Postoperative Rehabilitation and Return to Play After Anterior Cruciate Ligament Reconstruction

Robert A. Panariello, MS, PT, ATC, CSCS, * †
Timothy J. Stump, PT, CSCS, * †
and
Dean Maddalone, PTA, CSCS * †

An anterior cruciate ligament (ACL) disruption of the knee can be a devastating injury to the athletes, as they are faced with possible reconstructive surgery and the extensive months of physical rehabilitation that follows. Within the first postoperative year, many athletes are unable to return to their previous level of athletic performance and some athletes are unable to return to play at all. Strength and Conditioning (S&C) Professionals utilize specific exercises and training principles to enhance an athlete’s athletic performance in the arena of competition. As a major component of the ACL rehabilitation process involves the implementation of exercises for the athlete to execute, these S&C exercises and training principles should also be a consideration for utilization by the rehabilitation professional during the ACL rehabilitation. These S&C exercises and training principles may not only assist in a desired return-to-play outcome, but would also familiarize or refamiliarize the athletes with the training program design that may be instituted during their off-season athletic performance-enhancement training.

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Approximately 200,000 anterior cruciate ligament (ACL) injuries occur each year in the United States and approximately 65% of these injuries are treated with ACL reconstruction (ACLR) surgery. With specific regard to the ACLR athletes, the postoperative rehabilitation that follows plays an integral role in the athletes’ ability to return to their previous level of optimal athletic performance. However, it has been documented that at the conclusion of the first postoperative year, less than an ideal percentage of these patients with ACLR return to their preinjury level of athletic performance or are unable return to play at all. Additionally, it has been reported that those athletes who return to sport with quadriceps strength deficits of less than 85% of the contralateral limb had poorer outcomes than those who displayed minimum strength deficits of 90% or greater.

Athletes at 6-months’ post-ACLR had also demonstrated diminished levels of rate of force development (RFD) when compared with their strength levels, suggesting that RFD should be an additional criterion to determine the ability to return to play. These findings suggest the significance for the restoration of these physical qualities, as well as others, during the ACLR rehabilitation process for successful return-to-play outcomes.

Various physical qualities are incorporated into the healthy athlete’s performance-enhancement training program to achieve optimal athletic performance. The enhancement of these same physical qualities should also be a consideration during the athlete’s ACLR rehabilitation. The rehabilitation professional should also acknowledge that the most successful athletes in the world are those who place the greatest amount of force into the ground surface area in the shortest period of time. To re-establish the proficiency to achieve this physical ability, the restoration of these physical qualities is essential. As an ample portion of the prescribed ACLR rehabilitation would be in the form of exercise, would not it be advantageous for the rehabilitation professional to acknowledge the training principles and exercises executed by the strongest.
familiar with the running gait cycle as this would assist to prepare the athlete for the phase of the rehabilitation program where running would be instituted.

This dialog would not provide the rehabilitation professional with specific ACLR rehabilitation protocols, but would include particular innovative strength and conditioning training principles and exercises that are appropriate to comprise each phase of the rehabilitation process. It is important to note that the “traditional” rehabilitation exercises and principles utilized during this process should not be disregarded. The training principles and exercises discussed should be an additional restoration consideration and introduced on a case-by-case basis. Also included would be the discharge testing criteria for the athlete’s return to play.

Figure 1  Vermeil’s hierarchy of athletic development. (Color version of figure is available online.)

Phase 1 of the Rehabilitation Process

The initial phase of rehabilitation places emphasis on the protection of the ACL graft, while resolving the athlete’s pain and edema. Also included is the restoration of the athlete’s knee range of motion (ROM), strength levels, normal gait cycle, and activities of daily living to name a few. The patients must also re-establish the ability to equally distribute their body weight on each lower extremity during gait as well as perform various lower-extremity activities. Equal weight distribution would ensure the correct technical performance of such bilateral lower-extremity exercises as the squat, leg press, and deadlift, to name a few. This also is required to perform various athletic tasks such as jumping, running starts, deceleration abilities, such as landing from a jump, and change-of-direction abilities, as many athletic endeavors are initiated and conclude on 2 feet.

