



ELSEVIER

ORTHOPAEDIC REHABILITATION OF THE ATHLETE: GETTING BACK IN THE GAME

Post-surgical Rehabilitation after Soft Tissue ACL Reconstruction (Autograft and Allograft)

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INDICATIONS FOR SURGICAL TREATMENT

The decision to go forward with an ACL reconstruction procedure is dependent on various factors and is highly individualized to each patient. Nonetheless, ACL reconstruction is generally recommended in the following circumstances:

- Young, high-demand patients
- Those with a desire to return to competitive or frequent recreational sports requiring cutting or pivoting
- Patients with combined ligament knee injuries, significant instability, or repairable meniscus tears

BRIEF SUMMARY OF SURGICAL TECHNIQUE

Major steps in technique

- General anesthesia with the patient in the supine position
- Physical exam or diagnostic arthroscopy to document all pathology
- Soft tissue graft harvest and/or preparation
- Preparation of notch and takedown of leftover ACL stump
- Tibial tunnel creation
- Femoral tunnel creation
- Graft passage through tibial and femoral tunnels
- Fixation of the ACL graft in femoral tunnel
- Fixation of ACL graft in tibial tunnel
- Wound closure

Details and choices that may affect details of rehabilitation:

- Surgical
 - Presence of other knee pathology:
 - Frequently, patients undergoing ACL reconstruction are noted to have other knee pathology preoperatively or at the time of diagnostic arthroscopy. These may include other ligamentous injuries, meniscus tears, or cartilage injuries. It is important to determine whether any other injuries exist or concomitant procedures were performed, as this may change post-surgical rehabilitation
 - Autograft versus Allograft Ligament Reconstruction:
 - ACL grafts may be derived from the patient's own tissue (autografts) or cadaveric tissue (allografts). The autograft soft tissue most commonly used for ACL reconstruction is the hamstring tendons (semitendinosus and gracilis tendons—frequently a quadrupled stranded construct). However, it is becoming more common to also use an autograft quadriceps tendon. Allograft

options for soft tissue ACL reconstruction include hamstring tendons, tibialis anterior tendon, and Achilles tendon grafts. It is important to know whether any autograft tendon was harvested in your patient as this may influence hamstring post-surgical rehabilitation.

- Graft type and graft fixation
 - ACL reconstruction can be performed with a soft-tissue graft (hamstring, Achilles tendon, tibialis anterior, quadriceps) or a Bone-Tendon-Bone graft (patellar tendon with 2 bone plugs).
 - Accelerated rehabilitation programs, similar to those commonly used following ACL reconstructions using the patellar tendon autograft, have been shown to be equally successful following reconstruction with a hamstring graft.
 - In cases where tibial or femoral tunnel fixation of the grafts are not as strong, a slightly less aggressive rehabilitation protocol may be suggested.
 - Soft tissue-to-bone healing takes 12 weeks to complete in most instances whereas bone-to-bone healing occurs in approximately 8 weeks.
- Anesthesia
 - Regional anesthesia, frequently in the form of a femoral nerve block, may provide excellent post-operative analgesia, leading to improved outcomes. However, the block may wear off 8-24 hours after surgery. Be cognizant of rebound pain and be quick to utilize other modalities.

BEFORE SURGERY: OVERVIEW OF GOALS, IMPORTANT MILESTONES AND GUIDELINES

A patient with an ACL tear can commonly present with a swollen, stiff and painful knee. The hemarthrosis after the injury can produce an inflammatory reaction that causes significant discomfort/dysfunction. The goals of pre-operative rehabilitation are to decrease swelling, return knee motion to normal or near normal, improve strength, and begin early therapy training. Achieving normal knee range of motion has been shown to decrease the probability of post-reconstruction stiffness. To achieve pre-operative goals:

Tools to manage swelling

- Cryo/compression devices – there are multiple commercially available devices that provide cooling and/or compression to the knee. These devices can also be used in the post-operative time period.

Restoration of normal knee range of motion

- Exercise training pre-operatively that can also be used post-operatively.

- Towel stretches – a looped towel around the midfoot is held with one hand as the foot is lifted and the other hand holds the thigh down (**Figure 1: Towel Stretch**).
 - An advancement of this is to have the patient contract the quadriceps and release the towel in order to hold the heel off the bed/ground.
- The affected leg should also be allowed to rest on a pillow with nothing under the knee. This encourages full extension.
- Wall and heel slides can be implemented to assist with flexion. The patient can be laying supine with the affected leg/foot extended against a wall. The foot is then allowed to slide down into flexion with assistance from the other leg as necessary.
- Quad sets and straight leg raises
- Full weight-bearing and ROM is encouraged.
- Activity can be completed as tolerated and good exercises include the stationary bike and elliptical machine.

