Objective Criteria for Return to Athletics After Anterior Cruciate Ligament Reconstruction and Subsequent Reinjury Rates: A Systematic Review

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Abstract

Objective: To review anterior cruciate ligament (ACL) clinical studies to assess the objective functional criteria used to determine when patients can return to athletics postoperatively, and to determine the rates of reinjury to either knee when these criteria are applied. Methods: A literature search was conducted using the Medline database. The inclusionary criteria were the English language, publication between April 2001 and April 2011, original clinical trials, all levels of evidence, primary ACL reconstruction, skeletal maturity, minimum 2 years of follow-up, and ≥1 objective test used to allow release to sports activities. The exclusionary criteria were revision ACL reconstructions or dislocated knees; studies that specifically excluded patients with ACL graft failure or reinjuries; major concomitant procedures such as high tibial osteotomy, meniscus allograft, other knee ligament reconstructions; and case reports, abstracts, review articles, and technical notes. Results: Three objective criteria were used to allow release to sports activities. The most common were lower extremity muscle strength, followed by lower limb symmetry, and knee examination parameters of range of knee motion and effusion. Twelve studies listed 1 criterion for release to sports, 8 studies listed 2 criteria, and 1 study recommended 3 criteria. Failure rates of the ACL reconstructions ranged from 0% to 3% in 7 studies, from 4% to 6% in 6 studies, from 7% to 10% in 4 studies, and from 14% to 24% in 4 studies. There were no injuries in the contralateral ACL in 14 studies (67%); in the other 7 studies, contralateral injury was reported in 2% to 15% of patients. Conclusions: Few objective functional criteria are used to determine when patients return to unrestricted sports activities. Clinically feasible recommendations are made for measurement of muscle strength, lower limb symmetry, lower limb neuromuscular control, and ligament function in patients who desire to return to athletics after ACL reconstruction. Future studies are required to determine whether the demonstration of normal lower limb function before return to sports is effective in reducing reinjury rates.

Keywords: anterior cruciate ligament; sports; functional; reinjury; return to athletics

Introduction

The most common ligament injury occurring in the knee joint is a tear of the anterior cruciate ligament (ACL). Most patients who sustain ACL injuries and undergo reconstruction are athletes who are aged ≤ 25 years and are involved in competitive or organized sports. The goals of this operation and postoperative rehabilitation for these individuals are to stabilize the knee to prevent reinjuries and allow a safe return to the athletes’ previous activities.
The published mid- to long-term (minimum 5-year follow-up) failure rates of ACL reconstructions range from 3% to 19%. Of equal or even greater concern are data demonstrating that 5% to 24% of patients will sustain an ACL rupture to the contralateral knee postoperatively.1–3 For instance, 1 study reported that 3% of 90 patients who underwent ACL bone-patellar tendon-bone (BPTB) autograft reconstruction experienced graft failure, whereas 11% subsequently tore the contralateral ACL.1 Another study reported a graft failure rate of 8% to 10 years postoperatively in 90 patients who underwent BPTB autograft ACL reconstruction; however, 22% of these patients sustained contralateral ACL tears on return to sports activities.2 A recent report of 90 patients who underwent ACL BPTB autograft reconstruction and were followed for 15 years postoperatively reported that 8% had graft failure and 24% had a contralateral ACL rupture.3 The consequences of these injuries in young, active patients include the need for further surgery, reduced rates of success in returning to prior activity levels, and increased risk of joint deterioration.

Postoperative rehabilitation plays a critical role in helping patients to return to athletic or demanding occupational activities as safely as possible. Because of the extensive documentation in the literature of neuromuscular deficits in both limbs following ACL injury and reconstruction,4,5 failure to fully rehabilitate both knees may be part of the reason for the high re-injury rates in ACL-reconstructed and contralateral limbs. In addition, questions exist regarding the appropriate functional criteria that should be used to release patients to unrestricted sports activities postoperatively.6 The first objective of this article was to review the current literature on ACL clinical outcome studies to examine the factors investigators use to determine when patients can return to athletics after surgery. The second objective was to determine the rates of reinjury to either knee in the studies that provided objective criteria for return to athletics.

