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# Criterion-Based Approach for Rehabilitation After ACL Reconstruction

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## 47.1 Introduction

Postoperative rehabilitation of anterior cruciate ligament reconstruction (ACLR) progresses in five phases from the time of surgery up to clearance for return to preinjury activity. Every patient will complete the first phase of rehabilitation to resolve impairments and return to normal activities of daily living. Patients may then progress through phases focused on more demanding activities to include running, jumping, hopping, and rotational activities including sports-specific skills based on strict criteria. Not every patient will have the same goals for their postoperative rehabilitation. Therefore, it is the responsibility of the orthopedic sports medicine team, including the surgeon and rehabilitation professional, to determine the ultimate phase of rehabilitation that needs to be completed by each patient. Ultimately, success must be judged

on an individual level, specifically based on the desires of the patient.

This chapter will present the protocol developed at the University of Pittsburgh Medical Center (UMPC) Center for Sports Medicine for rehabilitation and return to sports after ACL reconstruction. Recommendations for the return-to-sports phase and prevention of second injury were based on the literature, where available. The clinical decision-making process for return to sports emphasizes structured objective clinical and functional tests and patient-reported outcome measures with associated criteria [4, 21, 41]. While this protocol is evidence based as possible, further research regarding reinjury and successful return to sports is needed to determine the extent of rehabilitation after ACLR [25].

These guidelines are unique in their structured progression of rehabilitation after the immediate postoperative phase, using quantitative and qualitative criteria to progress sports activities. The rehabilitation principles remain the same throughout the rehabilitation process – mastery of basic tasks and progressive demands for demonstrating muscle strength and neuromuscular control. Patients must meet all criteria to progress to the next phase. Exercise selection matches the demands of the current stage and builds upon previous exercises. Balance, proprioception, motor control, agility, and plyometrics training are encouraged to improve performance and limit the risk of secondary injury [8, 15, 16, 26, 28, 36].

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This protocol can be followed in nearly every clinical setting with slight modifications by the physical therapist. No special equipment or facilities are needed for this rehabilitation.

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## 47.2 Assessment of Mastery

Patients must demonstrate mastery of the current phase before progressing to ensure that aberrant and deleterious movement patterns are resolved before beginning more demanding activities. This assessment is qualitative while the patient attempts maximum effort while completing the task, but quantitative measures are included when possible. Based on the visual assessment, patients are given remedial activities and deliberate practice to improve performance.

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## 47.3 Strength Measurement

Adequate quadriceps strength is a critical component of recovery and a predictor of performance in dynamic activities after ACLR [38, 39]. Quadriceps muscle strength deficits may be one of many components to increase risk of a second knee injury after returning to sports participation. When available, isometric or isokinetic dynamometry should be used to measure quadriceps strength, as it isolates the musculature and provides reliable objective measures. In our clinic, quadriceps and hamstrings strength are measured with a maximum volitional isometric contraction for 5 s on an electromechanical dynamometer. To reduce the risk of patellar fractures after patellar or quadriceps graft harvest, isometric strength testing with a dynamometer is delayed until 4 or 5 months post-op, and the knee is positioned at 60° of knee flexion to reduce bending forces across the patella.

In cases where dynamometry is not available, strength testing is recommended using a 1 repetition max (1-RM) on a knee extension machine [3, 30]. For the 1-RM leg extension, the individual is positioned with the hip and knee at 90° of flexion, with the resistance pad placed proximally to the malleoli. The individual extends their knee to 45° of knee flexion. If a patient has postoperative restrictions for range of motion (ROM) due to a concomitant injury

or surgical procedure, strength testing should not be completed until these restrictions are lifted.