AFTER SURGERY-POSTOPERATIVE REHABILITATION: OVERVIEW OF GOALS, IMPORTANT MILESTONES AND GUIDELINES

BOX A: GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Obtaining full passive knee extension and patellar mobility immediately following surgery
- Reducing post-operative inflammation and pain with the use of various modalities
- Restoring neuromuscular control with electrical muscle stimulation (for reestablishing voluntary quadriceps control), proprioceptive training, and other biofeedback modalities
- Gradually increasing applied loads to the knee
- Progressing to sport-specific training

Adapted from: Wilk KE, Macrina LC, Reinold MM, Hooks TR. Recent Advances in the Rehabilitation of ACL Injuries. ACL Surgery: How to Get it Right the First Time and What to Do if it Fails (pp. 341-56). SLACK 2010.

PHASE 1: IMMEDIATE POSTOPERATIVE PERIOD (First 14 days)

Goals for Day 0 - 14 days in the postoperative period:

- **Restoring full or near normal passive knee extension**
- **Reducing joint swelling and pain**
- **Restoring patellar mobility**
- **Progressively improving knee flexion**
- **Reestablishing voluntary quadriceps control**
- **Restoring independent ambulation**

CLINICAL PEARL

One of the most frequently seen complications following ACL reconstruction is the loss of full knee extension, thus creating an environment ripe for scar tissue formation. Lack of extension also often leads to increased patellofemoral and tibiofemoral joint contact pressure, difficulty with quadriceps activation, and excessive muscular fatigue. A drop-lock knee brace locked at full extension is often helpful, particularly when patients use it while ambulating and sleeping at night for 2-3 weeks after surgery.

Protection

- A drop-lock knee extension brace locked in full-extension is used immediately post-operatively
- The brace is worn in extension for 6 weeks during ambulation and sleeping activities if an autograft tendon was used, and 10-14 days if an allograft tendon was used.
- Crutches may be used for comfort initially but patients should try to assume full weight bearing by the second week. To facilitate the transition from crutches to full weight bearing, one may allow 2 crutches for the first 7-10 days, then progress to 1 crutch and finally full-weight bearing by 14 days.
- Weight bearing may be altered if the patient has other concomitant injuries (bone bruise) or other concomitant procedures are performed

Treatment for pain/analgesia

- In addition to oral analgesic medication, cryotherapy devices can be helpful. These units consist of a cooling apparatus and wrap that helps to decrease pain and spasm. It is thought that cryotherapy works by inhibiting afferent nerve conduction and decreases the local inflammatory response.
- Passive range of motion may support the neuromodulation of knee pain following surgery and improve symptoms.

Decrease swelling

- It is imperative to reduce knee swelling whenever possible in the immediate post-operative period.
- Knee effusions may cause muscle inhibition
- Cryotherapy and joint compression with a knee sleeve, ace wrap, or compression device are the most frequently used modalities
- The patient can also ice 20 minutes hourly and elevate lower extremity

Increase ROM:

- Full passive knee extension (Day 1-7)
- Achieve 90 degrees of knee flexion (Days 2-7)
- Patellar mobilization

Other therapeutic exercises and functional training:

- Ankle pumps
- Heel slides/wall slides
- Prone leg hangs for extension
- Hamstring stretches (**DO NOT DO UNTIL 4 WEEKS POST-OP IF HAMSTRING AUTOGRAFT USED IN SURGERY**)
- Straight leg raises (hip flexion, abduction, adduction)
- Aerobic Conditioning
 - Upper extremity ergometry
 - Well-leg bicycling

Muscle activation of primary muscles involved in injury area or surgical structures

- Quadriceps isometric (Days 1-14)
- Standing hamstring curls (**DO NOT DO UNTIL 6 WEEKS POST-OP IF HAMSTRING AUTOGRAFT USED IN SURGERY**)
- Straight leg raise in all planes with the brace until the quadriceps are strong enough to prevent an extensor lag.
- Electrical stimulation of quads (4-6 hours daily)

Sensorimotor exercises (balance proprioception, kinesthesia)

- Active/passive joint positioning
- Balancing activities
- Stable platform, eyes open
- Stable platform, eyes closed
- Seated ball throwing and catching

Closed (CKC) kinetic chain exercises

- Mini-squats
- Weight shifts

Neuromuscular dynamic stability exercises

N/A

Functional exercises

N/A

Sport-specific exercises

N/A

Milestones/criterion-based rehabilitation guidelines to progress to the next stage

- Ability to achieve full passive knee extension
- Passive knee flexion from 0-90 degrees
- Minimal knee swelling
- Good patellar mobility
- Quad strength and control as demonstrated by ability to perform good quad set and straight leg raise with no extensor lag
- Ambulation without crutches

