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Commentary

Beyond return-to-sport tests: A multifactorial approach to reducing re-rupture risk after ACL reconstruction

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Introduction

The study "Return-to-sport tests: Do they reduce risk of re-rupture after anterior cruciate ligament reconstruction?" [1] provides compelling evidence supporting the predictive value of return-to-sport (RTS) tests in assessing re-rupture risk following anterior cruciate ligament reconstruction (ACLR). With a re-rupture rate of 13.68%, the study highlights that patients who failed RTS tests were significantly more likely to experience graft failure. However, while RTS tests have predictive value, they are insufficient as standalone measures for determining return to sport. RTS readiness extends beyond biomechanical criteria; psychological readiness, rehabilitation adherence, and sport-specific demands must also be considered. Fear of reinjury remains a major barrier, and integrating psychological assessments such as the ACL-RSI scale may enhance decision-making. Additionally, rehabilitation adherence significantly impacts RTS outcomes, with limited participation in structured plyometric training raising concerns about neuromuscular recovery. While the study found no significant association between graft type and re-rupture, evidence suggests that certain graft choices, particularly in younger athletes, may influence long-term outcomes.

This commentary explores the implications of these findings, the need for a comprehensive rehabilitation strategy, and the limitations of using RTS tests as a sole determinant for return to sport.

Rehabilitation and RTS Testing: A Critical Component of ACLR Outcomes

The findings of Figueroa *et al.* reinforce the importance of functional assessments before RTS [1]. The study demonstrated that passing the RTS test correlated with a reduced likelihood of graft failure, which is consistent with existing literature [2,3]. Various test components, such as dynamic valgus assessment, isokinetic strength evaluation, and jump tests **(see Figures 1 and 2)**, provide critical insight into neuromuscular readiness [4-12]. However, RTS tests should not be viewed as a stand-alone measure but rather as part of a multidimensional evaluation that includes psychological, biomechanical, and sport-specific factors.

Time to RTS and Re-rupture Risk: Is Nine Months Sufficient?

An important consideration arising from this study is the optimal timing of RTS. While the median time to RTS testing in this cohort was approximately 330 days, evidence suggests that delaying RTS significantly reduces the risk of re-injury [13-15]. A recent study by Grindem *et al.* demonstrated a 51% reduction in reinjury risk for each additional month of delayed RTS up to nine months [13]. The interplay between biological healing, neuromuscular control, and psychological readiness must be acknowledged when formulating RTS criteria. It is also necessary to explore whether certain subpopulations, such as younger athletes, benefit from an even longer recovery period before resuming high-impact activities.

Figure 1. Isokinetic: The muscle strength of the quadriceps and hamstrings was assessed using an isokinetic dynamometer. Each leg performed 4 maximum concentric isokinetic contractions from 90° of knee flexion to 0° of extension at 60°/s and then at 180°/s. The test is considered passed if the muscle imbalance between legs for both extensors and flexors is <10%. If the patient has a difference >10%, they should continue strengthening and working on muscle balance before returning to sports.

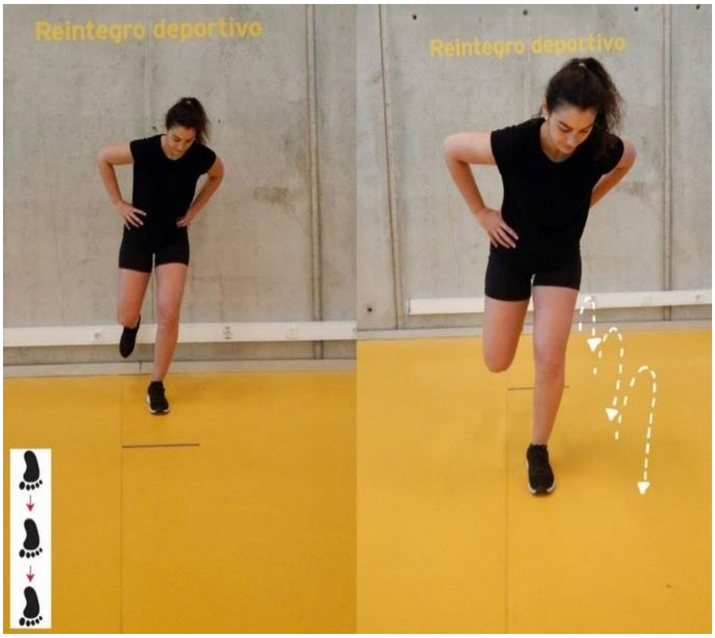

Figure 2. Initial and final position after performing three consecutives jumps during the Triple Hop Test. The best result obtained is recorded. The initial and final positions are recorded after performing three consecutive jumps during the Triple Hop Test. The best result obtained is then recorded. This test represents an activity that places significant demands on the leg muscles' ability to generate substantial knee joint moment and power during takeoff.

The Role of Psychological Readiness and Fear of Reinjury

Although the study emphasizes biomechanical and neuromuscular criteria for RTS, psychological factors are equally critical. Fear of re-injury has been identified as a key predictor of RTS failure [16]. Ardern *et al.* highlighted that psychological barrier, such as loss of confidence and anxiety about re-injury, often delay or prevent athletes from returning to their pre-injury level [17]. Incorporating psychological readiness assessments, such as the ACL-RSI (ACL Return to Sport after Injury) scale, alongside RTS tests may provide a more comprehensive approach to reducing re-rupture rates. Additionally, psychological readiness programs incorporating exposure therapy and cognitive-behavioral interventions could be explored as adjuncts to physical rehabilitation.

