Return to Sports After Anterior Cruciate Ligament Reconstruction: A Narrative Review from a Holistic Perspective

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Abstract

Introduction: Achieving a successful return to sport (RTS) following anterior cruciate ligament reconstruction (ACLR) remains a complex and multidimensional challenge. Despite high patient expectations, only about half of individuals successfully return to competitive sports, and up to 20% of those who do sustain a second ACL injury. Over the past decade, various RTS test batteries have been developed to evaluate readiness for sport participation and reduce re-injury risk. However, research shows that many athletes fail to meet established RTS criteria, and passing these tests does not consistently protect against second ACL injuries, indicating limited predictive validity. This suggests that current testing protocols may lack sufficient sensitivity. The outcomes of RTS assessments are likely reflective of the rehabilitation content, prompting a critical evaluation of current rehabilitation practices. Are we adequately preparing athletes for the complex, high-intensity, and unpredictable demands of pivoting sports? **Methods:** This narrative review synthesizes key insights from the past 15 years on three core areas: 1) RTS testing protocols, 2) the structure and quality of rehabilitation programs, and 3) the RTS continuum, all viewed through a comprehensive, “helicopter” lens. **Results:** Despite significant progress, many questions remain unanswered regarding RTS after ACLR. The past 15 years have provided valuable insights, but the journey is far from complete. **Conclusion:** RTS is inherently complex and individualized. However, by focusing on fundamental principles such as individualized testing, high-quality progressive rehabilitation, psychological support, neurocognitive integration, and on-field preparation we can improve outcomes. If these elements are implemented effectively, the glass is indeed half full, and the future of RTS after ACLR holds promise for better, safer returns to sport.

Keywords: Anterior cruciate ligament reconstruction, Return to sport, Narrative review, Functional testing, Rehabilitation

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Introduction

Injuries to the anterior cruciate ligament (ACL) are common in sports involving pivoting, cutting, and rapid changes in direction, such as soccer, handball, and basketball. For athletes aiming to resume high-level activity, ACL reconstruction (ACLR) is often recommended. The decision to allow RTS is inherently multifaceted, encompassing physical, psychological, and contextual factors, making it both intricate and demanding. Although more than 90% of patients anticipate returning to sports without limitations, the reality is less optimistic. Evidence indicates that only approximately 55% of individuals across both elite and non-elite levels successfully return to competitive play [1]. Furthermore, among those who do return, nearly one in five will experience a second ACL injury [2,3]. These outcomes highlight the need for improved strategies. This narrative review aims to provide an overarching analysis of key advancements and lessons learned over the last 15 years, focusing on three central themes: 1) RTS assessment methods, 2) the content and delivery of rehabilitation, and 3) the dynamic nature of the RTS process.

Methods

This narrative review synthesizes key insights from the past 15 years on three core areas: 1) RTS testing protocols, 2) the structure and quality of rehabilitation programs, and 3) the RTS continuum, all viewed through a comprehensive, "helicopter" lens.

Results

Part 1: Return to Sport Testing

Test Batteries and Their Limitations

Current consensus supports a criteria-based, time-anchored approach to RTS decisions. As a result, multifaceted test batteries have been developed, incorporating physical metrics such as muscle strength, hop performance, and movement quality, as well as psychological readiness. Common components include isokinetic or handheld dynamometry for strength, unilateral hop tests, jump-landing assessments (e.g., Landing Error Scoring System), and patient-reported outcome measures (PROMs) to evaluate self-perceived function and confidence.

While these batteries aim to identify athletes ready for RTS with minimal re-injury risk, their effectiveness remains questionable. Although passing RTS tests is associated with a higher likelihood of returning to sport suggesting that overall athleticism plays a role numerous studies have found no significant reduction in second ACL injury rates among those who meet criteria [3]. Some research indicates that failing to meet criteria increases re-injury risk [2,4], but methodological inconsistencies exist, particularly in whether all patients or only those who return are analyzed. Notably, one study suggested that meeting criteria lowered ipsilateral injury risk but increased contralateral risk, though methodological critiques have been raised. A reanalysis suggested that passing tests may indeed reduce overall second ACL injury risk, but concerns about test sensitivity and specificity persist [4]. Therefore, current RTS batteries may not be sufficiently accurate in predicting long-term outcomes.