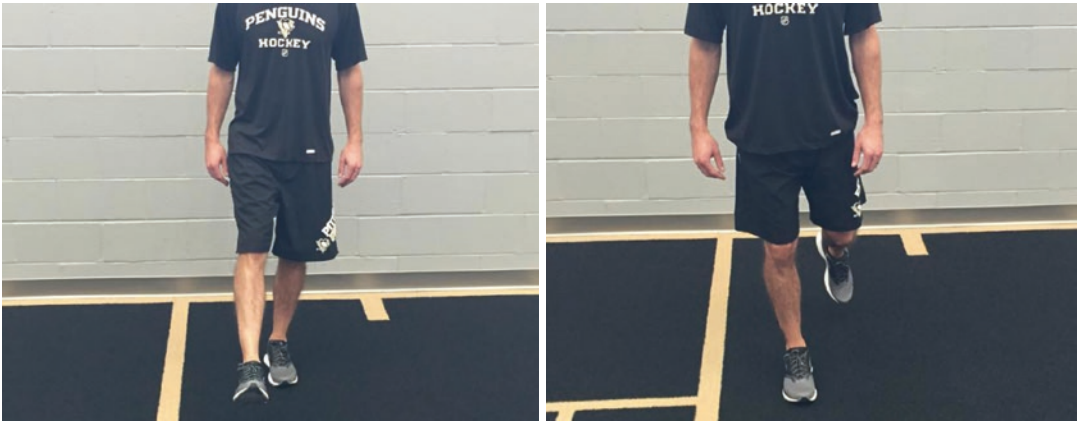
A limb symmetry index (LSI) is calculated as the 1-RM load of the involved limb divided by the 1-RM load of the uninvolved limb multiplied by 100. The leg extension 1-RM test has not been validated compared to isometric dynamometry to measure limb symmetry; however, this testing may be done easily in a clinical setting with standard equipment. The leg extension test is preferred because it isolates the quadriceps musculature and more closely simulates isometric dynamometry testing. Strength testing should occur serially to ensure strength is maintained at the least and ideally progressing.

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## 47.4 Neuromuscular Control

Neuromuscular control is tested with three basic tests with progressive criteria for each phase of rehab. The step and hold is a low-level approximation of running to screen for abnormal mechanics and pain. The patient steps from the uninjured limb onto the injured limb on a flat surface, at least the distance of the individual's normal stride length. The individual must land with a heel-toe gait pattern to simulate walking. The distance is progressed to prepare for running. Individuals must complete 30 step and holds without loss of balance, excessive knee stiffening, or excessive knee flexion (Fig. 47.1: *Step and Hold*). The single-leg squat is performed for ten consecutive repetitions to 45° or greater of knee flexion (depending on the phase of rehabilitation) to screen for deviations (Fig. 47.2: *Single-Leg Squat*). Deviations are operationally defined as the use of compensatory patterns including loss of balance, contralateral hip drop, excessive femoral abduction or adduction, excessive femoral internal rotation, or abnormal trunk movement [33].

The Y-balance test is a measure of stability between limbs that correlates with injury risk [12, 34]. The individual stands facing the stem of a “Y” made of tape on the floor, with two arms extending posterior at 135° clockwise and counterclockwise from the stem. While maintaining single-leg balance and not shifting weight to the opposite limb, the patient reaches as far along each point as



**Fig. 47.1** Step and hold. Patients must perform 30 step and holds without loss of balance or excessive motion in the frontal or transverse plane