FURTHER GOALS, IMPORTANT MILESTONES AND GUIDELINES

PHASE 2: 2-4 Weeks Postoperatively

Goals of the 2-4 weeks postoperative period:

- **Maintain range of motion (full knee extension) and patellar mobility established in previous phase**
- **Gradually increase knee flexion**
- **Diminish swelling**
- **Muscle training**
- **Muscle proprioception**

CLINICAL PEARL

At this phase, patients should be able to ambulate independently without crutches. The brace should be discontinued around week 2 if an allograft was used, but should be continued until week 6 if an autograft tendon was utilized. As this phase progresses, closed chain exercises gradually become more difficult. Pool work should only be performed if surgical wounds are fully closed.

Protection

- Full ambulation without crutches or a brace should be achieved by this phase

Treatment for pain/analgesia

- In addition to oral analgesic medication, cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices

may be helpful.

Decrease swelling

- Cryotherapy and joint compression with a knee sleeve or ace wrap are the most frequently used modalities
- The patient can ice for 20 minutes hourly and elevate the lower extremity

Increase ROM:

- Self-performed range of motion stretching exercises should be performed 4-5 times daily. There should be an emphasis on maintaining full, passive range of motion (full extension and full flexion)
- Overpressure into extension
- Passive range of motion from 0-115 flexion (by week 3)
- Continue patellar mobility

Other therapeutic exercises:

- Bicycle
- Straight leg raises (hip flexion, adduction, abduction, extension)
- Pool walking (begin at earliest during week 3, only if incision is fully closed)

Muscle activation of primary muscles involved in injury area or surgical structures:

- Isometric quadriceps sets
- Leg press (**Figure 2 – Leg Press**)
- Knee extension 90-40 degrees without weight
- Leg external and internal rotation maneuvers with knee bent 30 degrees to engage popliteus and hamstring muscles
- Calf raises with knee in extension
- Bent knee calf raises for soleus
- Hamstring curls (**DO NOT DO UNTIL 6 WEEKS POST-OP IF HAMSTRING AUTOGRAFT USED IN SURGERY**)

Sensorimotor exercises:

- Bicycle
- Progress to proprioception drills as tolerated

Open (OKC) and closed (CKC) kinetic chain exercises:

- Half squats
- Weight shifts
- Front and side lunges
- Eccentric quadriceps program (isotonic exercises only)
- Lateral step-ups
- Front step-ups
- Stair-stepper machine

Increase muscle strength, power, and endurance

- Bicycling for endurance

Neuromuscular dynamic stability exercises

- Perturbation training

Plyometrics

N/A

Functional exercises

N/A

Sport-specific exercises

N/A

Milestones/criterion-based rehabilitation guidelines to progress to the next stage

- Active range of motion from 0-115 degrees knee flexion
- Isometric quadricep strength is at least 60% of the contralateral side
- No joint line or anterior knee pain
- Lack of knee effusion

PHASE 3: 4-10 Weeks Postoperatively

Goals of the 4-10 weeks postoperative period:

- **Continue to increase strength**
- **Continue to increase range of motion (0-125 degrees)**
- **Increase proprioception, balance and neuromuscular control**
- **Improve endurance**
- **Improve limb confidence**

CLINICAL PEARL

As this phase progresses, difficulty of exercises (particularly those involving neuromuscular control and proprioception) also increases. Plyometrics may be incorporated by week 6.

Protection

- No more brace or crutches if an allograft was used, continue the brace until week 6 with an autograft.

Treatment for pain/analgesia

- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices may be helpful.
- Narcotic pain medication should not be used at this point.

Decrease swelling

- Continue the joint compression with a knee sleeve or ace wrap
- Ice the knee for 20 minutes hourly and elevate lower extremity

Increase ROM:

- Self-performed range of motion stretching exercises should be performed 4-5 times daily. There should be an emphasis on maintaining full, passive range of motion (full extension and full flexion)
- Perform hamstring stretching at this stage if a hamstring autograft was used during ACL surgery

Other therapeutic exercises:

- Bicycle
- Straight leg raises (hip flexion, adduction, abduction, extension)
- Pool running (provided no wound healing problems) – begin with backward running and hip/leg exercises, then progress to forward running

Muscle activation of primary muscles:

- Leg press
- Hamstring curls (begin at 6 weeks post-op if hamstring autograft used during ACL reconstruction)
- Progress isometric strengthening program

Sensorimotor exercises (balance proprioception, kinesthesia)

- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Open (OKC) and closed (CKC) kinetic chain exercises