Methods
A literature review was completed using the Medline database with the keywords “anterior cruciate ligament reconstruction,” “ACL reconstruction,” “ACL reconstruction rehabilitation,” and “ACL reconstruction results.” In addition, manual searches were performed of the following journals: The American Journal of Sports Medicine, Arthroscopy, The Journal of Bone and Joint Surgery (American and British versions), Knee, Clinical Orthopaedics and Related Research, Knee Surgery, Sports Traumatology and Arthroscopy, and The Journal of Orthopaedic and Sports Physical Therapy. This search yielded 717 articles.

The inclusion criteria were original clinical trials published in English between April 2001 and April 2011, involving research at all levels of evidence and investigating primary ACL reconstruction in skeletally mature patients, with a minimum of 2 years’ follow-up, and ≥1 objective test used to allow release to sports activities. Studies were excluded if they included patients undergoing revision ACL reconstructions or with dislocated knees, and those undergoing major concomitant procedures, such as high tibial osteotomy, meniscus allograft, and other knee ligament reconstructions. We did not include studies that specifically excluded patients with ACL graft failure or reinjuries, nor did we include case reports, abstracts, review articles, or technical notes.

Twenty-one articles were deemed appropriate for this review.7–27 These articles were carefully assessed to document the type of ACL graft, time of follow-up, objective criteria used to determine return to full sports activities postoperatively, number of patients who returned to sports activities, number of failed ACL reconstructions, and number of injuries to the contralateral ACL. The ACL reconstructions were considered to have failed if an International Knee Documentation Committee (IKDC) ligament rating of C or D was found, if > 5 mm of increased anteroposterior tibial translation was measured on knee arthrometer testing, or if the author indicated a graft rupture had occurred. All ACL reconstruction failures and injuries to the contralateral ACL were included in this review, even if they occurred before the minimum 2-year follow-up.

Results
The 21 studies included in this review followed 1641 patients from 2 to 14 years postoperatively (Table 1). The ACL grafts consisted of BPTB autografts in 554 patients, semitendinosus-gracilis tendon (STG) autografts in 384 patients, allografts in 328 patients, double-bundle STG autografts in 127 patients, STG autografts plus iliotibial band extra-articular12 in 114 patients, double-bundle allografts in 51 patients, and BPTB autografts plus ligament augmentation devices in 51 patients.

The included studies used 3 objective criteria to permit release to sports activities postoperatively (Table 2). The most common was lower extremity isokinetic muscle strength, found in 18 of the 21 studies. Only 1 study23 provided a definitive recommendation for the velocity of the isokinetic testing. Authors required a range from > 80% to > 90% of muscle strength of the contralateral side for return to athletics. There were no recommendations regarding a minimum or
Table 1. Objective Criteria for Release to Sports Activities and Results Following ACL Reconstruction Reported in English-Language Studies for the Past 10 Years

