Review Article

Current criteria for return to play after anterior cruciate ligament reconstruction: an evidence-based literature review

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Abstract: Anterior cruciate ligament reconstruction (ACLR) has continued to be a popular surgical option in the last decade, and frequently we have seen athletes complete successful surgical intervention and rehabilitation. Even more so, the time that it takes some athletes to return to play (RTP) has gained a lot of media attention. In light of these conditions, we set out to examine the status of research on rehabilitation protocols, tests and measures, and criteria for RTP after ACLR, especially bone-tendon-bone (BTB) procedures. An evidence-based literature review was conducted. PubMed and CINAHL database searches were performed using various combinations of the following keywords: ACL reconstruction, bone to bone graft, rehabilitation. The search was limited to systematic reviews of randomized control trials (RCT) published within the last 10 years in the English language. Ten systematic reviews were identified and nine of them were included in this review. Conflicting and inconsistent evidence exists for determining RTP criteria for athletes following ACLR. None of the systemic reviews established strong evidence for the specific qualities a patient should possess prior to returning to sport in order to minimize reinjury of the same knee or sustaining a new injury to the contralateral limb. There appears to be little consensus on what exactly should constitute RTP testing criteria following an ACLR. In addition, variance exists within the exact rehabilitation timeline and goals used to determine how ACLR rehabilitation protocols are structured. What is currently agreed upon for individuals participating in sports involving side to side/pivoting movements, ACLR is the preferred surgical procedure for returning these individuals back to their respective field of play after an ACL injury.

Keywords: Anterior cruciate ligament repair; anterior cruciate ligament reconstruction (ACLR); return to play (RTP)

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Introduction

An anterior cruciate ligament (ACL) injury is a devastating injury at any level or to any age group, and it has well been documented that the prevalence of ACL injuries is the highest in individuals participating in sport related athletic activities (specifically athletic activities that include pivoting) between the age 15 and 40 (1). However, ACL injuries in the 15 to 25 age group are the most prevalent due to peak participation in sport activities (2) with a yearly estimate of one injury in 3,500 individuals (3). ACL tears account for as much as 50% of all knee injuries, with an estimated one billion dollars spent on ACL reconstructions each year in the US (4). Specific ACL injury mechanisms have been noted in research that non-contact ("Pivot-shift") episodes occur during sporting activities—they are defined as a knee trauma that occurs is in a valgus and externally rotated position with slight knee flexion (2,5). Traumatic

knee hyperextension episodes and direct trauma to the knee with a valgus blow are two additional mechanisms of ACL tears. Analysis of different levels of competition has shed a light on more specific injury rates, as amateur athletes have an incidence rate of 3% yearly for ACL injuries while their elite athlete counterparts have as much as a yearly incidence rate of 15% yearly suffering from an ACL injury (1). Females are two to eight times more likely to sustain an ACL injury than their male counterparts (1). This can be attributed to many different intrinsic and extrinsic factors: biologic/neuromuscular factors affecting potential injury such as puberty, sport specificity, sport volume/frequency (1). Approximately 90% of patients with ACL tears seek surgical reconstruction and often want to return to their pre-injury level of function as soon as possible post-operatively (4). Most orthopedic surgeons vastly agree that anterior cruciate ligament reconstruction (ACLR) is the gold standard in restoring individuals sustaining an ACL injury (6,7). While non-operative options do exist like activity modification, bracing and strengthening, a surgical reconstruction is preferable in cases of functional instability (8), or "giving way" with activities of daily living (ADLs), and for those who wish to return to sports or demanding careers. Previous studies have shown that as many as 300,000 ACLR procedures are performed annually by orthopedic surgeons, with the goal to accelerate the patients' return to their prior level of function. With this high incidence of ACLR it becomes vitally important for the surgical patient to receive high quality, appropriate, and current evidence-based rehabilitation protocols to facilitate a full recovery from their ACL injury. Unfortunately for some, this return does not occur. Recent research has indicated that up to 35% of athletes specifically don't return to their previous levels of preinjury function within 2 years from ACLR (1,4). Furthermore, reinjury to the same surgical knee following an ACL injury has been reported often (1,3). The purpose of this review is to examine the status of research on rehabilitation protocols, tests and criteria for return to play (RTP) and to assess which criteria, if any, are best in determining the proper time to return an athlete to play, after an ACLR; most especially bone-tendon-bone (BTB) procedures.

Methods

Research questions

This evidence-based literature review addressed the following questions:

(I) Which measurements should be taken prior to making a RTP decision for an athlete status post ACLR?
(II) Is there an ideal time for athletes to begin sport-related activities following an ACLR?
(III) Which exercises, modalities and activities are required during an ACLR protocol to prepare for a successful RTP?

