

# Current Controversies in Rehabilitation After Anterior Cruciate Ligament Reconstruction

David J. Pezzullo, MS, PT, SCS, ATC\* and Paul Fadale, MD†

**Abstract:** Rehabilitation concepts after anterior cruciate ligament (ACL) reconstruction continue to advance rapidly. A review of the recent literature reveals numerous aspects of the rehabilitation program, the subject of investigation, and validation. Areas discussed in this article include the efficacy of functional bracing after ACL reconstruction and perturbation training programs in nonoperative, preoperative and postoperative rehabilitation programs. Also discussed is the need for criteria-based progression through the late stages (return to sports) of the ACL reconstruction rehabilitation.

**Key Words:** anterior cruciate ligament (ACL), rehabilitation, perturbation, functional bracing, return to sports

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The paramount goal for an athlete having anterior cruciate ligament (ACL) reconstruction is to return to a preinjury level of function. Advances in graft selection, graft placement, and fixation have allowed athletes to consistently return to sports participation after surgery. Today, the quality of the postoperative rehabilitation program has greater influence than ever before on the timeliness of returning of an athlete to sports and decreasing the risk of reinjury. The investigators reviewed the literature for the evidence related to perturbation training, criteria-based return-to-sport progression and functional knee bracing in rehabilitation programs after ACL injuries.

Perturbation exercises are used to re-establish neuromuscular control and dynamic stability of the knee joint after injury or surgery. The exercises involve controlled delivery of the forces to the lower extremity in various directions, whereas the patient is standing on an unstable surface. The delivery of these destabilizing forces to the lower extremity produce compensatory muscle activity that provides stability to the knee joint. The investigators also searched for an objective rehabilitation progression that included the late phase/return to sport phase after ACL reconstruction. Numerous ACL reconstruction protocols provide specific criteria-based guidelines for the early phases of rehabilitation, but, when examining the late phase/return to sport phase, most lack specific guidelines or clinical milestones for progression. The progression in the late phase of ACL reconstruction should not be entirely

determined by the physical therapist's clinical intuition and/or by the athlete's perceived readiness to return to sports. When athletes do return to sport, functional knee bracing after ACL reconstruction is a common practice owing to the belief that bracing provides protection against excessive force even without significant evidence in the literature to support this theory.

## PERTURBATION TRAINING

Loss of range of motion, strength, power, and abnormal gait mechanics are common findings after acute ACL injury. The goal of the rehabilitation specialist is to eliminate these deficits or abnormalities as effectively, efficiently, and safely as possible. Some investigators in the literature advocate the use of perturbation training/neuromuscular training to restore normal knee kinematics and dynamic knee stabilization strategies.

Fitzgerald et al proposed nonoperative guidelines for physically active individuals and athletes to return to preinjury level of function after an ACL injury.<sup>1</sup> The investigators hypothesized that, with improved patient selection for inclusion in a nonoperative rehabilitation program, the outcome would also improve. The investigators present their selection algorithm for inclusion in the nonoperative treatment group. All candidates were required to undergo an examination by a surgeon to rule out injuries to other anatomical structures of the knee (other ligaments, meniscus, cartilage) before advancement in the selection process. Once the ACL injury was determined to be an isolated injury, the investigators administered a series of functional tests and self-report surveys. The investigators provide minimum objective scores from these tests for inclusion in their nonoperative treatment group.

The rehabilitation program consisted of muscle performance training of the lower extremities, cardiovascular endurance training, agility, and sport-specific skill training and a perturbation training program. The 10 perturbation training sessions were carried out 2 to 3 times per week; the specific techniques consisted of translational and rocking perturbation utilizing a roller board and tilt board, respectively (Figs. 1, 2). The third perturbation technique required the patient to resist an imposed force to a roller board under the involved lower extremity, whereas the uninvolved leg was on a stationary platform (Fig. 3). At 6 months after the injury, the investigators found that 79% of the patients who qualified and selected a nonoperative treatment approach were able to return to preinjury level of function and complete their athletic season successfully. Success was defined as absence of giving away or buckling of the knee.

