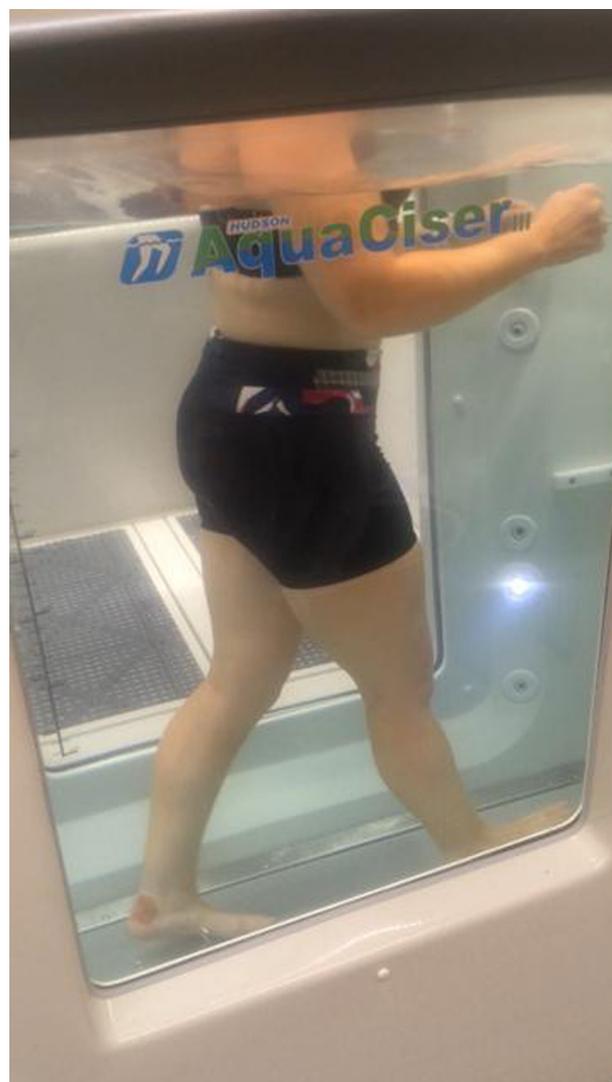


Figure 8 Aquaciser (Hudson Aquatic Systems, LLC. Angola, IN). (Color version of figure is available online.)

Phase 3 (Postoperative Week 13-20)

On meeting the criteria for advancement from the prior phase, a patient enters a phase of rehabilitation designed to restore full



Figure 9 Closed kinetic chain leg press performed inside a 0° → 60° arc of motion. (Color version of figure is available online.)



Figure 10 KT1000 knee ligament arthrometer test (MEDmetric Corporation, San Diego, CA). (Color version of figure is available online.)

ROM, improve lower extremity muscle strength and flexibility, and enhance dynamic stability (Table 3).

Knee ROM exercises are continued with the goal of achieving normal symmetrical ROM during this phase. Flexibility exercises take on a greater emphasis during this phase in preparation for the higher-demand or sport-specific activities that follow, for example, prone quadriceps stretching is added (Fig. 11).

Lower extremity strengthening is advanced with leg press, squats, and OKC knee extension ROM being performed inside an $80^\circ \rightarrow 0^\circ$ arc of motion. Advanced neuromuscular training activities are added to include sport cord agility activities, ball toss or catch on an unstable surface, and unilateral balance activities on multiplanar support surfaces with perturbation training. Advanced balance activities include altering sensory information from the visual, vestibular, and somatosensory systems during training activities to challenge the other systems.⁴³

At 4 months postoperatively should the patient demonstrate full ROM and a quality, pain-free descent from an 8" step (step down), a running program is initiated on a treadmill. Forward running is preceded by backward running, as decreased patellofemoral joint compression forces are generated with retro running when compared with forward running.⁴⁴ If available, the authors have found the AlterG Anti-Gravity treadmill (AlterG Fremont, CA) (Fig. 12) to be a useful modality during a return to running progression.

The initiation of plyometric training soon follows with the components of speed, intensity, load, volume, and frequency monitored and advanced accordingly. Activities should begin with simple drills and advance to more-complex exercises (eg, double-leg in-place jumping vs box drills). A patient's home therapeutic exercise program is continually updated based on evaluative findings.