The patients may initially be apprehensive to fully bear weight on their ACLR extremity. At the time they demonstrate the pain-free ability to sit to stand, a “posting” technique of the nonoperative extremity may be introduced. This posting technique is utilized to impart the ability of the athlete to fully bear weight on the ACLR extremity by placing the foot of the nonoperative extremity upon an elevated surface of a specific height. Depending on the height of the athlete, posting their nonoperative extremity foot on a 3-6-in height box or raised surface before a prescribed body-weight-exercise performance would make it more difficult for the athletes to shift away from their ACLR extremity (Fig. 2). A body-weight squat exercise may be performed to a safe and appropriate depth from this posted position, thus reinforcing increased weight bearing on the ACLR extremity. Once an appropriate squat-exercise pattern has been achieved, the surface height is lowered in 1-in increments until the patient demonstrates an appropriate evenly distributed body-weight squat exercise performance. This posting technique requires greater muscle activity and torque in the nonposted ACLR lower extremity. Weight intensities are not to be applied until the patient can demonstrate an appropriate evenly distributed body-weight squat exercise technique on a level surface.

This phase of rehabilitation also requires the restoration of knee ROM. Full knee extension is the initial priority as knee

The Hierarchy of Athletic Development

Hall-of-Fame Strength and Conditioning Coach Al Vermeil has developed a hierarchy of athletic development that has been successfully adapted and implemented as a guideline in the rehabilitation of the ACLR athlete (Fig. 1).

In review of this model of athletic development, it is noted that an evaluation takes place at the time of the ACLR patient’s initial visit. The next level in the pyramid requires the enhancement of the athletes’ work capacity, or their ability to sustain work (exercise) over time. The next 4 levels of this model comprise the development of the physical qualities necessary for optimal athletic performance. These physical qualities include strength, explosive strength (power), elastic or reactive strength (plyometrics), and speed. It is important to note that, although these physical qualities may be developed simultaneously, the emphasis should be placed on the physical quality most essential for the development of the athlete at each specific phase of the rehabilitation process. The ideal development of each physical quality is dependent on the optimal development of the preceding physical quality in the pyramid, with the physical quality of strength being the foundation from where all other physical qualities derive. Strength may be defined as the ability of muscles to produce maximal force. Thus, if an athlete does not have the ability to produce an appropriate level of muscular force, how would they possibly produce adequate muscular force quickly? The enhancement of the physical quality of strength in and of itself is not sufficient for the athletes to achieve their preinjury level of athletic performance. The physical quality of strength must coincide with the physical quality of explosive strength or elastic strength or both for the best athletic performance to transpire. The rehabilitation professional should also be
Flexion is restored over a longer period of time. Often the emphasis for the restoration of knee flexion is passive in nature. The achievement of full passive ROM knee flexion establishes the soft tissue compliance as a necessary prerequisite for the required active ROM (AROM) knee flexion for a proper running gait cycle. AROM knee flexion enables the athlete to assume a foot position at the gluteal fold of the buttock at the time of the initiation of the swing phase of the running gait cycle (Fig. 3). As the running gait is a “cycle,” a disruption of a part of the running cycle would have an adverse effect on the entire running cycle. Improper foot positioning before the initiation of the swing phase would result in a less than optimal running performance. Achievement of this knee AROM would assist to prepare the athlete for the eventual initiation of running. Knee AROM is re-established by incorporating a progression of exercises, such as standing knee flexion, butt kicks, and modified Mach Drills like “A” walks (Fig. 4).

The restoration of the strength and elastic abilities of the ACLR extremity, including the Achilles tendon, should also be introduced during this phase. During elastic-strength-type activities such as high-velocity sprinting and jumping, stored elastic energy is utilized via a stretch shortening cycle (SSC) of the lower-extremity tendons. The SSC is the foundation of elastic- or plyometric-type activities as well as a “rebonding” or “reactive” effect from the ground surface area. Much of this elastic energy is derived from the Achilles tendon as this structure contributes to both high-velocity power activities as well as physiological efficiency during activities such as distance running. The plyometric phase of amortization, or the time spent on the ground surface area, is an important component of elastic- or reactive-type training. A decreased amortization phase would result in a greater amount of elastic energy available for the exercise performance. Restoring the strength of the gastrocnemius and Achilles tendon complex via exercises such as heel raises would assist to enhance elastic abilities for force output and re-establish the muscle, tendon, and joint “stiffness” for an ideal SSC to occur during plyometric exercise and high-velocity elastic-ability performance.

The physical quality of strength is the cornerstone from where all other physical qualities derive. Restoring
postoperative lower-extremity strength as well as overall total body strength should be initiated early in the rehabilitation process. The restoration of strength may occur utilizing various methods, and would assist to ensure the progression to the additional physical qualities necessary for optimal athletic performance to occur. An outline of these innovated techniques for Phase 1 is displayed in Figure 5.