In a second study by Fitzgerald et al, they compared a standard nonoperative treatment (consisting of strengthening,

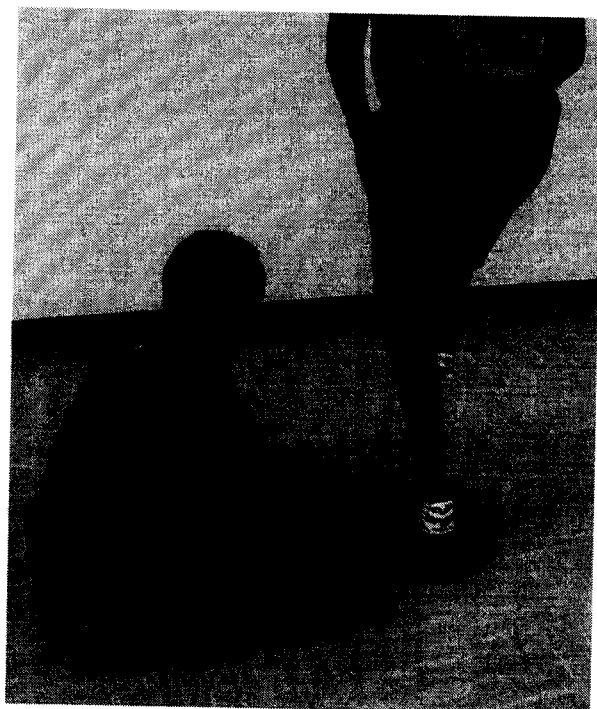
From the \*Physical Therapy, University Orthopedics, Inc; and †Sports Medicine, University Orthopedics, Inc., Medical Office Center, Providence, Rhode Island.

Reprints: Paul Fadale, MD, Sports Medicine, University Orthopedics, Inc., Medical Office Center, 2 Dudley Street, Suite 200, Providence, Rhode Island 02905 (e-mail: scastle@universityorthopedics.com).

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**FIGURE 1.** Roller board translational perturbation technique. Reprinted from *JOSPT*. 2000;30:194–203 with permission of the Orthopaedic and Sports Physical Therapy Sections of the American Physical Therapy Association.



**FIGURE 2.** Tilt board perturbation technique. Reprinted from *JOSPT*. 2000;30:194–203 with permission of the Orthopaedic and Sports Physical Therapy Sections of the American Physical Therapy Association.



**FIGURE 3.** Roller board perturbation technique. Reprinted from *JOSPT*. 2000;30:194–203 with permission of the Orthopaedic and Sports Physical Therapy Sections of the American Physical Therapy Association.

cardiovascular training, agility, and sport-specific skill training) with the same standard program augmented with perturbation training.<sup>2</sup> The inclusionary criteria, selection process, and perturbation techniques were the same as in the earlier study.<sup>1</sup> The results of this study revealed that the patients in the perturbation training group were 4.88 times more likely to experience a successful outcome (absence of giving way) than the patients that were in the standard training program without perturbation training. The investigators theorize that the perturbation training may provide a protective effect and allow for participation in higher level athletic activity.

Chmielewski et al studied the effects of 10 perturbation training sessions on 17 patients with acute unilateral ACL rupture.<sup>3</sup> The control group consisted of patients without injury who were matched by age, gender, and activity level. All study participants were tested before perturbation training. Testing consisted of walking across a platform that remained stationary or produced random anterior or lateral perturbations. Compensation strategies were recorded through motion analysis and electromyography. All patients then participated in 10 perturbation training sessions as described by Fitzgerald et al.<sup>1,2</sup> The results of the study found that patients with ACL deficient knees had stiffer knees with higher muscle co-contraction than matched healthy controls before training. After the perturbation training, the ACL deficient group more closely resembled the controls with a reduction in the thigh muscle co-contraction and the normalized knee kinematics. The investigators feel that the results indicate that perturbation training is effective at promoting coordinated muscle activity in ACL-deficient knees.