- Lateral lunge step-overs
- Front and side lunges
- Lateral step-downs
- Front step-downs
- Wall squats
- Vertical squats
- Toe calf raises
- Open chain resistance with extension can begin with 1 lb. weight only. Increase no more than 1 lb. per week. – **(Figure 3: Open Chain resistance with extension)**
- Stair-stepper machine

Increase muscle strength, power, and endurance

- Stair-stepper machine
- Bicycle
- Walking program

Neuromuscular dynamic stability exercises

- Biodex Stability system (Shirley, NY)
- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Plyometrics

N/A

Functional exercises

N/A

Sport-specific exercises

N/A

Milestones/criterion-based rehabilitation guidelines to progress to the next stage

- Active range of motion maintained at 0-125 degrees flexion
- Isometric quadricep strength is greater than 80% of the contralateral side
- Knee flexor/extensor strength ratio is at least 70-75%
- No pain
- No joint effusion
- Hamstring strength is equal bilaterally
- Hop test (80% that of contralateral leg)

PHASE 4: 10-16 Weeks Postoperatively

- **Return leg strength to normal**
 - **Improve muscular power and endurance**
 - **Enhance neuromuscular control**
 - **Perform sport specific drills**
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CLINICAL PEARL

This is the phase that most patients have been waiting for – a gradual return to sport specific training. The eager athlete must be reminded that a progression is necessary and they need to remain committed to the process and protocol.

Protection:

- No more brace or crutches for the majority of patients. However, some patients such as football lineman may benefit from the use of a functional ACL brace at this point.

Treatment for pain/analgesia

- Pain should be minimal to nonexistent at this point.
- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices can be used when necessary
- Narcotic pain medication should not be necessary at this point

Decrease swelling

- Joint compression with a knee sleeve or ace wrap are the most frequently used modalities
- Ice for 20 minutes hourly and elevate lower extremity

Increase ROM:

- Self-performed range of motion stretching exercises should be performed 4-5 times daily. There should be an emphasis on maintaining full, passive range of motion (full extension and full flexion)

Other therapeutic exercises

- Bicycle
- Straight leg raises (hip flexion, adduction, abduction, extension)
- Pool running (provided no wound healing problems) – forward and backwards running
- Can start running straight ahead at 12 weeks

Muscle activation of primary muscles:

- Hamstring curls
- Leg press
- Progress isometric strengthening program

Sensorimotor exercises (balance proprioception, kinesthesia)

- Continue balance training on a tilt board
- Continue balance training with medicine ball throws (**Figure 4: Balance training with medicine ball throws**)
- Continue perturbation training on single leg (**Figure 5: Perturbation training on single leg**)

Open (OKC) and closed (CKC) kinetic chain exercises

- Lateral lunge step-overs
- Front and side lunges
- Lateral step-downs
- Front step-downs
- Wall squats (**Figure 6: Wall squats**)
- Vertical squats
- Toe calf raises
- Continue open chain resistance with extension – after beginning with 1 lb. in week 3, increase no more than 1 lb. per week.
- Stair-stepper machine

Increase muscle strength, power, and endurance

- Stair-stepper machine
- Bicycle
- Walking program

Neuromuscular dynamic stability exercises

- Biodex Stability system (Shirley, NY)
- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Plyometrics

- Initiate plyometric leg press by weeks 12-16 (**Figure 7: Plyometric jumping exercises**)

Functional exercises

- Lunges with sport cord
- Running and agility progression
- Pool running (backwards and forwards)

Sport-specific exercises

- Cone drills
- Side shuffles
- Cariocas
- Sudden start/stops
- 45 degree cutting maneuvers
- 90 degree cutting maneuvers
- Combinations of agility drills
- Sports specific plyometric training drills by weeks 12-16

Milestones/criterion-based rehabilitation guidelines to progress to the next stage

- Full range of motion
- Quadriceps strength 80% or greater than opposite extremity
- Hamstring strength 110% or greater than opposite extremity
- Quadricep torque/body weight ratio 55% or greater
- Hamstrings/Quadriceps ration 70% or greater
- Proprioceptive test equivalent to contralateral leg
- Functional testing 85% or greater to contralateral leg
- Pain free knee

PHASE 5: 16-22 Weeks Postoperatively

- **Gradually returning the patient to full, unrestricted sports**
- **Maximizing leg strength and endurance**

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- **Normalizing neuromuscular control**
 - **Progressing skill training**
 - **Continuing to build limb confidence**
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CLINICAL PEARL

The key goal in Phase 5 is returning patients to their preoperative level of sports or activity. Much of this also includes building confidence in their reconstructed knee. Continuing to progress strengthening, functional, proprioceptive, and sport specific drills, all while increasing applied loads and difficulty will help your patients achieve these goals. The workhorse exercises of this phase include single leg squats and lunges in addition to sport-specific drills.