<table>
<thead>
<tr>
<th>Study</th>
<th>ACL Graft Type (N) (Follow-up)</th>
<th>Release to Sports Objective Criteria</th>
<th>Returned to Sports (N)</th>
<th>Failed ACL Reconstructions</th>
<th>Injuries Contralateral Knee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zaffagnini et al7</td>
<td>BPTB, auto (39) DB, STG, auto (40) (8–10 years)</td>
<td>Muscle: &gt; 90% isokinetic strength opposite side, &lt; 1 cm difference thigh circumference</td>
<td>Not given</td>
<td>2 (2%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limb symmetry: &gt; 90% single-leg hop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrett et al8</td>
<td>BPTB, FF, allo (78) (Mean, 63 months)</td>
<td>Muscle: &lt; 0.5-inch difference thigh circumference</td>
<td>Not given</td>
<td>19 (24%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limb symmetry: ≥ 90% single-leg hop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mascarenhas et al7</td>
<td>BPTB, auto (19) BPTB, FF, allo (19) (3–14 years)</td>
<td>Muscle: 90% weighted leg extension</td>
<td>All returned to high-demand sports 4–7 days/week</td>
<td>2 (5%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limb symmetry: ≥ 90% hop/jump testing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Knee examination: full motion, no effusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drogset et al10</td>
<td>BPTB, auto (51) STG, auto (48) (2 years)</td>
<td>Muscle: ≥ 85% contralateral side</td>
<td>Not given</td>
<td>2 (2%)</td>
<td>0</td>
</tr>
<tr>
<td>Lee et al11</td>
<td>STG, auto (125) BPTB, allo (60) Tibialis, ant, allo (153) (24–96 months)</td>
<td>Muscle: &gt; 80% contralateral knee</td>
<td>Not given</td>
<td>16 (5%)</td>
<td>0</td>
</tr>
<tr>
<td>Marcacci et al12</td>
<td>STG auto + EA (54) (11 years)</td>
<td>Muscle: &lt; 1 cm difference thigh circumference</td>
<td>Not given</td>
<td>3 (6%)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limb symmetry: &gt; 90% single-leg hop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sajovic et al13</td>
<td>BPTB, auto (30) STG, auto (31) (5 years)</td>
<td>Muscle: &gt; 90% muscle strength opposite side</td>
<td>85% returned to preinjury sports level</td>
<td>6 (10%)</td>
<td>5 (8%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Knee examination: full motion, no effusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zaffagnini et al14</td>
<td>STG auto + EA (35) DB, STG, auto (37) (3–5 years)</td>
<td>Muscle: &gt; 90% strength isokinetic test</td>
<td>69 (96%)</td>
<td>5 (7%)</td>
<td>0</td>
</tr>
<tr>
<td>Fu et al15</td>
<td>DB, STG, auto (17) DB, tibialis, anterior, allo (83) (2 years)</td>
<td>Muscle: &gt; 85% isokinetic or isometric quadriceps strength</td>
<td>72% returned to strenuous sports</td>
<td>8 (8%)</td>
<td>0</td>
</tr>
<tr>
<td>Colombet et al16</td>
<td>DB, STG, auto (33) (2 years)</td>
<td>Muscle: ≥ 85% quadriceps and hamstrings strength isokinetic test</td>
<td>30 (91%)</td>
<td>3 (9%)</td>
<td>0</td>
</tr>
<tr>
<td>Siebold et al17</td>
<td>BPTB, auto (22) STG, auto (43) (2–5 years)</td>
<td>Knee examination: full motion, no effusion</td>
<td>Not given</td>
<td>2 (3%)</td>
<td>0</td>
</tr>
<tr>
<td>Zaffagnini et al18</td>
<td>BPTB, auto (25) STG, auto + EA (25) (5 years)</td>
<td>Muscle: &lt; 1 cm difference thigh circumference</td>
<td>All returned to same sports level</td>
<td>12 (16%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limb symmetry: &gt; 90% single-leg hop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isberg et al19</td>
<td>BPTB, auto (22) (2 years)</td>
<td>Muscle: ≥ 90% contralateral side</td>
<td>Not given</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(Continued)
target hamstring/quadriceps ratio. Three studies noted that a thigh circumference measurement of < 1 cm or < 0.5 in (difference between limbs) was required for release to sports.

The second most common objective criterion, recommended in 7 studies, was lower limb symmetry measured with the single-leg hop test. These studies required that the patient be able to hop on the reconstructed leg for > 90% of the distance hopped on the contralateral leg before returning to sports activities. The third category of objective criteria entailed the knee examination parameters of range of motion (ROM) and joint effusion, which were included in 6 studies. Authors indicated that full knee motion and no effusion were required before patients were allowed to return to sports.