**Phase 2 of the Rehabilitation Process**

This second phase of the rehabilitation process continues to improve the patient’s physical quality of strength, but when safe and appropriate, the emphasis may shift the focus to the physical quality of explosive strength (power). Power may be defined as a unit of work divided by a unit of time $P = \frac{W}{t}$. Thus, unlike the exercise performance for the physical quality of strength, the physical quality of power, much like many athletic endeavors, has a brief factor of time for successful performance. Therefore, these exercises are executed at the highest velocity possible in the shortest period of time.

An initial power exercise that may be prescribed during the ACLR rehabilitation is the box jump. When jumping up to a box or surface of a suitable prescribed height based on the patient’s abilities, the exercise is executed via an explosive jump performed by the lower extremities. The goal is to have the patient land softly on an elevated, forgiving surface as close to the “peak” height of the jump.
(the point where the body changes vertical direction) as possible. Landing on the box prevents the patient from descending to the ground surface area thus lowering the impact forces at the time of landing.

Kettlebell swings (Fig. 6) may also be incorporated at this phase of the ACLR rehabilitation. This ballistic exercise, when executed properly, promotes a proper hip-hinge pattern that is required for the technical performance of many lower-extremity exercises and activities of daily living. This exercise requires a higher executed velocity\textsuperscript{15,16} as well as the introduction of high-velocity deceleration proficiencies, which are critical for stopping, landing, and change-of-direction abilities.

Exercise progressions may continue to the Olympic-style weightlifting exercises such as the clean and the snatch or variations of these exercises such as the pulls. Olympic weightlifters have been documented as some of the strongest and most powerful athletes in the world, producing up to 6000 W of power during their weightlifting exercise performance.\textsuperscript{17,18} This power output exceeds that of strength-type exercises such as the back squat, which results in approximately 1200 W of power.\textsuperscript{19}

The technical instruction of these weightlifting exercises may be unfamiliar to the rehabilitation professional or difficult for application in the rehabilitation setting. Thus, “pulls” are a variation of these exercises that may be utilized to enhance explosive strength qualities, ground reaction forces, and RFD with little technical-exercise knowledge required. Pull variations have been documented to result in higher power output when compared with various Olympic-style weightlifting exercises\textsuperscript{20} and may be performed with dumbbells, weighted bars, and barbells.

The pull variation of the Olympic exercise performance requires the patient to assume an “athletic” posture, a common posture taught by sport coaches of athletic teams (Fig. 7A). Holding the selected free-weight apparatus of choice at a position just above the knee, the patients then triple extend by quickly extending their body at the hips, knees, and ankles to conclude in a fully extended posture on their toes with their shoulders assuming a shrugged position (Fig. 7B). The exercise concludes with the patient extended on their toes and not leaving the ground surface, as this would reduce the ground reaction forces necessary for optimal explosive strength development. The exercise performance occurs in approximately half the time (100 ms) when compared with the vertical jump (200 ms).\textsuperscript{21}

Achilles tendon exercises may also be progressed by adding a “propulsive” ground-reactive component. The advancement to modified ankling and ankling activities may transpire at this time. Low-impact “bunny hops” are performed by pushing off the balls of the feet simultaneously while slightly flexing the knees at the time of ground contact. This exercise is employed to reinforce the patient’s ability to react to the ground surface area. This modified ankling exercise may be progressed to ankling activities, whereby the patient alternates plantar flexing and dorsiflexing each foot in a modified straight leg cycling fashion while landing on the ball of the foot and immediately propelling themselves forward (Fig. 8). The knee and hip musculature have little contribution to the body’s forward movement during the exercise performance. These exercises are prescribed with sets of specific

![Figure 7](A and B) The pull variation for explosive strength enhancement. (Color version of figure is available online.)

![Figure 8](Ankling. (Color version of figure is available online.)
short distances for an accumulative effect on the elastic abilities of the Achilles tendon over the remaining course of rehabilitation.

Before the introduction of Phase 3 running, the athlete must demonstrate a controlled single-leg stepdown from a height of 8 in. An outline of these Phase II innovated techniques is displayed in Figure 9.

**Phase 3 of the Rehabilitation Process**

The third and final phase of the ACLR rehabilitation continues to progress the physical qualities of strength and explosive strength, but a greater emphasis is now placed on the physical qualities of elastic or reactive strength (plyometrics) and progression to the running gait cycle. Plyometric activities should be progressed from basic to more complex exercises, with the emphasis pertaining to a short amortization phase during exercise performance. The eventual linear running skills are then progressed to deceleration and change-of-direction skills in preparation for discharge from the ACLR rehabilitation program. An outline of the innovated techniques for Phase 3 is displayed in Figure 10.