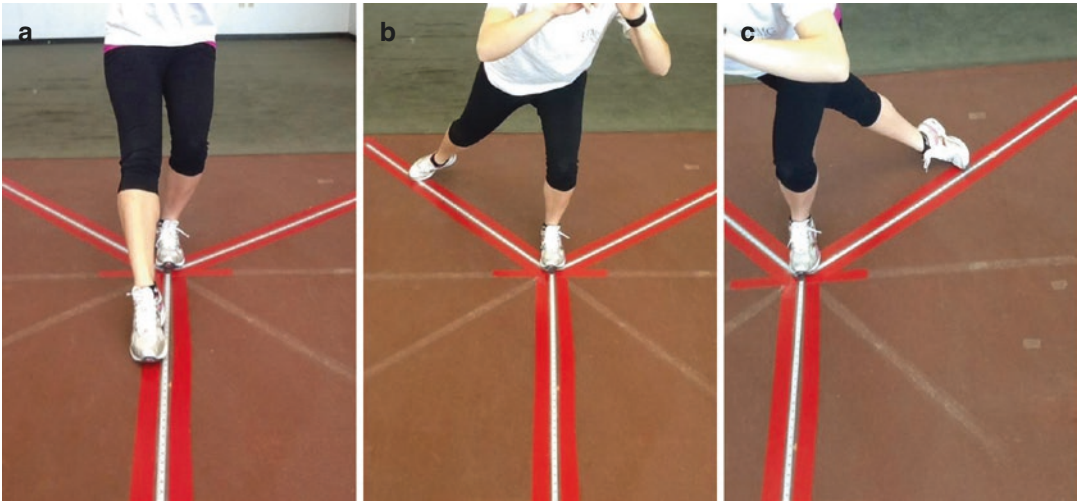


**Fig. 47.2** Single-leg squat. This task is performed to the appropriate prescribed angle of knee flexion for ten repetitions to screen for deviations

possible with the opposite leg limiting gross compensatory patterns (Fig. 47.3: *Y-balance test*). Two practice trials and four measured trials are completed for each direction. The distance is mea-

sured from the center of the Y in centimeters to the position of maximum reach. Performance is normalized to leg length measured from the inferior aspect of the anterior superior iliac spine

$$Y - \text{balance composite score} = \frac{(\text{anterior reach} + \text{posteromedial reach} + \text{posterolateral reach})}{(3 \times \text{limb length})}$$



**Fig. 47.3** Y-balance test. The individual stands with the toe of the testing foot at the center of the Y and reaches as far along each point as possible without transferring

weight to the reach limb. (a) Anterior reach on the right leg; (b) posteromedial reach on the right leg; (c) posterolateral reach on the right leg

to the most prominent aspect of the lateral malleolus. Comparisons between limbs are made for each reached distance and a composite score.

## 47.5 The UPMC Center for Sports Medicine Functional Training and Return to Sports Rehabilitation Protocol

### 47.5.1 Phase 1: Immediate Postoperative Rehabilitation

The immediate postoperative rehabilitation begins 2–7 days after surgery depending on the amount of preoperative rehabilitation and education provided. The goals of phase 1 are to (1) prevent ROM loss, (2) promote activation of the quadriceps, (3) reduce the inflammatory process in the knee (swelling and pain), and (4) ensure safe and effective ambulation. Once these primary goals have been achieved, postoperative physical therapy aims to normalize ROM, strength, and daily activity.

After ACLR, the knee joint is significantly inflamed, as evidenced by swelling and postoperative pain. Swelling is associated with both impaired quadriceps activation and limited flex-

ion ROM. Slight knee joint flexion is the position of minimal joint contact and is typically the preferred position of comfort for individuals with pain and swelling. Therefore, patients after ACLR may be unable to achieve full active extension due to poor quadriceps activation and discomfort.

The initial focus of rehabilitation is to achieve active knee joint extension to neutral ( $0^\circ$ ) with a quadriceps contraction that produces a superior patellar glide. The patient should be positioned sitting on the ground (or a long table) with their legs straight in front of them and nothing underneath the knee joint. The heel may be propped to allow for full extension or mild joint hyperextension. Patellar mobilizations are effective in increasing the available ROM of the patellofemoral joint. Quadriceps activation can be facilitated with simultaneous contraction of the contralateral quadriceps, manual facilitation of a superior patellar glide, or neuromuscular electrical stimulation (NMES) [11]. Care should be taken to avoid common compensations for an inability to activate the quadriceps. Compensations include contraction of the gluteus maximus to extend the femur or dorsiflexion of the ankle joint to create a sensation of tension across the posterior capsule (i.e., perceived stretch by the patient). Low-load,

prolonged stretch exercises may be of benefit to the patient who struggles with extension ROM. These exercises may include prone positioning with a weight on the heel to promote extension or a long sitting position (as described above) with the heel propped on a bolster. These exercises may be used but care should be taken to ensure that the patient is able to relax enough to allow extension to occur. Patients who do not achieve neutral extension by the end of postoperative week 2 or extension within  $3^\circ$  of the contralateral limb by 4 weeks postoperative should be referred back to their treating surgeon for evaluation.