The failure rates for the ACL reconstructions ranged from 0% to 24%. The failure rate ranged from 0% to 3% in 7 studies, from 4% to 6% in 6 studies, from 7% to 10% in 4 studies, and from 14% to 24% in 4 studies. Fourteen studies (67%) reported no injuries in the contralateral ACL, but in the other 7 studies, the rates of contralateral ACL injuries ranged from 2% to 15%.

Seven studies reported the number of patients who returned to sports following surgery, which ranged from 72% to 100%. The other 14 studies provided

### Table 1. (Continued)

<table>
<thead>
<tr>
<th>Study</th>
<th>ACL Graft Type (N) (Follow-up)</th>
<th>Release to Sports Objective Criteria</th>
<th>Returned to Sports (N)</th>
<th>Failed ACL Reconstructions</th>
<th>Injuries Contralateral Knee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poehling et al²⁰</td>
<td>BPTB, auto (28)</td>
<td>Muscle: &gt; 90% quadriceps strength contralateral side, equal hamstring strength contralateral side</td>
<td>Not given</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Drogset et al²¹</td>
<td>BPTB, auto (41)</td>
<td>Muscle: &gt; 85% contralateral side</td>
<td>Not given</td>
<td>2 (5%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Wagner et al²²</td>
<td>BPTB, auto (68)</td>
<td>Limb symmetry: &gt; 90% single-hop test</td>
<td>Not given</td>
<td>6 (5%)</td>
<td>9 (7%)</td>
</tr>
<tr>
<td>Beynnon et al²³</td>
<td>BPTB, auto (22)</td>
<td>Muscle symmetry: &gt; 90% contralateral side</td>
<td>All returned to sports</td>
<td>6 (14%)</td>
<td>0</td>
</tr>
<tr>
<td>Drogset et al²⁴</td>
<td>BPTB auto (49)</td>
<td>Muscle: &gt; 85% contralateral side</td>
<td>Not given</td>
<td>22 (22%)</td>
<td>15 (15%)</td>
</tr>
<tr>
<td>Henriksson and Granvedt²⁵</td>
<td>BPTB auto + LAD (51) (8 years)</td>
<td>Muscle: &gt; 90% contralateral side at 180°/s</td>
<td>Not given</td>
<td>0</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>Möller et al²⁶</td>
<td>BPTB auto (62)</td>
<td>Muscle: &gt; 90% contralateral side</td>
<td>Not given</td>
<td>1 (2%)</td>
<td>0</td>
</tr>
<tr>
<td>Aune et al²⁷</td>
<td>BPTB, auto (29)</td>
<td>Knee examination: full motion, no effusion</td>
<td>Not given</td>
<td>4 (6%)</td>
<td>3 (5%)</td>
</tr>
</tbody>
</table>

All grafts single-bundle unless designated as double-bundle.

Abbreviations: allo, allograft; AT, Achilles tendon; auto, autograft; BPTB, bone-patellar tendon-bone; DB, double-bundle; EA, extra-articular augmentation; FF, fresh-frozen; LAD, Kennedy ligament augmentation device; STG, semitendinosus gracilis.

*Fully positive pivot-shift and/or Lachman tests, Grade C or D International Knee Documentation Committee ligament grade, > 5 mm on knee arthrometer testing, or required anterior cruciate ligament revision.

### Table 2. Objective Criteria Cited in Studies for Release to Sports Activities

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Number of Studies Cited</th>
<th>Criteria Parameters for Release to Athletics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isokinetic quadriceps, hamstring muscle strength</td>
<td>18</td>
<td>&gt; 80% or &gt; 90% of opposite side or &lt; 1 cm difference in thigh circumference</td>
</tr>
<tr>
<td>Lower limb symmetry: single-leg hop test</td>
<td>7</td>
<td>≥ 90% compared with opposite side</td>
</tr>
<tr>
<td>Knee examination</td>
<td>6</td>
<td>Range of knee motion: equal to opposite side, knee joint effusion: none</td>
</tr>
</tbody>
</table>

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a mean activity rating score and not the number of patients who participated in athletics after surgery. In the studies reporting the rates of patients who returned to sports after ACL reconstruction, graft failure occurred between 5% and 9% in 5 studies9,13–16 and between 14% and 16% in 2 investigations.18,23 Only 113 of these 7 studies reported injuries to the contralateral ACL.