Search strategy

PubMed and CINAHL database searches were performed using various combinations of the following keywords: ACL reconstruction, bone to bone graft, rehabilitation. The search was limited to systematic reviews of RCTs published within the last 10 years in the English language.

Study selection

Eleven systematic reviews were identified and ten of them were included in this review.

Inclusion criteria: systematic reviews of RCTs published within the last 10 years in the English language. The studies included one or more the following variables: Quad strength, size of the limb, isolated ACL tears, bone to bone graft Neuromuscular recovery, quality of movement, RTP, therapeutic interventions, at least a year follow-up.

Exclusion criteria: hamstring graft only, efficacy trials (placebo *vs.* controls), narratives, multiple ligament injuries, meniscal tears, concomitant cartilage damage, animal studies.

All systematic reviews were critically appraised using the PRISMA statement appraisal tool.

Data extraction

Quad strength, size of the limb, isolated ACL tears, bone to bone graft Neuromuscular recovery, quality of movement, RTP, therapeutic interventions, at least a year follow-up.

Synthesis

Rehabilitation considerations

Much discussion has gone into the timelines and specifics of ACL rehabilitation over the past 2 decades. Clinically, we have seen a swing from 12-month RTP, to 16–20 weeks RTP, and now we are heading back towards the longer

rehab cycle, in part because of greater understanding of graft healing and restoration timelines (9). Based on clinical experience, physicians are now suggesting at least 6 months for BTB, 7+ months for hamstring grafts to initiate a gradual return to sport (non-contact). Regardless of graft type, investigations into time for RTP ranged from approximately 12 weeks to approximately 12 months, with 6 months or more being the most prevalent time frame (3). This decision is made primarily utilizing a battery of functional tests (1-3,6,9) to compare the strength, power and stability of the non-injured limb to that of the injured limb.

Protocols for rehabilitation are generally divided into phases with specific goals in place to indicate time to move on to the subsequent phase. While the exact timelines may vary slightly, most agree that there is immediate emphasis on control of pain and swelling, achievement of full knee extension, early quadriceps function and neuromuscular control (2,10). There is some variation depending on the type of graft (BTB *vs.* hamstring) used and surgical procedure, yet the end-goal is the same: to return to sport safely and without further risk of reinjury to the same or opposite limb. Rehabilitation protocols used may vary between physicians, some even deciding the timeline first and developing the rehab criteria to fit their desired discharge times, which is not recommended (3). Some current literature supports time-based protocols that are founded on the remodeling process of the graft (1). However, physiological remodeling time frames are not definite for each person, so van Melick *et al.* suggests a "traffic light progression" through rehabilitation that is goal-based and incorporates patient differences in neuromotor learning and flexibility following ACLR (1). Progression to the next phase should be based upon goals achieved in the previous phase and confirmed with objective measures (1).

Phase I of rehabilitation begins immediately after surgery (between days 1–3) and can extend between 2–4 weeks. Early exercises often include isometric quadriceps strengthening, flexion and extension range of motion (ROM), straight leg raises (SLRs) with either a brace to maintain full extension or care to avoid quad lag. Cryotherapy should be utilized to control inflammation and pain, and gait training should begin weight bearing as tolerated with bilateral crutches to prevent patellofemoral pain and decrease quad atrophy (2). Goals for moving forward to subsequent phases usually include satisfactory performance of full knee extension and at least 90 degrees of knee flexion ROM, quadriceps recruitment and function, normalized gait without crutches, and decreased inflammation goals of the previous phase. Open kinetic chain (OKC) and closed kinetic chain (CKC) quadriceps strengthening exercises have been scrutinized over the years—whether and when they should be used in ACLR. Contrary to the belief of many physical therapists and rehabilitation professionals, there is moderate evidence to support equal effectiveness of OKC versus CKC but suggests that further long-term (1 year) RCTs be performed (6,9,11). Additionally, proprioceptive and neuromuscular control activities should begin 2–4 weeks post-operatively, as soon as walking without crutches is possible (2) in order to promote static and dynamic control of the limb. These activities and emphasis on proper mechanics and quality of movement are necessary foundations for sport-specific activities. Practically speaking, lunges, single limb squats, gravity-eliminated running and plyometrics should not begin without mastering early goals and a thorough discussion with the surgeon about patient progress and tissue reactions to stress.

Modality selection post-operatively has also faced some scrutiny in the medical and rehabilitation communities, with some surgeons opting specifically for the use of a continuous passive movement (CPM) machine and long-term post-operative bracing—immediate immobilization and custom bracing. However, multiple studies invalidated the need for a CPM for early ROM and immobilization bracing for the ACL reconstructed knee as neither has been shown to provide any significant improvement in ROM or limb stability compared to those who did not use a CPM or bracing (6,11,12). Lobb *et al.* determined that there was strong evidence against additional benefit of bracing after 6 weeks post-op, compared to standard therapies for outcomes of ROM, strength, laxity, pain and return to sport in short (6 months) or long-term (2–5 years) during their critical appraisal of systematic reviews (6,11).