**The Discharge Criteria**

The criteria for patient discharge are often based on a comparison of the ACLR extremity to the nonsurgical extremity. Isokinetic testing for strength and power as well as various hop, jump, and additional tests have been noted for use as criteria for return to play (Fig. 11). The physical quality requirements for the sport of participation often are not considered. Fry and Kraemer have noted the physical requirements for Division I, II, and III college football players regarding the squat, power-clean, and bench-press exercises. If the athletes’ tests results are 90% or better when comparing the ACLR extremity with the uninvolved extremity, but their demonstrated physical qualities are less than the physical quality standards of their sport of participation, is the returning

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**Figure 9** Innovative techniques for Phase 2.

**Figure 10** Innovative techniques for Phase 3.
athlete increasing his or her risk of injury? If the stresses of the athletic competition, including the confrontation of a more physically developed opponent, exceed the physical abilities of the returning ACLR athlete, are they placed at greater risk of injury? When considering the return to play of a highly-ranked, 18-year-old male high school football player, to rank in the top 10% of physical quality performance when compared with the performance of his high school football peers, he would be required to back squat, power clean, and bench press 465, 250, and 275 pounds, respectively. If he is a top-rated running back athlete, can he return to his previous levels of performance, demonstrating a long jump distance of greater than 9 ft, a vertical jump of approximately 33 in, and run a 4.49-second 40-yard sprint?

The return-to-play testing criteria documented above not only includes a comparison of the 2 lower extremities, but also acknowledges the testing of the physical qualities necessary for the return to the athlete’s sport of participation.

Summary

The rehabilitation of the ACLR athlete should consider the exercises and principles of training of all of the physical
3. Single Leg Reverse Step Down (Hips 90 / Knees 90) (10 reps) (Ant)

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<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Knee Valgus</td>
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<tr>
<td>Knee Varus</td>
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<td>Hip Drop</td>
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<td>Trunk lean</td>
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<td>Loss of balance</td>
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<td>Insufficient Eccentric Control</td>
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<td>Bounce during touch</td>
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<td>Toe Touch first</td>
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<td>No</td>
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<td>Pain</td>
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**PHASE 3- POWER**

1. Vertical Jump (jump mat) 3 Jumps (video- Ant) Cue-Jump and Reach

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2. Standing Long Jump (2 warm ups / 3 Trials) (video-Ant) Cue-Jump far and land soft

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3. Single Leg Vertical Jump (jump mat) 3 Jumps (video- Ant) Cue-Jump and Reach

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<td>PASS &gt;85%</td>
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4. Single Leg Long Jump (2 warm ups / 3 Trials) (video- Ant) Cue-Jump far and land soft

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<td>PASS &gt;85%</td>
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5. Lateral Push off for distance (2 warm ups / 3 Trials) (video-Ant) Cue-Jump far and land soft

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**Figure 11 (continued)**
PHASE 4 – REACTIVE STRENGTH

1. GCT- 4 inch box (video- camera on floor lateral view)  Cue-Quick off the ground

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<th>R sec</th>
<th>L sec</th>
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2. Tuck Jump (10 secs) (video-Ant / lat)  Cue-Bring knees to chest

- Knee and Thigh: Knee Valgus
- Foot Position Landing: Not shoulder width
- Technique: Excessive noise with landing

If 6 or more – Fail

3. Borzov 90 / 90 (5 x each leg) (video-Ant)  Cue- Jump and Land quickly

- Knee Valgus: Yes  No
- Knee Varus: Yes  No
- Trunk lean: Yes  No

4. Skaters Hop for Time (video-Ant) (30 sec)  Cue- Jump as quick as possible

R foot Contacts ___________  L foot Contacts ___________

- Knee Valgus: Yes  No
- Excessive Trunk Lean: Yes  No

PHASE 5- SPEED

1. Change of Direction (video-Ant)  Cue: Cut and decelerate

Figure 11 (continued)
qualities necessary for optimal athletic performance, the physical requirement standards of the sport of participation, and an understanding of the running gait cycle, as many competitive events require the athlete to run at high velocities. The discharge testing criteria also should correspond to these same requirements as to constrain the return-to-play criteria as a comparison to the noninvolved extremity that may be a limitation to the return-to-play criteria as well as place the athlete at risk of reinjury.

References