Discussion
This systematic review of clinical studies assessing outcomes after ACL reconstruction found that, in the past 10 years, 3 primary objective criteria have been used to assess patients’ readiness to return to unrestricted sports activities postoperatively. Twelve of the 21 studies listed just 1 criterion required for release to sports activities; 8 studies listed 2 criteria; and 1 study recommended all 3 criteria.

The goals of ACL reconstruction are to restore normal knee joint stability and function and return patients safely to their desired activity levels. Both the operative procedure and rehabilitation program are paramount in achieving a successful outcome. There is strong evidence in the literature that deficits in balance, proprioception, muscle...
strength, and neuromuscular control persist for many months postoperatively.4,5

Chmielewski5 recently discussed problems with asymmetry that have been documented in various activities after ACL surgery, including squatting, stair climbing, single-leg hopping, and drop-vertical jumping. Despite these well-known problems, our review demonstrates that few objective functional criteria are typically used to determine when patients may return to unrestricted sports activities.

Young patients (aged < 21 years) who return to high-risk sports such as basketball or soccer appear to be at increased risk for a reinjury after surgery.2,29–32 Studies assessing factors that may be associated with reinjury have not taken into account the status of the athletes’ strength, stability, neuromuscular control, and general knee condition upon return to sports. Only 1 of the long-term outcome studies shown in Table 1 provided objective criteria for return to sports. Sajovic et al13 required > 90% muscle strength of the contralateral limb, normal knee motion, and no effusion before release to sports. This study reported that, after 5 postoperative years, 10% of ACL reconstructions had failed and 8% of the contralateral knees had sustained ACL tears.

Other articles have proposed rigorous testing prior to return to sports following ACL reconstruction. Although these articles did not meet the strict criteria for inclusion in this systematic review, we believe it is valid to summarize their recommendations. Hartigan et al6 noted requirements in 9 different measures for release to sports, including:<1

Figure 2. The single-leg hop may be used to provide a qualitative assessment of an athlete’s ability to control the upper and lower extremity upon landing, which may be rated as A) good, B) fair to poor, or C) complete failure (fall to ground).41

These figures were published in Noyes’ Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes, Barber-Westin SD, Noyes FR, Decreasing the risk of anterior cruciate ligament injuries in female athletes, 428-463, Copyright Elsevier, 2009.
knee effusion, full ROM, ≥ 90% scores on the quadriceps strength index, 4 single-leg hop tests (single hop, triple hop, triple crossover hop, and timed hop), the Knee Outcome Survey activities of daily living scale, and a global rating of overall knee function. These authors highlighted the lack of consensus regarding functional assessment used to determine when release to full activity should be allowed postoperatively and advocated their strict criteria. They further concluded that return to sports should be based on functional abilities and not solely on the time elapsed since surgery. In a systematic review of rehabilitation literature, van Grinsven et al. recommended full ROM, > 85% quadriceps and hamstring strength, < 15% deficit on hamstring/quadriceps strength ratio, and > 85% on single-leg hop tests, compared with the opposite leg, as criteria for return to athletics. Kvist proposed criteria for return to sports that included factors related to rehabilitation (< 10%–15% deficit in muscle strength and the single-leg hop test, no pain or effusion, full ROM, and functional knee stability evaluated by objective measurements such as motion analysis), surgery (static knee stability measured by knee arthrometer), and other factors (eg, social and psychological status, associated injuries).