Although most now agree that factors like the "remodeling process for the graft" (1), quad strength/size of the limb, neuromuscular recovery and quality of movement are important in determining RTP, there is little agreement on how to get there, and what exactly is optimal to measure (1,3). Barber-Westin *et al.* found that only 13% of published literature reviewed had some measurable objective criteria for RTP, and other than time, only 1 or 2 additional benchmarks were included (3,13). The recent addition of blood flow restriction (BFR) training to elite athlete ACLR rehabilitation has gained some popularity for its ability to increase strength and limb size without

early heavy loading. The use of the BFR requires an electronically-monitored blood pressure cuff to be placed around the proximal thigh of the post-surgical limb and inflated to an optimal pressure relative to the cuff size and individual. When inflated, intermittent limb occlusion is achieved and the patient is advised to perform a low load exercise at 30% of 1RM for a period, followed by deflation and a rest period (11). The number of repetitions, specific exercises, and number of sets often varies based on the prescriber. Hughes *et al.* performed a systematic review and meta-analysis of its clinical use and included 3 studies specific to ACL reconstruction. The premise behind BFR training is to use low-load (LL) training along with BFR training to promote physiological adaptations in leg strength and vascular and pulmonary components to cause high levels of metabolic stress that ultimately lead to muscle hypertrophy (14). The units monitor venous and arterial blood flow, allowing for safe application of low load BFR strengthening at times when heavy load strengthening is contraindicated. While there are concerns regarding the inability to blind participants and assessors, and randomization was not achieved, there were still some promising results for increases in muscle cross sectional area that more closely resembled those of heavy-load training (14). It was recommended that LL-BFR be used as a progression towards heavy-load exercises during clinical rehabilitation (14). Although the importance of quadriceps strength and muscle hypertrophy are criteria that most everyone agrees on as a factor for RTP, very little research, particularly RCTs, has been published that evaluates the use of BFR during early phases of rehabilitation, and whether or not there is any carryover into the later phases of the plan of care (14). While muscle size and function are undeniably important, one would surmise that the presence of girth alone would not indicate a patient's readiness to return.

One major area that seems to allude traditional ACLR rehabilitation programs is the advanced strength and conditioning phase. Maybe because physical therapy clinics are not frequently equipped with Olympic weight lifting equipment, there is often not enough space to progress plyometrics and speed/sport-specific training, or there is a lack of communication between the treating physical therapist and a fitness professional that is familiar with the needs of the post-surgical patient. There is also a misconception that sport-specific training and strengthening should be initiated in the minimum protection or RTP phases of the rehabilitation process. However, Panariello *et al.* suggests early athletic movement development should begin much earlier, as in body weight squats to an appropriate depth with the uninvolved foot on a 3–6-inch box to promote weight bearing onto the post-surgical limb during the maximum protective phase at a depth that is tolerable (10). This exercise not only promotes a gradual progression to full weight bearing by decreasing the height of the platform until the patient can support evenly with both feet on the floor, but it also introduces functional and sport-related multi-joint movements. Active ROM necessary for a full running cycle can also be initiated and restored during the maximum-to-moderate protection phases with early exaggerated hip-knee flexion and ankle dorsiflexion ("A") walks (10). The importance of restoring strength and elastic abilities to the ACLR extremity should, according to Panariello, begin during the moderate phase (10), although no specific timelines for these phases were given.

As quadriceps strength increases and quality of movement improves, one may include modified weight lifting techniques that are building blocks for explosive strength training. Every joint from the ankles, knees, hips and even core should be included in order to mimic the activities that are specific to the sport. Small box (4–6 inches) jumps, kettlebell swings, and the pull variation of a power clean are all of technical importance (10). While the idea is not to have a strength and conditioning coach or fitness professional become the primary provider, theirs is a case that integrates with the plan of the physical therapist and orthopedic surgeon to enhance the overall rehabilitation program.

Additional emphasis in the systematic reviews seemed to be put on why athletes did not RTP at the designated time. We are all aware that risk factors such as infection, faulty graft placement, and increased pain may play a significant role in the athlete's ability to RTP efficiently. There is also much more attention being put on influences that are not as obvious such as psychological concerns-depression, the fear of returning to the sport and anxiety about potential reinjury, impaired knee function and social/family reasons (1,7,12).