Phase 4 (Postoperative Weeks 20-?)

The last phase of rehabilitation following PCL reconstruction is dedicated to prepare a patient or athlete for a safe return to the individual's sport (Table 4). Meeting listed criteria for advancement in phase 3 must be met to meet the demands of sport-specific activities used in this phase.

Lower extremity strengthening continues to be advanced via progressive resistance exercise and functional strengthening programs. The exercise arc for the leg press, squat, and OKC isotonic knee extension exercise is increased to $0^\circ \rightarrow 90^\circ$.⁴⁵ Isokinetic training for quadriceps and hamstrings musculature is initiated using moderate to fast velocities. Training speeds are gradually lowered as tolerated. A rehabilitation specialist should carefully monitor any complaints of anterior knee pain or crepitus with these activities.

Table 3 Postoperative Phase 3 (Week 12-20)

Goals

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

Precautions

- Avoid descending stairs reciprocally until adequate quadriceps control and lower extremity alignment
- Avoid resistive knee flexion exercises
- Avoid pain with therapeutic exercise and functional activities
- Monitor activity level (prolonged standing or walking)

Treatment strategies

- Leg press or squats (ROM $80^\circ \rightarrow 0^\circ$ arc)
- AAROM exercises
- Proprioception training: unilateral balance on Multiplanar surfaces
- Perturbations
- Lunges
- Agility exercises (sport cord)
- Step machine
- Retrograde treadmill running
- Forward running
- Lower extremity PRE and flexibility programs
- Active knee extension—PRE (OKC) to (ROM $80^\circ \rightarrow 0^\circ$)
- NO resistive (OKC) hamstring exercises

Criteria for advancement

- ROM to WNL
- Demonstrate ability to descend an 8" step with good leg control without pain
- Functional progression pending functional assessment
- Improved flexibility to meet demands of running and sport-specific activities

AAROM, active assistive range of motion; WNL, within normal limits. Hospital For Special Surgery, Sports Rehabilitation and Performance Center.

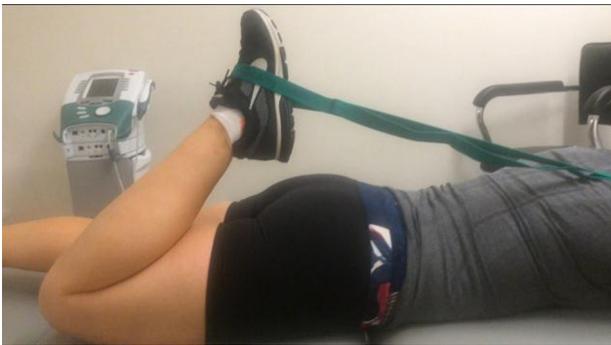


Figure 11 Prone quadriceps stretch. (Color version of figure is available online.)

Dynamic stability is continued to be challenged by advanced neuromuscular training. Flexibility exercises are continued as part of an exercise session's warm up and cool down.

Forward running is progressed with an emphasis on speed over shorter distances vs slower distance running. Sport-specific exercises are incorporated into the program based on that sport's requirements, for example, deceleration training, cutting, and change of direction. Plyometric exercises are progressed as appropriate, for example, bilateral box jumps, unilateral pattern jumps, box jumps, and depth jumps.

Final assessment can include a KT1000 test, functional hop tests, an isokinetic test, and a quality movement assessment. These tests are performed to substantiate laxity, strength, power, endurance, and qualitative movement. The information



Figure 12 AlterG anti-gravity treadmill (AlterG Fremont, CA). (Color version of figure is available online.)

Table 4 Postoperative Phase 4 (Week 20-?).