Protection

- No more brace or crutches

Treatment for pain/analgesia

- Pain should be minimal to nonexistent at this point.
- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices can be used when necessary
- Narcotic pain medication should not be necessary at this point

Decrease swelling

- Joint compression with a knee sleeve or ace wrap are the most frequently used modalities
- Knee sleeve can be discontinued but some patients psychologically feel more comfortable when wearing it
- Ice for 20 minutes hourly and elevate lower extremity

Increase ROM:

- Self-performed range of motion stretching exercises should be performed 4-5 times daily. There should be an emphasis on maintaining full, passive range of motion (full extension and full flexion)

Other therapeutic exercises

- Bicycle
- Straight leg raises (hip flexion, adduction, abduction, extension)
- Pool running (provided no wound healing problems) – forward and backwards running

Muscle activation of primary muscles:

- Hamstring curls
- Leg press
- Progress isometric strengthening program

Sensorimotor exercises (balance proprioception, kinesthesia)

- Continue balance training on a tilt board
- Continue balance training with medicine ball throws
- Continue perturbation training on single leg

Closed (CKC) kinetic chain exercises

- Lateral lunge step-overs
- Front and side lunges
- Lateral step-downs
- Front step-downs
- Wall squats
- Vertical squats
- Toe calf raises
- Stair-stepper machine

Increase muscle strength, power, and endurance

- Stair-stepper machine
- Bicycle
- Walking program

Neuromuscular dynamic stability exercises

- Biodex Stability system (Shirley, NY)
- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Plyometrics

- Can progress plyometric leg presses
- Continue other plyometric training drills

Functional exercises

- Lunges with sport cord
- Progress running and agility training

Sport-specific exercises

- Cone drills
- Side shuffles
- Cariocas
- Sudden start/stops
- 45 degree cutting maneuvers
- 90 degree cutting maneuvers

- Combinations of agility drills
 - Continue other plyometric training drills
 - Sport specific skill training (e.g. coming out of a 3 point stance for football lineman, changing direction from backpedal to sprint, etc).
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CRITERIA FOR RETURN TO SPORT

6 month time point:

- No knee effusion
- Full knee range of motion
- Quad atrophy less than 2 cm
- No more than 3mm on Lachman test
- No more than a trace pivot shift
- Lysholm score > 75
- SANE score > 75
- No subjective sense of instability
- No difficulty with activities of daily living
- Knee extension and flexion at least 70% of normal
- Single-leg leg press at least 70% of normal
- Single leg squat possible

Specific Situations:

- Contact athletes (e.g. football or hockey players) should first return to practice on a limited basis before full contact is allowed. Often, this can be achieved by allowing the athlete to participate in practice while wearing a noncontact (e.g. red colored) jersey.
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AFTER RETURN TO SPORT

Continuing fitness or rehabilitation exercises:

- Athletes are encouraged to continue strength and agility exercises on their own to preserve strength, functional and proprioceptive gains
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Exercises and other techniques for prevention of recurrent injury:

- Lateral box jumps
- Single leg hurdles
- Single leg lunges and squats

EVIDENCE

1. Howell SM, Deutsch ML. Comparison of endoscopic and two-incision technique for reconstructing a torn anterior cruciate ligament using hamstring tendons. *Arthroscopy*. 1999;15:594.

This study compared the differences in clinical outcome between an endoscopic (67 of 70) and two-incision (41 of 49) technique used to reconstruct torn anterior cruciate ligaments (ACL) using a double-looped semitendinosus and gracilis (DLSTG) graft. The postoperative treatment featured an aggressive rehabilitation protocol without a brace, and allowed unrestricted sports participation 4 months after reconstruction. Age, sex distribution, duration from injury to surgery, and preoperative laxity were not significantly different between treatment groups.

2. MacDonald P, Hedden D, Huebert D. Effects of an accelerated rehabilitation program after anterior cruciate ligament reconstruction with combined semitendinosus-gracilis and a ligament augmentation device. *AJSM*. 1995;23:588.

Forty patients undergoing ACL reconstruction using semitendinosus and gracilis autografts and a ligament augmentation device were retrospectively reviewed at minimum 20 months post-operatively to determine if accelerated rehabilitation was detrimental. Of the 37 patients available for follow-up, 34 had good-excellent results. The study concluded that early accelerated rehabilitation of ACL reconstruction using this type of graft does not adversely affect outcome.

3. Janssen RPA, Wijk J, Fiedler A, et al. Remodelling of human hamstring autografts after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(8):1299–1306.

Human hamstring grafts showed typical stages of graft remodelling, which was not complete up to 2 years after ACL reconstruction. The remodelling process in humans was prolonged compared with the results obtained in several animal studies.