In a study by Risberg et al, the investigators compared a neuromuscular training program versus a traditional strength training program after ACL reconstruction.<sup>4</sup> Seventy-four patients were randomly assigned into 1 of the 2 training groups. The investigators tested all patients preoperatively and again at 3 and 6 months postoperatively.

The investigators used self-report surveys (Cincinnati Knee Score, Visual Analog Scale for pain intensity and global knee function and the SF-36), isokinetic strength testing, and functional tests (hop tests, position sense, and static and dynamic balance testing) to assess the changes in the strength training and neuromuscular training groups. The patients in the neuromuscular training group did balance exercises, dynamic joint stability exercises, plyometric exercises, agility exercises, and sport-specific exercises. The patients in the strength training group did exercises designed to develop strength in the muscles of the involved lower extremity. The investigators provide a detailed outline of both training programs in the article. The results of the study show significant improvement in the neuromuscular training group's Cincinnati Knee Scores and the Visual Analog Scale for global knee function, when compared with the strength training group's scores. No significant difference was found between the 2 groups' isokinetic knee strength tests and functional tests. The investigators feel that because of the subjective improvement in the knee function in the neuromuscular training group that exercises from the neuromuscular training group should be incorporated into a standard ACL reconstruction rehabilitation program.

Recently, Hartigan et al investigated whether perturbation training with standard strength training before ACL reconstruction would improve muscle function and gait mechanics postoperatively.<sup>5</sup> Nineteen patients with acute ACL injury were included in the study and randomly assigned to either a strengthening-only group or a perturbation/strength training group. Preoperative data, quadriceps strength, and gait mechanics were collected and compared with the data collected 6 months after the ACL reconstruction. The results find that the patients in the perturbation group had a more symmetrical gait pattern and strength at 6 months after ACL reconstruction than the strengthening-only group.

### RETURN TO SPORTS

One of the primary reasons for an individual to have an ACL reconstruction is to return to athletic activities. The early phases of ACL reconstruction rehabilitation use a combination of time-since-surgery and specific criterion-based guidelines for progression. In the later stages of ACL reconstruction rehabilitation the progression can become vague and less structured. The late progression becomes more time-based often with less emphasis on objective measures of strength, power, and functional stability of the knee. Commonly the athlete progresses in the late stages of rehabilitation or returns to sports on the basis of the athlete's perception of readiness.

In review articles by Kvist<sup>6</sup> and Casio et al,<sup>7</sup> many studies investigating the late phases of rehabilitation after the ACL reconstruction, used time-since-surgery as the primary determinant for the return-to-light activities and contact sports. These studies presented neither measurable objective tests for the progression of the late stages of the ACL reconstruction rehabilitation, nor objective criteria for the return to sports. This raises concern regarding the potential attenuation of the ACL graft before developing appropriate muscular strength, power, and dynamic stability of the involved knee, when doing high-joint-load functional drills.<sup>8</sup>

On account of the absence of objective criteria for assessing how and when to promote an athlete through the return-to-sport phase after the ACL reconstruction, Myer et al present a clinical commentary of their criteria-driven progression.<sup>8</sup> The investigators present a 5-stage return-to-sports program with minimum objective criteria required for qualification. Athletes are eligible to begin the return-to-sports program, when they have a minimum International Knee Documentation Committee score of 70, no functional instability ("giving way" or "buckling") of the involved knee, and a specific baseline isokinetic strength measure (knee extension peak torque-body mass of 40% for males and 30% for females at 300°/sec). The investigators operationally define the goals and the criteria for progression (Fig. 4) of all the 5 stages and provide specific functional exercises to achieve the goals of each stage. They also provide examples of common performance errors during functional tests that would prohibit advancement to next stage. Most of the objective measures were functional tests (hop tests, tuck jumps, agility T-tests, vertical jumps) that could be conducted in a vast majority of clinical situations, but some of the of the objective criteria required measurement with equipment that is not available in most outpatient rehabilitation settings.