Goals

- Hop test $\geq 85\%$ limb symmetry
- Isokinetic testing $\geq 85\%$ limb symmetry
- Lack of apprehension with sport-specific movements
- Quality movement assessment
- Maximize strength and flexibility to meet demands of individual's sport activity

Precautions

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

Treatment strategies

- Continue lower extremity strengthening, leg press, squat, and OKC extension ($0^\circ \rightarrow 90^\circ$ arc)
- Lower extremity flexibility program
- Advance proprioception training
- Advance forward running program
- Advance plyometric program (sport specific)
- Sport-specific agility activities
- Isokinetic training or testing
- Functional testing
- Quality movement assessment
- Knee ligament arthrometer examination at 6 months
- Home therapeutic exercise program: evaluation based

Criteria for discharge

- Hop test $\geq 85\%$ limb symmetry
- Isokinetic test $\geq 85\%$ limb symmetry
- Lack of apprehension with sport-specific movements
- Quality movement assessment
- Flexibility to accepted levels for sport performance
- Independence with gym program for maintenance and progression of therapeutic exercise program at discharge

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gathered from these tests would provide evidence in determining an athlete's readiness for return to sport.

Isokinetic testing velocities should be determined for the individual patient. Slower-velocity testing (30° , 60° , and 90° per second) is avoided in most patients undergoing PCL reconstruction, as joint compressive, shear, and tibial displacement forces, as well as patellofemoral reaction forces, are greater at these speeds than at intermediate (120° , 150° , and 180° per second) and fast (240° and $300^\circ +$ per second) test velocities.^{46,47} Faster-velocity testing can also replicate knee velocity during functional activity. Wyatt and Edwards⁴⁸ have reported the angular velocity of the tibiofemoral joint during walking to be 233° per second. Data interpretation can include peak torque, peak torque to body weight ratio, total work, average power, quadriceps to hamstring ratio, force decay rate, and torque curve analysis among other parameters. The goals of isokinetic testing include a less than 15% deficit in the involved extremity vs the contralateral limb.

Functional testing allows a more functional approach to strength assessment by using a CKC environment during measurement. Functional testing links specific components of function with the actual task and provides direct evidence to prove functional status. Observation during testing can assist rehabilitation specialists in ascertaining an athlete's apprehension or lack thereof in performing a functional task (eg, landing from a jump). Daniel et al⁴⁹ introduced the one-legged hop test for distance in 1982 (Fig. 13). Barber et al⁵⁰ described 4 hop tests to assess lower extremity functional limitations: single-legged hop for distance, timed hop, triple hop for distance, and crossover triple hop for distance. The single-legged hop for time and the crossover hop have been reported to be the most sensitive and best indicators of function.^{50,51} Normal limb symmetry was identified as limb values within 85% of one another for both men and women regardless of limb dominance or sports activity level.

A quality movement screening links the entire kinetic chain with the components (ROM, flexibility, strength, and balance) that are necessary to move in ADL and with sport-specific movements. Qualitatively, movements such as a step-down, a single-leg squat, and dynamic lateral landing are assessed for symmetry and neuromuscular control (Fig. 14). Video analysis can be incorporated to better assess movement patterns.

Deficits demonstrated in these batteries of tests as well as observed difficulty in stabilization on landing, apprehension, or complaints of pain indicate the need for continued therapeutic interventions in the areas of strength, flexibility, power, and balance development. Information obtained, whether subjective or objective, can be presented to a referring physician for consideration. The patient or athlete is then advised regarding the level of sports participation, with or without modifications, to which he or she can return. Surgeon's preference determines the need for bracing for sport

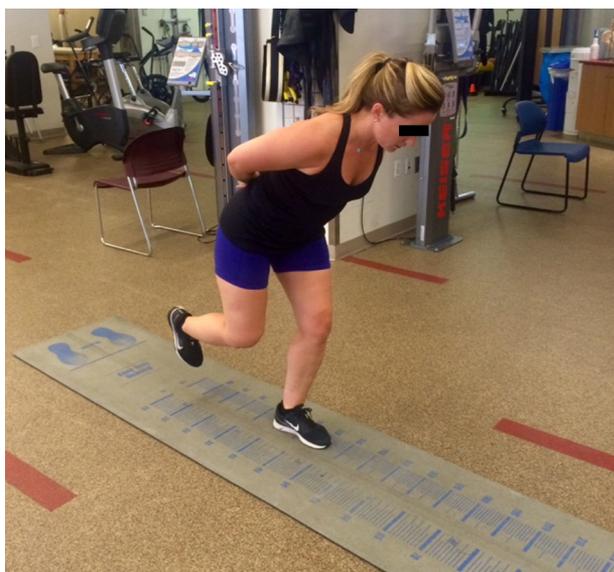


Figure 13 Single-leg hop test for distance: A patient performs 3 single jumps on each extremity for distance. Distance is summarized and averaged. Limb symmetry is then calculated. (Color version of figure is available online.)