Flexion ROM can be increased with active ROM exercises and active assisted ROM exercises (e.g., heel slides). For individuals with hamstring autograft ACLR, care should be taken early after surgery to avoid resisted or strenuous activation of the hamstrings while healing occurs. For individuals who are unable to increase ROM independently with active and active assisted ROM exercises, patellofemoral joint mobilizations are beneficial. Specifically, inferior joint mobilizations replicate the normal arthrokinematics of knee joint flexion. Medial patellar joint mobilizations may also be helpful when knee joint effusion forces the patella to deviate laterally during knee joint flexion. Patients who do not achieve  $90^\circ$  flexion by the end of postoperative week 2 or  $120^\circ$  by 4 weeks postoperative should be referred back to their treating surgeon for evaluation, if a regularly scheduled appointment does not already exist.

To promote increases of ROM, it is also important to reduce the overall amount of swelling in the knee joint. Aside from potential pharmacological intervention from the medical provider, the rehabilitation professional can assist the process through the application of compression and elevating the limb. Cryotherapy is also of benefit to decrease inflammation and control pain. Effusion should be tracked with the modified stroke test [40], with an expectation that the patient achieve a grade of 2+ between weeks 2 and 4 postoperative and a 1+ by week 8.

Patients with noncomplicated ACLR (i.e., no meniscus repair or chondral surgery) should be encouraged to assume a normal gait as soon as

possible after surgery. Depending on surgeon preference and recommendation, patients may be issued a postoperative brace and/or assistive device. To initiate the normal gait cycle, exercises such as terminal knee extension to simulate the midstance phase of gait and weight shifts to simulate initial contact and weight acceptance can be implemented. As the patient demonstrates a consistent, normal step through gait without pain or excessive aberrant movements, they can discontinue crutch use. Until gait is completely normal, they should use the crutches with weight bearing as tolerated to practice a normal walking pattern. Patients are recommended to use the postoperative brace in crowded or uncertain situations (e.g., inclement weather).

The primary strength focus of postoperative rehabilitation is for the quadriceps muscle in both weight-bearing and non-weight-bearing exercises. Non-weight-bearing exercise is crucial to isolate the quadriceps muscle. There is concern that non-weight-bearing knee extension exercises may put excess stress on the reconstructed ACL due to anterior tibial shear. However, limiting the ROM to between  $90^\circ$  and  $45^\circ$  of knee flexion limits that anterior strain [9]. Weight-bearing exercises in the  $45^\circ$  to  $0^\circ$  ROM also produce limited strain on the graft. Therefore, these range restrictions are imposed for the first 8–12 weeks after ACLR, after which the ranges of motion are slowly increased. Weight-bearing exercises typically reflect the demands of daily activities to improve performance in those tasks (e.g., step-ups, step-downs, sit to stand). Various versions of squats and leg presses may also be used. Any irritation to the patellofemoral joint should be treated with specific patellar mobilizations to increase mobility, stretching exercises for the quadriceps especially the rectus femoris, and additional strengthening of the quadriceps. All exercises should be pain-free, and the patient should not complain of pain after therapy.

In addition to the quadriceps, the other lower-extremity muscles affecting the knee joint should be strengthened as needed. The hip abductors, external rotators, and extensors are important for dynamic control of the femur. The calf muscles, especially the muscles to dynamically support the arch of the foot, are also important to control

the tibia. As a general treatment approach, abdominal and lumbar strength should be targeted with specific exercise to limit aberrant trunk motions which influence the demands on the knee joint.