### FUNCTIONAL KNEE BRACING

Functional bracing after the ACL reconstruction surgery continues to create controversy. In response to a survey, 87% of the orthopedic surgeons prescribed functional knee braces for their patients after ACL reconstruction.<sup>9</sup> Numerous studies and review articles show the limited effect that functional knee braces have on knee joint stability,<sup>10-12</sup> reinjury rates,<sup>10,12</sup> and kinesthetic awareness.<sup>12,13</sup>

McDevitt et al conducted a prospective randomized clinical trial to assess the effectiveness of the functional knee bracing after ACL reconstruction.<sup>10</sup> The study included 100 patients who were randomly assigned to a brace or a nonbrace group. Both the groups of 50 patients each were postoperatively braced in extension for 3 weeks after the surgery. The brace group received a functional knee brace at 6 weeks post-op and was instructed to wear the brace with all the activities until 6 months after the surgery. The functional brace was then only applied for higher level activities at 6 months until 1-year post-ACL reconstruction. The nonbrace group received no brace after the discontinuation of the knee immobilizer 3 weeks after the surgery. The patients were followed up for 2 years and no statistical difference in knee stability, hop test, range of motion, isokinetic strength, International Knee Documentation Committee or Lysholm was identified.

Sterett et al recently conducted a prospective cohort study to investigate the effect of functional braces on injury rates of skiers after ACL reconstruction.<sup>14</sup> This 6-year study involved 820 skier-employees who had an ACL reconstruction 2 or more years ago. In this study, 257 patients chose to wear a functional knee brace while skiing and 563 patients opted against wearing a functional brace. Injury data were recorded on all skiers. The results revealed that the nonbraced skiers were 2.74 times more likely to suffer a knee injury than a skier in the braced group. The investigators report 61 subsequent knee injuries in all patients. The injury incidence rate was 9% (51/563) in the nonbraced group and 4% (10/257) in the braced group.