RTP testing

Prior to making a decision for RTP, one must determine when to initiate training in preparation for the testing. Grinsven *et al.* suggests that if there is minimal pain and swelling, full knee extension is maintained and at least 130 degrees of knee flexion is possible, there is a normal gait pattern and no difficulties with previous exercises that a patient can move forward with dynamic stability

and plyometric exercises—ideally between weeks 9–16 post-operatively (2). During this time double-legged hopping should begin and progress to single-legged hops, weights should be increased with strengthening exercises, and running should be normalized outdoors from week 13 (2). Moving forward to the next phase of maximal muscle strength and endurance, advanced jumping, agility and sport-specific activities between weeks 16–22 should be marked by quadriceps and hamstring strength >75% of the uninvolved side, and hop tests >75% of the contralateral limb (2). Strength should be tested isokinetically when available, at 180 degrees/sec (2). Throughout the rehabilitation, the International Knee Documentation Committee Subjective Knee Form (IKDC) may be given to help determine progression to the next phase.

The most recent systematic review completed by van Melick *et al.* considers multiple factors in ACLR, including the prescribed criteria for RTP. Of the ten articles reviewed, the only highly-rated conclusion was the rate of return to preinjury play level for pivoting athletes after ACLR is 65% for non-professional athletes (1). In 2011, another systematic review cited that the most common criteria for RTP was lower extremity muscle strength and that, of the 12 studies reviewed between 2001–2011, the only other criteria found were lower limb symmetry, knee ROM and effusion (13). Many professionals suggest that the size and overall function of the ACLR limb be within 90% of the healthy limb in all tests prior to return to full sport, although there are some who suggest less (1). Valid recommendations for exact testing batteries to determine RTP are non-existent, but should include strength tests, hop tests, and video analysis to determine the quality of movement (1,10). Specifically, single-leg plyometric tests with <10% deficit compared to the uninvolved side was also recommended, in the form of single hop, triple hop, triple crossover hop or timed hop (3) and the drop-jump test (7).

Weaker evidence is present for a limb symmetry index (LSI) within 80–100% of the non-involved limb, higher for sports that require pivoting (1-3). However, slightly older research [2010] suggests the use of the visual analog scale (VAS) for pain, circumferential limb measurement, ROM, hop tests, isokinetic testing and the IKDC as part of an evidence-based rehabilitation protocol to determine RTP (2). Other tests loosely recommended were the single-limb squat test to 90 degrees, assessment of knee laxity and sports-specific drill examination, although no strong evidence has been identified to support these tests (10).

In many articles, the Tegner scale was used to determine if the patient had reached his/her desired level of activity, the Lysholm and Cincinnati Knee forms (5,7,11,12) to measure pain and function. Although, one review cited conflicting evidence between RTP and the IKDC and Lysholm scores, and post-operative LSI for single-limb hop or crossover hop for distance (7). van Grinsven *et al.* suggests an RTP initiation around 22 weeks post-operatively, following a period of maximal endurance and strengthening, plyometrics, running and sports-specific training (2). However, very little emphasis has been put on the physical and overall strength qualities necessary for an athlete to return to the sport in comparison to their teammates for optimal sports performance (10).

Discussion

Many of these systematic reviews remain outdated and don't address many newer factors like double bundle ACLR surgical techniques, newer modalities like BFR for strength and dry needling for soft tissue management and flexibility that could assist in regaining active and passive ROM. Also, accelerated rehabilitation programs appear to be getting phased out for return to 9–12-month full RTP protocols. As mentioned previously, there are also multiple variables in the surgical procedure, knowledge of the orthopedic surgeon, and knowledge and execution of the physical therapist and rehabilitation team to do what is appropriate for the patient consistently throughout the entire rehabilitation process. How many days a week, and how many hours per day that a patient spends in rehab, and what that time consists of each session is yet another irregularity. There is also, as we know, the factor of patient compliance outside of the rehabilitation setting. Is he/she doing too much? Too little? Did he or she have a few good days and want to "test it out" too soon? It is unlikely that these factors were considered or answered truthfully if asked.

How many therapists have access to space, equipment (BFR) and environments that encourage a multidisciplinary approach between healthcare professionals that can address early symptoms (infections, inflammation, laxity) immediately, psychological concerns like fear, depression and anxiety, and additional consultation with athletic trainers and strength coaches that can provide services to support the rehabilitation plan in the later months. The authors identified the following limitations of this study: articles in a language other than English and gray literature

were excluded from this study. Articles published more than 10 years ago were also excluded.

Conclusions

There appears to be very little consensus on what exactly should constitute RTP testing criteria following an ACLR. In addition, variance exists within the components used to determine how ACLR rehabilitation protocols are structured and how to progress a patient safely from one phase to the next. What is currently agreed upon is the ACL injuries are the most prevalent knee injury and for individuals participating in sports involving side to side/pivoting movements ACLR is the preferred surgical procedure for returning these individuals back to their respective field of play.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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