### 47.5.2 Phase 2: Running

Running on a treadmill or track provides controlled environment to systematically increase the load placed on the knee joint between 3 and 5 months after ACLR. Progression to the running phase is only allowed after mastery of phase 1 has been determined. This includes symmetrical ROM, trace or less knee joint effusion, and minimal gait deviations during fast treadmill walking. Gait deviations including decreased stride length, contralateral pelvic drop, femoral internal rotation, and medial collapse of the knees while walking indicate the patient is not ready for running. The patient must then complete a Y-balance test composite score of at least 90%, 30 step and holds, and 10 consecutive single-leg squats on the involved leg to at least 45° of knee flexion without compensatory patterns. Finally, the individual must demonstrate 80% quadriceps muscle strength symmetry.

When the patient achieves the criteria without increased pain or inflammation, a run-walk progression is implemented with progressive increases

in distance (see example in Adams et al. [1]). The authors advocate a distance-based progression rather than a time-based progression to more accurately monitor knee joint loading during this phase. When an appropriate running gait pattern is consistently observed, the individual can complete the running progression independently.

### 47.5.3 Phase 3: Basic Agility Drills

To demonstrate mastery of phase 2, the individual must be able to run 2 miles continuously without any complaints of pain, signs or increased swelling, and without gait deviations. Neuromuscular control is tested with 10 consecutive weighted single-leg squats to 45° of knee flexion without aberrant movements with a limb symmetry index of greater than or equal to 75% and a Y-balance test with a composite score of at least 100%. Individuals must also demonstrate greater than or equal to 85% LSI for quadriceps strength.

Once these tests are passed, the individual can begin agility training. Basic agility drills include straight plane movements (anteroposterior and lateral), such as shuttle running, side shuffling, carioca (lateral shuffling while crossing your trail leg over the lead leg), and agility drill ladder exercises or small agility hurdles in forward and

#### Criteria to Start Jogging at 4–6 Months

##### Post-Op

- No abnormal gait patterns while walking as fast as they can on the treadmill for 15 min
- Thirty step and holds without loss of balance or excessive motion outside of the sagittal plane
- Ten consecutive single-leg squats to 45° of knee flexion without deviation
- ≥80% 1-repetition maximum (1-RM) on the knee extension machine (90–45°)
- ≥90% composite score on Y-balance test

#### Criteria to Start Agility Training

- Be able to run 2 miles continuously without pain, swelling, warmth, or gait deviations
- Ten consecutive single-leg squats >45° of knee flexion without deviation while holding ≥75% extra weight compared to the other side (dumbbells, weight vest, etc.)
- ≥85% 1-RM on the knee extension machine (90–45°) or Biodex testing if available
- One hundred percent composite score on Y-balance test

lateral directions. Direction changes with appropriate hip and knee flexion to absorb the load are emphasized. To promote safe movements, effort begins at approximately 50% speed and progresses as performance improves. Compensatory patterns should be quickly resolved with cueing from the physical therapist.

#### 47.5.4 Phase 4: Double-Limb Jumping

To demonstrate mastery of phase 3 (low-level agility drills), the patient must complete forward/backward shuffling, side shuffling, carioca, and ladder drills at full speed without compensation patterns. Individuals must also demonstrate adequate neuromuscular control by performing ten consecutive weighted single-leg squats to at least 60° of knee flexion with a limb symmetry index of at least 85% and demonstrate quadriceps muscle strength symmetry of greater than or equal to 90% LSI.

Phase 4 of rehabilitation includes double-limb jumping, in which the individual begins with forward jumps, lateral jumps, and rotational jumps. Progression to ascending and descending box jumps is at the discretion of the physical therapist. Rebounding jumps and combination movements are the final stage of progression. The patient must avoid abnormal frontal and transverse plane movements (dynamic valgus) and should be cued to exaggerate hip and knee flexion with a soft and quiet landing with equal weight distribution for takeoff and landing [8, 15, 26, 32].