4. Gulotta LV, Rodeo SA. Biology of Autograft and Allograft Healing in Anterior Cruciate Ligament Reconstruction. *Clin Sports Med*. 2007;26(4):509–524.

Excellent review article regarding the biology of anterior cruciate ligament healing written by experts in the field.

3. Grinsven S, Cingel REH, Holla CJM, Loon CJM. Evidence-based rehabilitation following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(8):1128–1144.

Following a bone-patellar tendon-bone auto-graft (BPTB) or four-stranded semitendinosus/gracilis tendons autograft (ST/G) anterior cruciate ligament

(ACL) reconstruction, the speed and safety with which an athlete returns to sports (or regains the pre-injury level of function) depends on the rehabilitation protocol. Considering the large differences in clinical and outpatient protocols, there is no consensus regarding the content of such a rehabilitation program. Therefore, we conducted a systematic review to develop an optimal evidence-based rehabilitation protocol to enable unambiguous, practical and useful treatment after ACL reconstruction. The results clearly indicated that an accelerated protocol without postoperative bracing, in which reduction of pain, swelling and inflammation, regaining range of motion, strength and neuromuscular control are the most important aims, has important advantages and does not lead to stability problems. Preclinical sessions, clear starting times and control of the rehabilitation aims with objective and subjective tests facilitate an uncomplicated rehabilitation course. Consensus about this evidence-based accelerated protocol will not only enhance the speed and safety with which an athlete returns to sports, but a standardized method of outcome measurement and reporting will also increase the evidential value of future articles.

5. Majima T, Yasuda K, Tago H, Tanabe Y, Minami A. Rehabilitation after hamstring anterior cruciate ligament reconstruction. Clin Orthop Relat Res. 2002;(397):370–380.

A prospective comparative study was conducted involving 62 patients to determine the effects and limits of accelerated rehabilitation on clinical outcome. The study focused on whether aggressive rehabilitation after anterior cruciate ligament reconstruction with the doubled semitendinosus and gracilis tendon autograft results in stretching the graft. Thirty patients had postoperative rehabilitation according to the current conservative protocol, and 32 patients had rehabilitation using an accelerated regime. Each patient was evaluated subjectively and objectively 36 months or more after surgery. Concerning the side-to-side difference in the anterior laxity, 87% of the patients in the conservative rehabilitation group had 3 mm or less and 80% of the patients in the accelerated rehabilitation group had the same acceptable laxity. There was no significant difference between the two groups. Muscle torque was restored significantly earlier in the patients in the accelerated rehabilitation group than in the patients in the conservative rehabilitation group. Nine months after surgery, however, there were no significant differences in the torque between the two groups. Accelerated rehabilitation significantly increased the incidence of knee effusion during rehabilitation. This study showed that acceleration of postoperative rehabilitation could rapidly restore muscle strength without significantly compromising graft stability in anterior cruciate ligament reconstruction with the doubled hamstring tendon autograft. However, this study also showed that acceleration significantly increases the incidence of synovitis. Acceleration of postoperative rehabilitation has advantages and disadvantages for clinical outcome after anterior cruciate ligament reconstruction.

6. Wright RW, Preston E, Fleming BC, et al. A systematic review of anterior cruciate ligament reconstruction rehabilitation: part I: continuous passive motion, early weight bearing, postoperative bracing, and home-based rehabilitation. *J Knee Surg.* 2008;21(3):217–224.

Many issues regarding ACL reconstruction rehabilitation have been evaluated using randomized controlled trials. The methodologic quality of the studies reviewed is mixed. Most of the studies have some form of potential bias. This is especially true of the studies published prior to 2000, when many of the study quality issues were not yet recognized. Despite this, some reasonable conclusions can be made from the studies and used in developing an ACL reconstruction rehabilitation protocol. Early weight bearing appears beneficial and may decrease patellofemoral pain. Early motion is safe and may help avoid problems with later arthrofibrosis. Continuous passive motion is not warranted to improve rehabilitation outcome in patients and can avoid the increased costs associated with CPM. Minimally supervised physical therapy in selected motivated patients appears safe without significant risk of complications. Postoperative rehabilitative bracing either in extension or with the hinges opened for range of motion does not offer significant advantages over no bracing.

7. Wright RW, Preston E, Fleming BC, et al. A systematic review of anterior cruciate ligament reconstruction rehabilitation: part II: open versus closed kinetic chain exercises, neuromuscular electrical stimulation, accelerated rehabilitation, and miscellaneous topics. *J Knee Surg.* 2008;21(3):225–234.