Bridging the Gap Between Clinic and Field

A major limitation of current testing is the ecological disconnect between controlled clinical environments and the dynamic, unpredictable nature of sports. Most tests assess closed, predictable skills, whereas ACL injuries typically occur in open, reactive scenarios involving opponents, teammates, and external distractions. Pivoting sports demand complex physical attributes such as repeated sprint ability, reactive agility, and sport-specific endurance capacities often diminished due to injury-related detraining.

Assessing jump-landing mechanics in a non-fatigued, pre-planned clinical setting may not capture true movement patterns under game-like conditions. Recent findings demonstrate differences in biomechanics when the same athletes are tested in lab versus on-field settings, highlighting the poor ecological validity of traditional assessments [5]. To address this, a shift toward on-field testing is recommended. Wearable inertial measurement units (IMUs) offer portable solutions for real-time movement analysis outside the lab, though their practicality in routine clinical use remains limited due to cost and data processing demands. Alternative tools like the Cutting Movement Assessment Score (CMAS) allow video-based evaluation of cutting mechanics [6]. Additionally, incorporating neurocognitive elements such as decision-making under pressure can enhance test complexity and better reflect sport demands. However, no validated reactive agility tests currently exist for post-ACLR populations. Future research should prioritize developing ecologically valid, field-based testing protocols that integrate wearable technology and cognitive challenges.

Moving Beyond a One-Size-Fits-All Approach

RTS readiness cannot be reduced to isolated strength or hop metrics. Historically, rehabilitation followed standardized protocols, but individual variability in recovery trajectories is now well recognized. Studies reveal that some patients meet RTS criteria early, while others lag in specific domains, such as movement quality or strength, even when hop symmetry is achieved [6]. The absence of consensus on RTS criteria further complicates interpretation across studies. As the number of required tests increases, the likelihood of failing at least one criterion rises a phenomenon known as the "penalty of multiple tests."

Instead of rigid pass/fail models, a personalized, dynamic approach is advocated. Individual RTS profiles, updated through repeated assessments (e.g., every 2–3 months), can track progress and highlight strengths and weaknesses. For instance, one athlete may regain strength by six months but still exhibit risky landing mechanics, while another may perform well in hop tests but lack quadriceps strength at nine months [6]. Testing should begin early in rehabilitation not just at discharge to guide program adjustments. Criteria should be phase-specific; for example, return-to-run benchmarks differ from those for on-field rehabilitation (OFR). Quadriceps strength, for example, should be prioritized before initiating cutting drills, as deficits are linked to higher re-injury risk [5]. Yet, consensus on phase-specific milestones is lacking, and clinicians must use clinical reasoning to tailor testing and rehabilitation accordingly. This iterative process fosters patient motivation and supports a truly individualized RTS journey.

Part 2: Rehabilitation Content

Avoiding Under loading

The outcomes of RTS tests are a direct reflection of the rehabilitation program's quality. Despite structured protocols, many patients fail to meet RTS benchmarks. This raises concerns about whether traditional rehabilitation adequately prepares athletes for sport-specific demands. Evidence suggests that enhancing training intensity and volume through progressive strength training can significantly improve RTS test performance [7]. Programs based on established resistance training principles, gradually increasing load from below 50% to over 80% of one-repetition maximum (1RM), have shown superior results. This underscores the importance of sufficient training stimulus. Rehabilitation before surgery may also enhance postoperative outcomes. To optimize readiness for high-demand sports, rehabilitation must avoid under loading and ensure adequate physical preparation.

The Role of Language and Instruction

The way clinicians communicate significantly influences motor learning and psychological outcomes. Explicit instructions, which focus on body mechanics (internal focus), may lead to overthinking and suboptimal movement patterns. In contrast, external focus cues directing attention to the effect of movement (e.g., "push off the ground forcefully") promote implicit motor learning, leading to better movement quality, performance, and retention [8,9]. Studies support the benefits of external focus in improving jump-landing technique post-ACLR [10]. However, evidence remains limited, and further research is needed to fully integrate these principles into clinical practice.