##### Criteria to Start Jumping

- No compensation patterns with deceleration during agility drills performed at near 100% effort.
- Ten consecutive single-leg squats to 60° of knee flexion without deviation while holding  $\geq 85\%$  extra weight compared to the other side (dumbbells, weight vest, etc.). Body weight is not part of the equation.
- $\geq 90\%$  1-RM on the knee extension machine (90–45°) or Biodex testing if available.

#### 47.5.5 Phase 5: Single-Limb Hopping and Cutting and Sports-Specific Drills

The patient must demonstrate mastery of rebound and combination jumps without compensations. To demonstrate neuromuscular control, individuals must perform ten consecutive weighted single-leg squats to at least 60° of knee flexion with a limb symmetry index of greater than or equal to 90% and demonstrate quadriceps muscle strength symmetry of greater than or equal to 90% LSI (Table 47.1).

In phase 5, hopping drills follow the same progression as jumping drills in phase 4. Rotational demands are added with cutting and pivoting drills including running in an “S” pattern or a figure of 8, progressing to 45° cuts, and then to sharper angle cuts. Pivoting should begin when the individual is competent with cutting at sharp angles. Similar to phases 2–4, confidence and performance dictate the speed of cutting and pivoting drills, and the individual should not progress to high-level cutting and pivoting drills if they demonstrate compensatory patterns or poor confidence [7]. The final aspect of these drills is to perform unanticipated cutting, pivoting, and hopping (i.e., reactionary drills). Once the individual performs these drills with confidence and at pace, rehabilitation will solely focus on the specific demands needed to return to sports.

##### Criteria to Start Hopping and Cutting

- No display of medial collapse of the knees when loading into or landing from jumps and equal weight distribution when initiating and landing the jumps.
- Ten consecutive single-leg squats to 60° without deviation while holding  $\geq 90\%$  extra weight compared to the other side (dumbbells, weight vest, etc.). Body weight is not part of the equation.
- $\geq 90\%$  1-RM on the knee extension machine (90–45°) or Biodex testing if available.

**Table 47.1** Criteria to advance to each new phase

<b>Criteria to enter phase 2 – running:</b>		
Phase 1 mastery	Symmetrical ROM, minimal knee joint effusion (trace or less)	
	Maximal treadmill walking ×15 min without deviations <sup>a</sup>	
Neuromuscular control	Step and hold	30 repetitions without deviation <sup>a</sup>
	Single-leg squats	10 repetitions to 45° of knee flexion without deviation <sup>a</sup>
	Y-balance test <sup>b</sup>	≥90 % composite score
Quadriceps strength	Strength battery	Leg extension ≥80 % 1-RM LSI (90–45°)
	OR	
	Isometric dynamometry	≥80 % limb symmetry index
<b>Criteria to enter phase 3 – low-level agility drills:</b>		
Phase 2 mastery	Run 2 miles continuously without pain, swelling, warmth, or gait deviations	
Neuromuscular control	Single-leg squats <sup>c</sup>	10 repetitions to >45° of knee flexion without deviation <sup>a</sup> and 75 % LSI
	Y-balance test <sup>b</sup>	≥100 % composite score
Quadriceps strength	Strength battery	Leg extension ≥85 % 1-RM LSI <sup>d</sup> (90–45°)
	OR	
	Isometric dynamometry	≥85 % limb symmetry index
<b>Criteria to enter phase 4 – double-leg jumping:</b>		
Phase 3 mastery	No compensation patterns with deceleration during phase 3 agility drills performed at full speed	
Neuromuscular control	Single-leg squats <sup>c</sup>	10 repetitions to 60° of knee flexion without deviation <sup>a</sup> and 85 % LSI
Quadriceps strength	Strength battery	Leg extension ≥90 % 1-RM LSI (90–45°)
	OR	
	Isometric dynamometry	≥90 % limb symmetry index
<b>Criteria to enter phase 5 – single-leg hopping and cutting:</b>		
Phase 4 mastery	No deviations when initiating and landing jumps	
Neuromuscular control	Single-leg squats <sup>c</sup>	10 repetitions to 60° of knee flexion without deviation <sup>a</sup> and 85 % LSI
Quadriceps strength	Strength battery	Leg extension ≥90 % 1-RM LSI (90–45°)
	OR	
	Isometric dynamometry	≥90 % limb symmetry index