Early weight-bearing appears beneficial and may decrease patellofemoral pain. Early motion is safe and may help avoid problems with later arthrofibrosis. Continuous passive motion is not warranted to improve rehabilitation outcome in patients and can avoid the increased costs associated with CPM. Minimally supervised physical therapy in selected motivated patients appears safe without significant risk of complications. Until further studies are performed, protocols should use closed kinetic chain exercises in the first 6 weeks. Postoperative rehabilitative bracing either in extension or with the hinges opened for range of motion does not offer significant advantages over no bracing. Neuromuscular electrical stimulation, if deemed necessary for patients, should be instituted early in the postoperative period and should be of high intensity to achieve meaningful results. Accelerated rehabilitation appears safe, at least in the 5-month to 6-month time frame. Water-based therapy, stair climber, and slide board exercise programs appear safe and may add variety if available for patients. Gait, proprioception, and psychological training may be of some benefit. Creatine, at least in the dosage and time frame used by offered no benefit. Restricting blood flow during rehabilitation sessions requires further studies before it becomes regularly prescribed by most clinicians. Despite more than 50 randomized controlled trials in the field, many questions remain, and further studies are warranted to continue to add evidence to our ACL reconstruction rehabilitation protocols.

CAPTIONS

Figures

Figure 1. Towel Stretch exercise. The towel is used to lift the heel of the affected leg to end range knee hyperextension by pulling the towel upwards.



Figure 2. Leg Press



Figure 3. Open chain knee extension with leg weight. This exercise should begin with no more than 1 lb. of resistance. Each week, increase resistance by 1 lb. increments if tolerated.



Figure 4. Single leg balance training with medicine ball throws. This medicine ball exercise is performed while balancing on a tilt board with one leg.



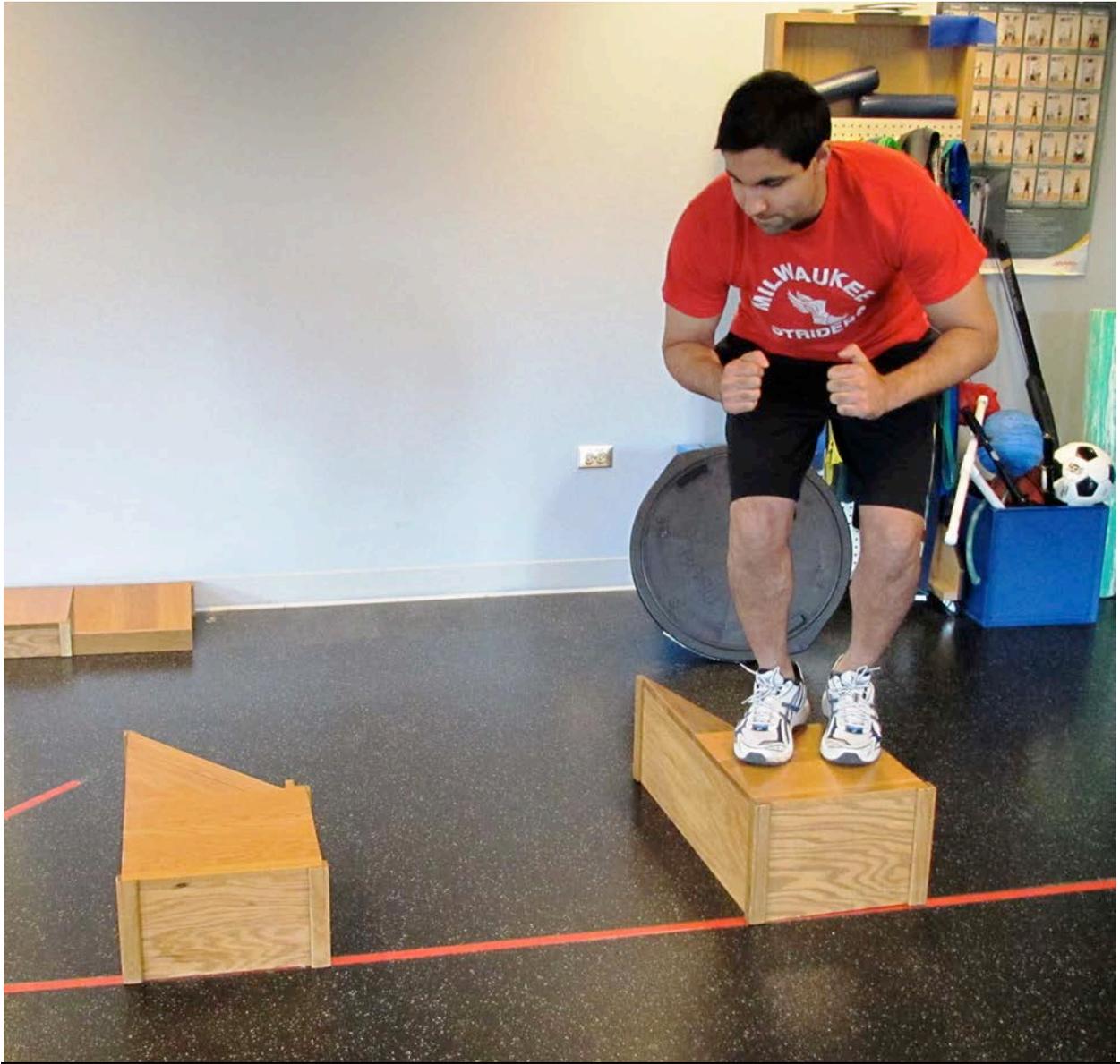
Figure 5. Single leg perturbation training using a tilt board.