Reducing the risk of reinjury on return to athletics following ACL reconstruction requires consideration of pre-, intra-, and postoperative factors. These include determining which patients are appropriate candidates for surgery, correcting deficits in muscle strength and knee motion before surgery, selecting the appropriate graft, achieving anatomic graft placement, and using secure internal fixation.

The postoperative rehabilitation program should be gradually intensified, while considering any major concomitant operative procedures or noteworthy articular cartilage damage that may require modification of the protocol. Many authors have advocated advanced neuromuscular training as a requirement for patients who desire to return to high-risk activities following ACL reconstruction. Risberg and Holm concluded that the combination of strength training and neuromuscular exercises was required to achieve the best outcomes, including the patient’s perception of knee function and knee performance on strength and hop tests. Athletes in our clinic who wish to return to high-risk sports are encouraged to complete a formal 6-week course of neuromuscular retraining as the final phase of rehabilitation after successful completion of a running and initial plyometric program. This program involves more difficult jump training (Figure 1) and enhanced strength and flexibility exercises. Future studies are required to determine if this advanced training will reduce reinjury rates following ACL reconstruction.

We agree with the findings of this review that muscle strength, lower limb symmetry, and knee ROM and effusion should be assessed before athletes are allowed to perform unrestricted sports activities (Table 3). Lower limb symmetry may be directly measured as the difference in distance hopped between limbs as previously described. In addition, a qualitative assessment may be made of the athlete’s ability to control and hold the landing (Figure 2).

When isokinetic testing equipment is not available, a 1-repetition maximum (RM) bench press and leg press are recommended if weight room equipment is available, along

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**Table 3. Recommended Functional Criteria for Return to Sports Activities Following ACL Reconstruction**

<table>
<thead>
<tr>
<th>Functional Test</th>
<th>Indice Tested</th>
<th>Minimum Accepted Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isokinetic test 180°/s, 300°/s, or 1 repetition maximum test</td>
<td>Hamstring, quadriceps strength</td>
<td>&lt; 10% deficit compared with contralateral side</td>
</tr>
<tr>
<td>Single-leg triple crossover and timed hop tests</td>
<td>Lower limb symmetry</td>
<td>&lt; 15% deficit compared with contralateral side</td>
</tr>
<tr>
<td>Video drop-jump test</td>
<td>Lower limb neuromuscular control</td>
<td>&gt; 60% normalized knee separation distance</td>
</tr>
<tr>
<td>Single-leg squat test 0°–90°</td>
<td>Lower limb neuromuscular control</td>
<td>No valgus motion of knee, no medial/lateral movement of knee</td>
</tr>
<tr>
<td>Knee arthrometer test</td>
<td>Anteroposterior tibial displacement</td>
<td>&lt; 3 mm increase compared with normal, contralateral side</td>
</tr>
<tr>
<td>Lachman, pivot-shift tests</td>
<td>ACL function</td>
<td>&lt; 3 mm Lachman, grade 0–1 pivot-shift</td>
</tr>
<tr>
<td>Knee examination</td>
<td>Range of knee motion,</td>
<td>Full knee motion, no effusion, normal patellar mobility, no/slight patellar crepitus</td>
</tr>
<tr>
<td>Trial of function during running, plyometrics,</td>
<td>Lower limb function</td>
<td>No pain, swelling, or giving way</td>
</tr>
</tbody>
</table>

Abbreviation: ACL, anterior cruciate ligament.
with an experienced test administrator and sufficient time to safely conduct these tests. The athlete should warm up by performing 5 to 10 repetitions of the exercise at 40% to 60% of their estimated 1-RM value (maximum weight lifted). After 1 minute of rest, the athlete performs 3 to 5 repetitions of the exercise at 60% to 80% of his or her estimated 1-RM value. Then, with a conservative increase in weight, the athlete should attempt a 1-RM lift. If successful, a rest period of 3 to 5 minutes is allowed. Then, the weight is increased and the same procedure is followed until the athlete cannot complete the lift.

