



Retrospective Comparative Study

INFLUENCE OF EARLY VS LATE RETURN TO SPORT ON OUTCOMES IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A RETROSPECTIVE COMPARATIVE STUDY

E. Mazzini¹, G. Placella¹, N. Biavardi¹, M. Alessio-Mazzola^{2,3}, S. Mosca¹ and V. Salini¹

¹Vita-Salute University San Raffaele, Milan;

²Department of Surgical Sciences and Integrated Diagnostic (DISC), University of Genoa, Genoa, Italy;

³IRCCS Orthopaedic Clinic, Policlinic Hospital, San Martino, Genoa, Italy

Correspondence to:

Mattia Alessio Mazzola, MD

Department of Surgical Sciences and Integrated Diagnostic (DISC),

University of Genoa,

Viale Benedetto XV n. 6,

16132 Genova, Italy;

IRCCS Orthopaedic Clinic,

Policlinic Hospital San Martino,

Largo Rosanna Benzi 10,

16132 Genova, Italy

e-mail: mattia.alessio@hotmail.com

ABSTRACT

The optimal timing for return to sport (RTS) following anterior cruciate ligament (ACL) reconstruction remains controversial. Accelerated rehabilitation protocols may increase the risk of re-injury, whereas delayed RTS could enhance recovery outcomes. To investigate the effects of rehabilitation timelines on functional outcomes and reinjury rates post-ACL reconstruction, comparing standard RTS protocols with delayed RTS approaches. In this retrospective cohort study, 54 highly active athletes aged 15-35 years who underwent primary ACL reconstruction using a hamstring autograft were analyzed. Participants were divided into two groups based on rehabilitation duration: the Standard RTS group (returning to sport within 5-7 months, n=28) following MOON guidelines, and the Delayed RTS group (returning after ≥ 9 months, n=26) adhering to Delaware-Oslo guidelines. Outcomes measured included the Lysholm Knee Score for functional assessment, Tegner Activity Scale (TAS) difference for activity level changes, ACL Return to Sport Index (ACL-RSI) for psychological readiness, and incidence of ACL re-rupture and contralateral ACL injuries over a 30-month follow-up. The Delayed RTS group demonstrated significantly better functional outcomes (Lysholm score: 94.1 ± 4.7 vs 79.6 ± 6.9 , $p < 0.001$), smaller reductions in activity levels (TAS difference: -0.33 ± 0.8 vs -1.9 ± 0.8 , $p < 0.001$), and higher psychological readiness (ACL-RSI: 85.6 ± 13.2 vs 51.9 ± 16.4 , $p < 0.001$) compared to the Standard RTS group. The Standard RTS group had a seven-fold increased risk of ACL re-rupture (Relative Risk (RR)=7.0, Odds Ratio (OR)=6.5) and doubled the risk of contralateral ACL injury (RR=2.0, OR=2.17). The combined risk of an ACL injury was significantly higher in the Standard RTS group (RR=3.53, OR=5.27), with an absolute risk increase of 29%. Delaying

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RTS beyond nine months post-ACL reconstruction significantly improves functional outcomes psychological readiness, and reduces the risk of reinjury compared to standard rehabilitation timelines. These findings support the adoption of extended, criterion-based rehabilitation protocols to optimize patient recovery and enhance long-term knee health.

KEYWORDS: *anterior cruciate ligament reconstruction, return to sport, rehabilitation timeline, re-injury risk, functional outcomes, MOON guidelines, Delaware-Oslo guidelines*

INTRODUCTION

Anterior cruciate ligament (ACL) reconstruction is an extremely delicate surgery that significantly affects an athlete's life. From the time of injury to return to sports activities, many crucial steps must be carried out perfectly to ensure optimal recovery, both in knee function and return to sport at pre-injury levels.

The incidence of these injuries has been increasing, with an estimated 120,000 to 200,000 ACL injuries occurring annually in the United States (1, 2). ACL injuries are most prevalent in high school and college-aged individuals, with a peak incidence occurring between 15 and 25 years of age (3, 4).

The impact of ACL injuries on athletes is serious, often resulting in significant time lost from sports, surgical intervention, and long-term health consequences. These injuries are associated with an increased risk of early-onset osteoarthritis, regardless of treatment approach (5-7). Furthermore, ACL injuries can have substantial psychological impacts, affecting an athlete's confidence and potentially altering their future athletic pursuits (8, 9). Gender and sport type significantly influence ACL injury risk. Females consistently demonstrate a higher incidence of ACL injuries compared to males in sex-comparable sports, with risk ratios ranging from 1.5 to 4.6 (10, 11). High-risk sports include soccer, basketball, and football, with soccer showing particularly high rates for females (12, 13).

The optimal timing for return to sport following ACL reconstruction remains debatable. While traditional protocols often suggest a 6–9-month recovery period, recent evidence indicates that only about two-thirds of athletes return to their pre-injury level of competition within 12 months post-surgery (14, 15). Some researchers argue for a more conservative approach, suggesting that delaying return to sport beyond 12 months may reduce the risk of re-injury (16).

The high incidence and significant impact of ACL injuries underscore the importance of prevention programs and optimized rehabilitation protocols. Future research should focus on refining injury prevention strategies, improving surgical techniques, and developing evidence-based guidelines for safe return to sport to mitigate the long-term consequences of these injuries on athletes' health and careers.

Objectives

This study aimed to investigate the effects of two different rehabilitation timelines on the success rates of ACL reconstruction, focusing on the timing of return to sport as a critical factor. Specifically, the study aimed to compare functional outcomes, the frequency of reinjury, and overall knee stability between patients who adhered to a standard RTS protocol and those who delayed their return to sport. Through this comparison, the study seeks to provide clear evidence to guide clinicians in recommending the most effective rehabilitation strategy for minimizing the risk of reinjury and ensuring long-term knee health post-ACL reconstruction.