Figure 6. Wall squats.



Figure 7. Plyometric jumping exercises



REHABILITATION TIMELINE

Title of Topic: Post-surgical Rehabilitation after Soft Tissue ACL Reconstruction (Autograft and Allograft)

Weeks 1-2 post-op	<ul style="list-style-type: none">Knee extension brace locked in full extensionCrutches for comfort, WBATROM: full passive knee extension and 90 degrees knee flexionPatellar mobilizationAnkle pumps, wall slides, SLR, prone leg hangs
Weeks 2-4	<ul style="list-style-type: none">Slowly discontinue brace and crutchesPT ModalitiesOverpressure into full knee extensionPassive ROM from 0-115° flexionContinue patellar mobilityBicycle, SLRIsometric quad sets, half squatsFront and side lungesLateral step upsFront step upsPerturbation trainingBicycling for endurance
Weeks 4-10	<ul style="list-style-type: none">No brace or crutchesPT Modalities as neededPROM-full, continue self performed ROM exercisesBicycleSLR (hip flexion, adduction, abduction, extension)Pool running (backwards/forward)Leg pressHamstring curl (begin at 6 weeks post-op if hamstring autograft was harvested)Progress isometric strength programBalance training on tilt board and with medicine ball throwsLunge exercisesWall squats, vertical squats, toe calf raisesOpen chain resistance with extension – begin slowly with 1 lb. weightStair stepper machinePerturbation training
Weeks 10-16	<ul style="list-style-type: none">PT Modalities as neededPROM-fullBicycleStraight leg raisesProgress Pool RunningCan start running straight ahead at 12 weeksLeg press, hamstring curlsProgress isometric strengthening programsPerturbation training on a single legContinue balance training with medicine ballContinue open chain resistance trainingBiodex Stability System (Shirley, NY)Initiate Plyometric leg press by weeks 12-16

ORTHOPAEDIC REHABILITATION OF THE ATHLETE:

GETTING BACK IN THE GAME

Reider, Provencher & Davis

Weeks 16-22

Initiate sport specific exercises (cone drills, side shuffles, cariocas, cutting)
Combinations of agility drills

PROM-maintain full motion
Bicycle
Straight leg raises
Continue to Progress Pool Running – full forward and backwards running
Increase cutting maneuvers
Leg press, hamstring curls
Progress isometric strengthening programs
Perturbation training on a single leg
Progress open chain resistance training
Biodex Stability System (Shirley, NY)
Progress Plyometric leg press and sport specific plyometric drills
Continue sport specific exercises (sudden start/stops, cone drills, agility drills)
Sport specific skill training (e.g. coming out of 3 point stance for football lineman)

Weeks 22-52

Gradual return to sports participation
Contact athletes should first return to practice on limited basis before full contact
Maintenance program for strength and endurance
Continue sport specific skill training

MULTIPLE-CHOICE QUESTIONS

Provide up to five multiple-choice questions. Questions should include four responses, with only one response being correct. Indicate the section of your text where the answer may be found.

Question: When should bracing be discontinued?

- a. 2-4 weeks
- b. 16 weeks
- c. 10 weeks
- d. 12 weeks

Correct answer: A. Indicate where in the preceding text the answer may be found (e.g., see Week 2-4): see Week 2-4

Question: Which of the following are not good treatments for post-operative pain in the immediate post-operative period?

- a. Cryotherapy
- b. TENS devices
- c. Passive range of motion
- d. Open chain exercises

Correct answer: D. Indicate where in the preceding text the answer may be found (e.g., see see Week 2-4): see Week 0-2

Question: Which of the following is not a goal for the immediate post-operative period?

- a. Restore full passive knee extension
- b. Reduce joint swelling
- c. Reestablish voluntary quadriceps control
- d. Return leg strength to normal

Correct answer: D. Indicate where in the preceding text the answer may be found (e.g., see see Week 2-4): see Week 0-2