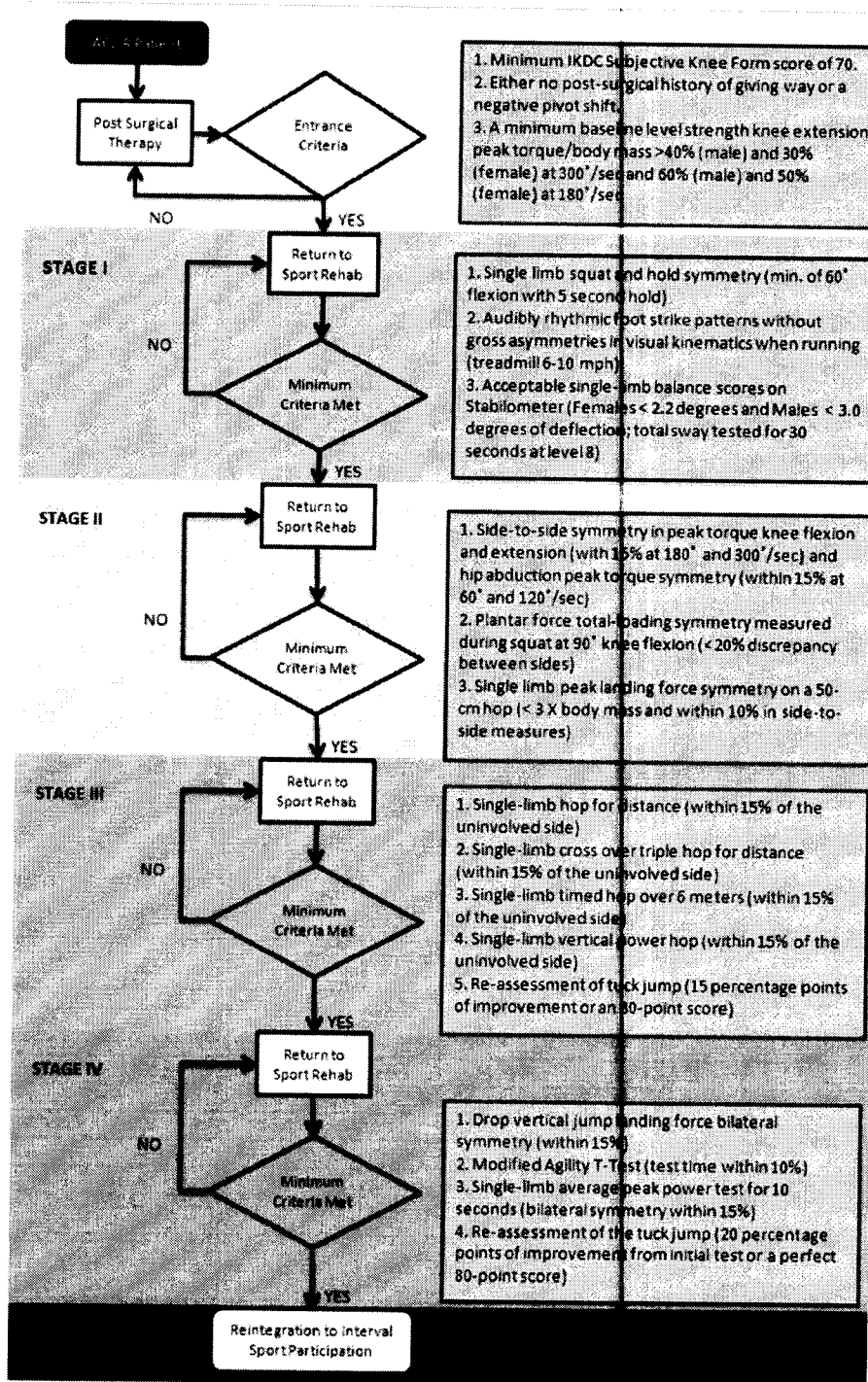


FIGURE 4. Algorithm for return-to-sports progression after ACL reconstruction. Reprinted from *JOSPT*, 2006;36:385–402 with permission of the Orthopaedic and Sports Physical Therapy Sections of the American Physical Therapy Association.

Surgical intervention was required for such injuries in 4% (25/563) of the patients in the nonbrace group compared with 1% (3/257) in the braced group. This study explains that nonbraced skiers were at greater risk of injury and subsequent surgery; therefore, Sterett et al advocate the use of functional knee braces for patients who wish to return to skiing.

Recently, Birmingham et al conducted a randomized controlled trial comparing the use of a traditional functional knee brace with a neoprene sleeve after ACL reconstruction.<sup>11</sup> The study included 150 patients who were randomly assigned to a knee-sleeve (74) group or functional group (76). The random assignment was conducted 6 weeks after ACL reconstruction with a hamstring allograft.

Outcomes were assessed utilizing self-report surveys (Anterior Cruciate Ligament-Quality of Life Questionnaire and Tegner Activity Scale), tibial translation with a knee arthrometer and a single leg hop test. The 2 groups were compared at 6 weeks and 6, 12, and 24 months after the surgery and the results showed no statistical significance in any outcome measure at 1 and 2 years follow-up. Patients in the braced group did report an increased sense of confidence when compared with the knee sleeve group, but the results do not support the use of functional knee brace after anterior cruciate ligament reconstruction.