<sup>a</sup>Deviations include loss of balance, excessive motion outside of the sagittal plane, abnormal trunk movement, contra-lateral pelvic drop, femoral internal rotation, and medial collapse of the knees

<sup>b</sup>Y-balance test composite score:  $\frac{\text{Anterior reach} + \text{posteromedial reach} + \text{posterolateral reach}}{3 \times \text{limb length}} \times 100\%$

<sup>c</sup>Single-limb squat limb symmetry index:  $\frac{\text{External load during involved limb single leg squat}}{\text{External load during uninvolved limb single leg squat}} \times 100\%$

<sup>d</sup>1-RM LSI:  $\frac{\text{Involved limb 1-RM}}{\text{Uninvolved limb 1-RM}} \times 100\%$

## 47.6 Return-to-Practice Testing and Return to Sports

Return-to-practice testing occurs when the individual can run and perform all agility, plyometrics, and sports-specific drills without any hesitation and compensatory patterns and with no

complaints of pain, instability, or signs or symptoms of inflammation. The battery of return-to-sports testing (Table 47.2) includes a strength assessment, functional testing for symmetrical performance, and functional testing for running situations. Individuals must demonstrate greater than or equal to 90 % quadriceps LSI to pass the



**Table 47.2** Post-op ACL reconstruction return-to-sports test

Post-op ACL reconstruction return-to-sports testing				
Quadriceps strength	Involved limb	Uninvolved limb	Limb symmetry index	Passing score
1-RM on the knee extension machine or Biodex testing				≥90 %
Hop tests	Involved limb performance	Uninvolved limb performance	Limb symmetry index	
Single-leg forward hop				≥90 %
Single-leg triple hop				≥90 %
Single-leg triple crossover				≥90 %
Timed 6-m single leg				≥90 %
Single-leg vertical hop				≥90 %
Functional runs	Patient performance	Recommended range for males	Recommended range for females	
<i>10-yard lower-extremity functional test<sup>a</sup></i>		18–22 s	20–24 s	
Trial 1				
Trial 2				
<i>10-yard pro-agility run<sup>b</sup></i>		4.5–6.0 s	5.2–6.5 s	
Toward injured limb				
Toward uninjured limb				

<sup>a</sup>Lower-extremity functional test

Sprint/back-peddle, shuffle, carioca, sprint

Must perform at perceived full speed and not display hesitation or compensation strategies when decelerating

<sup>b</sup>10-yard pro-agility test

Must perform at perceived full speed and not display hesitation or compensation strategies when decelerating

**Criteria to Return to Practice**

MD clearance

Pass return-to-sports test with ≥90 % results for each test

**Criteria to Return to Competition**

MD clearance

Tolerate full practice sessions with opposition and contact (if applicable) performed at 100 % effort without any increased pain, increased effusion, warmth, or episodes of giving way

return-to-sports testing. Once adequate strength is determined, functional testing is completed.