Figure 14 Qualitative movement assessment of an 8" step-down. (Color version of figure is available online.)

activity. On a patient's discharge from a formal rehabilitation program, a rehabilitation specialist should provide the patient with a comprehensive home or gym therapeutic exercise program to maintain and advance the present level of function.

PCL Reconstruction With PLC Surgery

In cases where a combined PCL and PLC has been addressed surgically, the postoperative rehabilitation program follows a more conservative approach than that in an isolated PCL reconstruction. The guidelines to rehabilitating a combined PCL and PLC (Table 5) include similar guidelines to an isolated PCL protocol with the following modifications: (1) Weight-bearing is restricted for the first 6 postoperative weeks: non-weight-bearing at week 0-4 and toe-touch weight-bearing at week 4-6 with the brace locked in extension.

(2) A postoperative brace has to be worn at all times, including when performing exercises to protect the knee from falling into varus, hyperextension, and tibial external rotation. We use a hinged leg immobilizer and bend it to a valgus mold

Table 5 Posterior Cruciate Ligament Reconstruction With Posterior Lateral Corner Surgery Postoperative Rehabilitation Guideline

Postoperative phase I (postoperative week 0-6)

Goals

- Control postoperative pain and swelling
- Range of motion 0° → 90°
- Prevent quadriceps inhibition
- Improve patella mobility
- Independence in home therapeutic exercise program

Precautions

- Avoid knee hyperextension, varus forces, and tibial external rotation
- Avoid active knee flexion
- Avoid heat application
- Avoid ambulation without brace locked at 0°
- Avoid exceeding ROM and weight-bearing limitations
- Avoid pain with therapeutic exercise and functional activities

Treatment strategies

- Passive extension (pillow under calf)
- Quadriceps reeducation (quad sets with NMES)
- Gait: restricted weight-bearing first 6 weeks with brace locked at 0° with crutches
- NWB week 0 → 4 and TTWB week 4 → 6
- Patella mobilization
- Active-assisted knee extension or passive flexion exercise (ROM 0° → 70°)
- Progress to 90° as tolerated, week 4-6
- SLRs (all planes except S/L Abduction) or progressive resistance, brace locked at 0°
- Multiple-angle quadriceps isometrics (ROM 60° → 20°)
- Proximal (hip) strengthening PREs
- Hamstring or calf flexibility exercises
- Short-crank ergometry
- Cardiovascular exercises (UBE, Airdyne, etc) as tolerated
- Cryotherapy
- Emphasize patient compliance to home therapeutic exercise program and weight-bearing precautions

Criteria for advancement

- ROM 0° → 90°
- Ability to SLR without quadriceps lag
- Continued improvement in patella mobility and proximal strength

Postoperative phase II (week 7-12)

Goals

- ROM 0° → 130°
- Progress weight-bearing to full weight-bearing by end of phase II
- Restore normal gait
- Demonstrate ability to ascend 8" stairs with good leg control without pain
- Demonstrate ability to descend 4" stairs with good leg control without pain
- Improve ADL endurance
- Improve lower extremity flexibility
- Protect patellofemoral joint

Precautions

- Continued use of bracing to protect against knee hyperextension, varus forces, and tibial external rotation
- Avoid exceeding ROM limitations in therapeutic exercises
- Avoid resistive knee flexion exercises
- Avoid pain with therapeutic exercise and functional activities
- Monitor activity level (prolonged standing or walking)

Treatment strategies

- D/C crutches when gait is nonantalgic (week 8-10)

Table 5 (continued)

Brace changed to MD preference (OTS brace, patella sleeve, unloader brace, etc)
 Standard ergometry (if knee ROM > 115°)
 Leg press or mini squats (ROM 60° → 0° arc)
 AAROM exercises
 Proprioception training: multiplanar support surfaces
 Progress to unilateral support or contralateral exercises (elastic band)
 Perturbation training
 Forward step-up program
 Underwater treadmill system or pool (gait training)
 Retrograde treadmill ambulation
 Active knee extension—PRE (OKC) 60° → 0° (*monitor patella symptoms*)
 NO active (OKC) hamstring exercises
 Initiate step-down program when able to ascend an 8" step up without pain and good control