These interventions address the emotional and cognitive factors that influence recovery, such as fear and self-doubt, which can hinder the return to sport. The ACL-RSI scale, which quantifies these psychological factors, has shown that psychological readiness increases gradually during follow-up, and is strongly correlated with a successful return to sport [18].

Furthermore, prehabilitation—rehabilitation before surgery—has proven to be an effective tool in improving neuromuscular function and self-reported knee function. Studies show that patients who engage in prehabilitation tend to achieve significantly higher levels of knee function and have a faster return to sport [19]. This highlights the importance of integrating both physical and psychological components into rehabilitation programs, from preoperative stages through to recovery, to enhance overall outcomes and ensure a safe and timely return to sport.

Rehabilitation Adherence and RTS Success

Another essential factor influencing RTS outcomes is rehabilitation adherence. The study reported that only 30% of patients completed a plyometric training program, which raises concerns about the generalizability of RTS testing results [20]. Insufficient rehabilitation may contribute to suboptimal neuromuscular recovery, thereby increasing the risk of re-rupture despite RTS testing. Patients who consistently followed prescribed exercise protocols showed more favorable outcomes than those who did not. Noncompliance not only reduces treatment effectiveness but also increases associated costs. Adherence to postoperative exercise is essential, as it plays a pivotal role in patient confidence in exercise's ability to reduce pain and facilitate functional recovery [21]. A longer duration of supervised rehabilitation is associated with an increased chance of meeting functional and return to sport criteria; however, the optimal supervised rehabilitation frequency is yet to be determined. Identification of the barriers to and facilitators of adherence and participation in ACL rehabilitation provides an opportunity for further research to be conducted to address personal, environmental and treatment-related factors, with the aim to improve rehabilitation outcomes [22].

Future studies should investigate the impact of rehabilitation adherence on RTS test performance and long-term outcomes. Furthermore, understanding patient barriers to adherence—such as socioeconomic factors, access to specialized rehabilitation, and motivation—could guide interventions to improve compliance and RTS success.

Graft Selection and Re-rupture Risk

The study found no significant association between graft type and re-rupture rates, but previous research suggests that certain graft choices, particularly hamstring tendón (HT) grafts, may have a higher failure rate in younger athletes [23]. Although the study excluded patients with extra-articular tenodesis or osteotomies, it would be valuable to examine how graft selection influences RTS test outcomes and long-term joint stability.

Extensive evidence exists regarding the rates of ACL revision surgery for bone-tendon-bone (BTB) and HT grafts. Among eleven registry studies, nine reported a significant association between graft choice and revision rates, with patients who underwent HT ACLR having up to a twofold higher risk of revision. In contrast, four systematic reviews and meta-analyses found no statistically significant differences in re-rupture and reoperation rates; however, a tendency toward higher re-rupture rates with HT grafts persists [24]. And in relation to the type of graft and sports return, a recent meta-analysis involving 2,348 athletes yielded similar results, showing no significant difference in initial RTS rates between HT (81%) and BTB (71%) grafts, or in the rates of return to pre-injury levels of activity [25].

Sonnery-Cottet Bin *et al.* conclude that in a high-risk population of young athletes participating in pivoting sports, the failure rate HT graft combined with anterolateral ligament reconstruction grafts (HT+ALL) is 2.5 times lower than that of BTB grafts and 3.1 times lower than that of 4HT grafts. Additionally, the HT+ALL graft is associated with higher odds of returning to pre-injury levels of sport compared to the 4HT graft [26].

Given that ACL graft failure is multifactorial, future research should consider how factors such as tunnel positioning, graft tensioning techniques, and the role of augmentation procedures (lateral extra-articular tenodesis) interact with RTS testing outcomes.

The Impact of Sport-specific Demands on RTS Decisions

Another consideration is the influence of sport-specific demands on RTS readiness. The study population included athletes from various disciplines, yet different sports impose unique stresses on the knee joint. For example, cutting and pivoting sports like soccer and basketball may require a different RTS threshold compared to straight-line endurance sports such as distance running. A more tailored approach, incorporating sport-specific movement assessments, could refine RTS decision-making and further reduce the risk of re-rupture.

Future Directions: Towards an Individualized RTS Framework

Given the multifactorial nature of ACL re-ruptures, a more individualized RTS framework is warranted. A comprehensive RTS model should integrate the following:

1. Objective functional assessments (strength, balance, hop tests).
2. Psychological readiness evaluations.
3. Sport-specific training and biomechanics analysis.
4. Gradual exposure to competitive environments.

5. Consideration of biological healing timelines.
6. Assessment of rehabilitation adherence and patient education.

While RTS tests offer valuable predictive insights, they should be combined with these additional factors to maximize safe return to sport and minimize re-injury risk.

Conclusion

Our study underscores the importance of a multifaceted approach for optimal RTS outcomes, considering psychological factors, rehabilitation adherence, and graft-specific characteristics. Fears of re-injury and loss of confidence are key predictors of RTS failure. Incorporating psychological readiness assessments like the ACL-RSI scale, along with biomechanical tests, can reduce re-rupture rates. Programs that include exposure therapy and cognitive-behavioral interventions can address emotional barriers and enhance recovery.

Rehabilitation adherence also plays a critical role; incomplete rehabilitation can lead to suboptimal neuromuscular recovery, increasing the risk of re-rupture. Future research should focus on the impact of adherence on RTS outcomes. To improve RTS success, clinicians should use an integrated model that combines biomechanical, psychological, and rehabilitation adherence criteria, ensuring a safer and more sustainable return to sport.

Authors Contribution

All the authors contributed to the design, analyses and reporting for this manuscript. Both authors read and approved the final submitted manuscript.

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