Addressing Psychological Readiness

An ACL injury is not only physical but also psychological. Fear of re-injury is a major barrier to RTS. While improved physical capacity often correlates with greater psychological readiness (e.g., higher ACL-RSI scores), some patients require targeted psychological support even when physically prepared [11]. Clinicians should foster a positive rehabilitation environment by applying self-determination theory, which emphasizes autonomy, competence, and relatedness. Strategies include involving patients in goal setting, providing supportive (not controlling) feedback, and creating group training sessions to enhance social support. Misalignment between patient expectations and actual outcomes can lead to frustration and reduced motivation. Improving communication can enhance satisfaction, motivation, and psychological readiness, although more research is needed to confirm these benefits [12].

Incorporating Neurocognitive Training

An ACL injury may also involve neural disruption, as the ligament contributes to proprioceptive feedback. Graft replacement (e.g., hamstring or patellar tendon) necessitates cortical reorganization. Given the high neurocognitive demands of sports requiring rapid decision-making under pressure rehabilitation should include cognitive challenges [13]. Dual-task exercises, memory games, and decision-making drills can progressively increase neurocognitive load. Starting with low-complexity tasks and gradually advancing to high-load scenarios helps prevent overload. This integration of brain training is currently underutilized but represents a critical gap in traditional programs [14-16]. More research is needed to evaluate its impact on RTS outcomes.

Implementing On-Field Rehabilitation (OFR)

OFR is essential in the later stages of recovery, serving as a bridge between clinic-based rehab and full sport participation. It addresses sport-specific physical and psychological demands, helping athletes rebuild chronic training load and confidence. OFR typically begins with controlled, pre-planned movements (e.g., curved running) and progresses to reactive agility drills under pressure. Frameworks like the control-chaos continuum offer structured progression from linear running (high control) to unpredictable, high-speed scenarios (high chaos) mirroring real-game conditions [17,18]. Patients often report OFR as the most enjoyable part of rehab, which can boost motivation. However, no empirical evidence yet supports the efficacy of the control-chaos model in ACLR rehab, warranting further investigation.

Emphasizing Secondary Prevention

Rehabilitation should not end at RTS. Current programs often fail to reduce second ACL injury risk, and physical function may decline post-rehabilitation if training is discontinued. Studies show decreased hop performance years after ACLR, suggesting a rise in re-injury vulnerability [1]. Clinicians must educate patients about the importance of ongoing training to maintain strength, movement quality, and neuromuscular control. Long-term adherence to injury prevention strategies is crucial for sustained protection [19].

Part 3: The RTS Continuum

RTS is not a single event but a dynamic, individualized process. The RTS continuum model comprising on-field rehabilitation (OFR), return to training (RTT), return to competition (RTC), and return to performance (RTP) emphasizes progressive reintegration into sport [16,18]. RTP is achieved when athletes compete at pre-injury levels with minimal re-injury risk. Clinical RTS tests should serve as baseline prerequisites for entering OFR, not as final gatekeepers for full RTS. Transitions between stages should be monitored using tools like GPS to manage external load and avoid spikes that increase injury risk.

The relationships between physical, psychological, and contextual factors and RTS outcomes are non-linear and interconnected. A holistic, systems-based approach such as complex systems theory is recommended, viewing the athlete as a dynamic network of interacting variables rather than a collection of isolated metrics. This “web of determinants” acknowledges uncertainty and the need for individualized decision-making. Shared decision-making involving the patient, medical team, and coaching staff is essential to balance rehabilitation, training, and competition demands [20].

Discussion and Conclusions

Despite significant progress, many questions remain unanswered regarding RTS after ACLR. The past 15 years have provided valuable insights, but the journey is far from complete. RTS is inherently complex and individualized. However, by focusing on fundamental principles such as individualized testing, high-quality progressive rehabilitation, psychological support, neurocognitive integration, and on-field preparation we can improve outcomes. If these elements are implemented effectively, the glass is indeed half full, and the future of RTS after ACLR holds promise for better, safer returns to sport.

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Ethical consideration

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Conflict of interest

None.

Authors' contributions

All authors contributed equally to the preparation of this article.

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