**47.7 Objective Functional Symmetry Testing**

Functional testing batteries are becoming more prevalent [13, 14, 23, 24, 29, 41, 42]. Unilateral hop tests correlate with quadriceps strength mea-

asures [23, 24], but do not eliminate the need for isolated testing of the quadriceps [39]. Early functional testing with hop tests can be predictive of self-reported normal knee function at 1 year after ACLR [23]. Unilateral hop test batteries are used to challenge strength and stability in a repeatable manner in the clinic, using the opposite limb as a benchmark [13, 14, 23, 24, 29, 31, 41]. Limb symmetry indexes of greater than or equal to 85 % [5], 90 % [13, 14, 23, 24, 29], and

95 % to 100 % [41, 42] have been used to indicate “normal” or symmetrical performance and used for clearance to return to sports. These cutoffs have not been validated as predictors of safe return to play. The authors recommend the use of greater than or equal to 90 % limb symmetry of hop test measures as an adequate cutoff for clearance to return to sport. A LSI threshold of 90 % is used as opposed to 95 or 100 % as recommended by the European Sports Rehabilitation Board [41] as these thresholds may be too stringent and unattainable for some individuals.

The Noyes’ hop series has been well described and involves four tests: the single hop for distance, the triple hop for distance, the triple crossover hop for distance, and the timed 6 m hop [6, 10, 31, 35]. All takeoffs and landings must occur in single-limb stance without excessive trunk or arm motions for balance. As noted above, involved limb performance is normalized to the uninvolved limb and expressed as a limb symmetry index. Because the uninvolved limb is expected to move the individual more rapidly down the line during the 6 m timed hop, the uninvolved limb is expressed as a percentage of the involved limb to maintain the convention that scores less than 100 % indicate superior performance of the uninvolved limb.

Muscular power is tested with a single-limb vertical hop test. The individual stands next to a wall and jumps as high as possible from one limb, using their preferred countermovement strategy. The landing is uncontrolled, but monitored for compensations. The individual attempts to jump as high as possible, measured by either having the individual put a piece of tape on the wall or using a Vertec System (Gill Athletics, Champaign, IL). Limb performance is expressed as a ratio of the best recorded jump height of three trials on the reconstructed limb compared to the contralateral limb.

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## 47.8 General Functional Agility Testing

Bipedal agility tests are not sufficient to identify asymmetries between limbs [29]. To provide a consistent method for assessing movement quality in bipedal tasks, patients complete two functional runs that focus on quickness and con-

fidence when making direction changes. The lower-extremity functional run (Fig. 47.4a) is set up on a 10-yard (30 ft) course. The athlete begins sprints 10 yards, back pedals 10 yards, plants on the involved limb and shuffles 10 yards in each direction, followed by a 10-yard carioca in each direction, and ends with a final 10-yard sprint. The pro-agility test (Fig 47.4b) involves complete direction changes on both limbs. The athlete begins straddling the center line of a 10-yard course. The athlete must sprint 5 yards and touch the cone, change direction, sprint back 10 yards and touch the cone, change direction, and sprint back through the center line. This is completed in both directions.

After successful completion of the return-to-sports test, the athlete brings the test results to their physician for final clearance. The return to practice should begin with individual drills, followed by controlled contact drills, and eventually team scrimmages. The athlete, coach, physical therapist, and surgeon should be in contact about performance and modifications. Individuals return to their physician for full return-to-competition clearance when they can practice at 100 % effort (with contact if applicable) and have no complaints of pain or signs and symptoms of inflammation.

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## 47.9 Patient-Reported Outcome Measures

Patient-reported outcome measures (PROs) are important measures of patient perception of knee function, activities of daily living, sports performance, and fear of reinjury and movement. The international medical community agrees that PROs are an important component of measuring success after ACLR; however, consensus on which specific measure to use has not been reached [25]. The authors recommended the International Knee Documentation Committee (IKDC) 2000 subjective knee form due to its comprehensive qualities and normative database [2]. The IKDC 2000 is a valid and reliable measure of knee symptoms, knee function, and sports activity in patients with a variety of knee injuries [17]. A relationship has been established between



## Conclusion

These guidelines provide a structure for returning the patient from surgery through rehabilitation. Constant communication and logical decision making are crucial to the success of this protocol and the athlete. Rehabilitation may be stopped at any of the phases if the patient does not need to progress further to meet the demands of their sport or desired level of activity. This guideline for functional testing and rehabilitation progression has been developed to be patient specific with criterion-based milestones.

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