It is also important to understand that, regardless of gender, at least two-thirds of ACL tears occur during noncontact activities, such as cutting, pivoting, accelerating, decelerating, or landing from a jump. Fatigue appears to increase the risk of ACL injury in both males and females. Videotaped analyses of ACL injuries frequently reveal reduced knee flexion angles, increased hip flexion angles, valgus collapse at the knee, reduced ankle plantar flexion angles, increased hip internal rotation, and increased internal or external tibial rotation occurring at the time of, or just prior to, ACL injury. Because of neuromuscular deficiencies and the documented findings of abnormal mechanics during ACL injuries, we believe that it is important to conduct additional tests assessing dynamic neuromuscular control, such as the drop-jump and single-leg squat tests, prior to allowing the patient to return to sports activities.

The drop-jump test is a cost-effective and simple method...
of determining lower limb alignment in the coronal plane. Performed with a single camera in any setting, this procedure can clearly identify a valgus lower extremity alignment on landing (Figure 3), which is believed to be a potential risk factor for a future noncontact ACL injury.\(^5\) The International Olympic Committee has recommended that the drop-jump screening test be used to identify athletes at risk for a noncontact ACL injury.\(^5\) The single-leg squat test has been described in several studies as a useful clinical measure to detect dynamic knee control and hip muscle function.\(^5\)\(^1\)\(^5\)\(^5\) Clinicians should also consider using the multistage fitness test to determine VO\(_2\) max,\(^5\) the 60-second sit-up test,\(^5\) or other core strength measures\(^9\) to determine fitness levels.

One consideration is that some of investigations in this review may have objectively measured certain factors before athletes were released to full sports activities, but did not include this information in the publication. Limits of space in journals may prevent a comprehensive description of both the rehabilitation program and criteria required for release to athletics. It was not the purpose of this review to compare the failure rates of the ACL reconstructions or injuries to the contralateral ACLs in the 21 reviewed studies with those reported in other published clinical outcome studies. This type of analysis would require a separate investigation in which cohorts are carefully matched for many variables, including graft type, sex ratio, patient age, chronicity of injury, concomitant injuries, articular cartilage deterioration, postoperative sports activity level, and time of follow-up. Future studies are required to determine if the suggested recommendations for functional assessment criteria are effective in reducing the reinjury rates after surgery.

**Conclusion**

The goals of ACL reconstruction in the majority of patients are to stabilize the knee to prevent future reinjuries and allow a safe return to previous activity levels. The goals of this study were to review ACL clinical studies to determine the objective functional criteria used to determine when return to athletics is allowed postoperatively, and secondly, to determine the rates of reinjury to either knee in studies that contained such objective criteria.

We found that few objective functional criteria have been published over the past 10 years to allow patients to return to unrestricted sports activities. This conclusion was based on our systematic review that involved 21 clinical outcome studies, with a minimum of 2 years’ follow-up, which cited objective criteria were used to allow a return to athletics. The most common criterion was lower extremity muscle strength, and this is followed by lower limb symmetry and knee examination parameters of range of knee motion and effusion. Twelve studies listed just 1 criterion required for release to sports activities; 8 studies listed 2 criteria; and 1 study recommended 3 criteria. Other authors have recommended more comprehensive functional assessments; however, clinical outcome data are lacking in terms of demonstrating the effectiveness of these recommendations in reducing reinjury rates.

We provide recommendations that are clinically feasible to measure muscle strength, lower limb symmetry, lower limb neuromuscular control, and ligament function, in patients who desire to return to athletics after ACL reconstruction. Future studies are required to determine if advances in surgery, rehabilitation, and the demonstration of normal lower limb function prior to return to sports are effective in reducing reinjury rates after surgery.

**Conflict of Interest Statement**

Sue D. Barber-Westin, BS and Frank R. Noyes, MD disclose no conflicts of interest.

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