### DISCUSSION

Perturbation training has shown to normalize muscle activity and provide improved joint mechanics and stability in anterior cruciate deficient knees. It has also shown to restore symmetry of gait and strength after the ACL reconstruction surgery. The supportive evidence suggests that perturbation training should be included in both the preoperative and the postoperative ACL rehabilitation programs. We feel that criteria-based ACL reconstruction rehabilitation programs from the early through the late phases are vital for the continued advancement of functional outcomes. The criteria-based progression through the return-to-sport program presented by Myer et al is novel in its attempt to provide objective steps in returning an athlete to sports participation. Future investigation to validate this program and to provide long-term follow-up is required. Their current progression requires the use of specific equipment that may not be available to all rehabilitation professionals. Future program development should focus on clinical objective measures and functional tests that can be reproduced in most sports medicine clinics. Contrary to current brace prescription patterns, the use of the functional knee bracing to lower the risk of reinjury is not supported in the literature (except possibly in skiing). Owing to the significant cost related to and lack of evidence in support of functional knee bracing, it is difficult to include it as a component of the standard ACL rehabilitation protocol. There is evidence that shows the value of the functional knee bracing, which rebuilds in an athlete a sense of confidence when returning to sport participation. It should, therefore, be prescribed only on a case-by-case basis.

### REFERENCES

1. Fitzgerald GK, Axe M, Snyder-Mackler L. Proposed practice guidelines for nonoperative ACL rehabilitation of physically active individuals. *J Orthop Sports Phys Ther.* 2000;30:194-203.
2. Fitzgerald GK, Axe M, Snyder-Mackler L. The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physically active individuals. *Phys Ther.* 2000;80:128-140.
3. Chmielewski T, Hurd W, Rudolph K, et al. Perturbation training improves knee kinematics and reduces muscle co-contraction after complete unilateral anterior cruciate ligament rupture. *Phys Ther.* 2005;85:740-754.
4. Risberg A, Holm I, Myklebust G, et al. Neuromuscular training versus strength training during first 6 months after anterior cruciate ligament reconstruction: A randomized clinical trial. *Phys Ther.* 2007;87:737-750.
5. Hartigan E, Axe M, Snyder-Mackler L. Perturbation training prior to anterior cruciate ligament reconstruction improves gait asymmetries in non-copers. *J Orthop Res.* 2009;27:724-729.
6. Kvist J. Rehabilitation following anterior cruciate ligament injury. Current recommendations for sports participation. *Sports Med.* 2004;34:269-280.
7. Casio B, Culp L, Cosgarea A. Return to play after anterior cruciate ligament reconstruction. *Clin Sports Med.* 2004;23:395-408.
8. Myer G, Paterno M, Ford K, et al. Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-sport phase. *J Orthop Sports Phys Ther.* 2006;36:385-402.
9. Decoster L, Vailis J. Functional anterior cruciate ligament bracing: a survey of current brace prescription patterns. *Orthop.* 2003;26:701-706.
10. McDevitt E, Taylor D, Miller M, et al. Functional bracing after anterior cruciate ligament reconstruction. A prospective, randomized, multicenter study. *Am J Sports Med.* 2004;32:1887-1892.
11. Birmingham TB, Bryant DM, Litchfield RB, et al. A randomized controlled trial comparing the effectiveness of functional knee brace and neoprene sleeve use after anterior cruciate ligament reconstruction. *Am J Sports Med.* 2008;36:648-655.
12. Wright RW, Fetzter GB. Bracing after anterior cruciate ligament reconstruction: a systematic review. *Clin Orthop Relat Res.* 2007;455:162-168.
13. Beynnon B, Good L, Risberg M. The effect of bracing on proprioception of knees with anterior cruciate ligament injury. *J Orthop Sports Phys Ther.* 2002;32:11-15.
14. Sterett W, Briggs K, Farley T, et al. Effect of functional bracing on knee injury in skiers with anterior cruciate ligament reconstruction. A prospective cohort study. *Am J Sports Med.* 2006;34:1581-1585.