Criteria for advancement

ROM 0° → 130°
 Normal gait pattern
 Demonstrate ability to ascend an 8" step
 Demonstrate ability to descend a 4" step

Postoperative phase III (week 13-24)

Goals

Restore full range of motion
 Demonstrate ability to descend 8" stairs with good eccentric control without pain
 Improve ADL endurance
 Improve lower extremity flexibility
 Protect patellofemoral joint

Precautions

Avoid descending stairs reciprocally until adequate quadriceps control and lower extremity alignment
 Avoid resistive knee flexion exercises
 Avoid pain with therapeutic exercise and functional activities
 Monitor activity level (prolonged standing or walking)

Treatment strategies

Leg press or squats (ROM 80° → 0° arc)
 AAROM exercises
 Proprioception training: unilateral balance on multiplanar surfaces
 Perturbations
 Lunges
 Progress forward step down (with eccentric control emphasis)
 Single-leg squat progression
 Agility exercises (sport cord)
 Step machine
 Retrograde treadmill running
 Forward running progression
 Initiation of plyometric exercise progression
 Lower extremity PRE and flexibility programs
 Active knee extension—PRE (OKC) to (ROM 80° → 0°)
 NO resistive (OKC) hamstring exercises

Criteria for advancement

ROM to WNL
 Demonstrate ability to descend an 8" step with good leg control without pain
 Functional progression pending functional assessment
 Improved flexibility to meet demands of running and sport-specific activities

Table 5 (continued)

Postoperative phase IV (week 24+)**Goals**

- Hop test $\geq 85\%$ limb symmetry
- Isokinetic testing $\geq 85\%$ limb symmetry
- Lack of apprehension with sport-specific movements
- Quality movement assessment
- Maximize strength and flexibility as to meet demands of individual's sport activity

Precautions

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

Treatment strategies

- Continue lower extremity strengthening, leg press, squat, and OKC extension (full ROM arc)
- Lower extremity flexibility program
- Advance proprioception training
- Advance forward running program
- Advance plyometric program (sport specific)
- Sport-specific agility activities
- Isokinetic training or testing
- Functional testing
- Quality movement assessment
- Knee ligament arthrometer examination at 6 months
- Home therapeutic exercise program: evaluation based

Criteria for discharge

- Hop test $\geq 85\%$ limb symmetry
- Isokinetic test $\geq 85\%$ limb symmetry
- Lack of apprehension with sport-specific movements
- Quality movement assessment
- Flexibility to accepted levels for sport performance
- Independence with gym program for maintenance and progression of therapeutic exercise program at discharge

AAROM, active assistive range of motion; NMES, neuromuscular electrical stimulation; TTWB, toe-touch weight-bearing; WNL, within normal limits. Hospital For Special Surgery, Sports Rehabilitation and Performance Center.

to reduce stress on the lateral reconstruction. At 6 weeks postoperatively, a progressive weight-bearing program is initiated. The postoperative brace is transitioned to a 4-point functional brace, allowing ROM during gait. Bracing is discontinued for ADL at 12 weeks postoperatively. Similar to PCL postoperative guidelines, isolated hamstring exercises are deferred until 6 months postoperatively because of their potential deleterious forces generated on the PCL and the PLC reconstructions. PCL stress radiographs may be used to objectively gauge postoperative progression and to determine any modifications for a patient.⁵²

Summary

Rehabilitation following PCL or combined PCL-PLC surgery is a long process. Communication with the surgeon is essential in promoting a successful outcome. Encouraging patients to become active participants in their rehabilitation, that is, being compliant to therapeutic exercises prescribed as well as the

activity modifications as they present throughout the rehabilitation course, leads to a rehabilitation experience with fewer complications. Criteria in conjunction with time frames should be considered when progressing a patient throughout the phases of the individual's rehabilitation program. As patients return to their normal ADL and sport activity, volume of activities should be monitored within the first postoperative year.

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