MATERIALS AND METHODS

Study design

This retrospective cohort study was conducted to compare the clinical outcomes of two distinct rehabilitation protocols following anterior cruciate ligament (ACL) reconstruction. The study focused on the timing of return to sport (RTS) and its impact on functional recovery and reinjury rates. Data were collected from patients who underwent primary ACL reconstruction between 2017 and 2020.

Participants

A total of 127 patients who met the inclusion criteria were initially enrolled in the study. Inclusion criteria were as follows: age between 15 and 35 years at the time of injury, highly active or competitive athletes with a pre-injury Tegner Activity Score (TAS) of 5 or higher, and those who had undergone ACL reconstruction using a hamstring autograft

with a double-bundle technique (gracilis-semitendinosus). Exclusion criteria included patients with previous ACL injuries, those who did not complete the follow-up, and those with a TAS lower than 5. After applying these criteria, 54 patients remained for the final analysis.

Intervention

Participants were divided into two groups based on their rehabilitation timeline:

- **Standard RTS Group:** patients who returned to sport within 5-7 months post-surgery, following the MOON guidelines.
- **Late RTS Group:** patients who delayed their return to sport until at least 9 months post-surgery, following the Delaware-Oslo guidelines.

Outcome measures

To assess the outcomes of the two rehabilitation protocols, the following validated tools were employed:

- **Lysholm Knee Scoring Scale:** used to evaluate knee function, with scores ranging from 0 to 100, where higher scores indicate better knee stability and function.
- **Tegner Activity Scale (TAS):** employed to measure the level of physical activity before and after the injury. The difference between pre-injury and post-rehabilitation TAS scores was calculated to determine the impact on activity levels.
- **ACL Return to Sport Index (ACL-RSI):** a psychological measure assessing readiness to return to sport, with scores ranging from 0 to 100, where higher scores represent greater psychological readiness.

Data collection

Patients were interviewed retrospectively regarding the duration of their rehabilitation, any relapses of ACL injury, and the occurrence of new contralateral ACL injuries within a 30-month follow-up period. Data on Lysholm, TAS, and ACL-RSI scores were collected and analyzed for both groups.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) to compare the outcomes between the two groups. Continuous variables such as Lysholm, TAS, and ACL-RSI scores were analyzed using t-tests, while categorical variables, such as the incidence of relapses and new injuries, were compared using chi-square tests. Statistical significance was set at $p < 0.05$. Odds ratios (OR), relative risks (RR), and absolute risks (AR) were calculated to quantify the risk associated with the standard and late RTS protocols.

RESULTS

Patient demographics

Out of an initial cohort of 127 patients, 54 were eligible for inclusion after excluding those lost to follow-up, had Tegner Activity Scale (TAS) scores lower than 5, or did not provide consent. The patients, aged between 15 and 35 at the time of injury, had undergone primary ACL reconstruction using the same surgical technique. The study population consisted of 38 men and 16 women, with an average age of 26.7 ± 4.7 years. Participants were assigned to two groups based on the duration of their rehabilitation:

- **Standard RTS Group:** patients in this group returned to sport after an average rehabilitation period of 5.6 ± 0.7 months.
- **Delayed RTS Group:** these patients delayed their return to sport, with an average rehabilitation duration of 9.9 ± 1.2 months.

No gender- or sport-specific distinctions were made among the participants, all of whom were competitive or highly active athletes based on their pre-injury TAS scores.

The Lysholm Knee Scoring Scale was employed to evaluate functional outcomes post-ACL reconstruction, providing insights into knee stability, pain, swelling, and overall activity performance. Scores range from 0 to 100, where values above 84 indicate excellent function, while those between 65 and 83 denote good function. This metric was instrumental in comparing the effectiveness of the standard versus delayed rehabilitation protocols.

Lysholm score

In the standard RTS group, the mean Lysholm score was 79.6 ± 6.9 (range: 64 to 95; 95% CI: 75.0-84.0) points. The delayed RTS group demonstrated significantly superior functional recovery ($p < 0.001$), with a mean Lysholm score of 94.1 ± 4.7 (range: 84 to 100; 95% CI: 91.0-99.0) (Fig. 1).

The independent t-test showed a highly significant difference between the two groups ($p < 0.001$), with a mean difference of 14.5 ± 1.7 points in favor of the delayed RTS group.

Statistical analyses confirm that delayed rehabilitation yields significantly better functional outcomes than standard rehabilitation in terms of knee stability, pain management, and overall knee function.

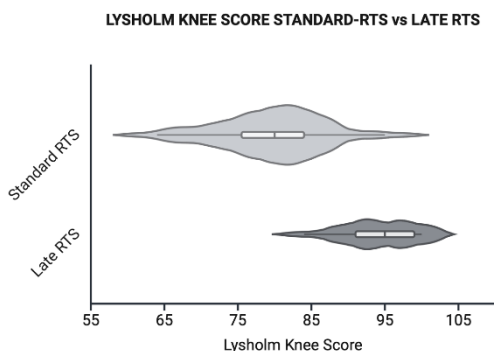


Fig 1. Lysholm Knee Score for standard vs late RTS

Tegner activity scale

The standard RTS group showed a mean TAS difference of -1.9 ± 0.8 (range: -3.0 to 0) (Fig. 2). The delayed RTS group performed significantly better, with a mean TAS difference of -0.3 ± 0.8 (range: -2.0 to 1.0). A Mann-Whitney U test confirmed a significant difference between the groups ($p < 0.001$), with a median difference of 2.0 in favor of the delayed RTS group. The Shapiro-Wilk test showed an abnormal distribution of values.

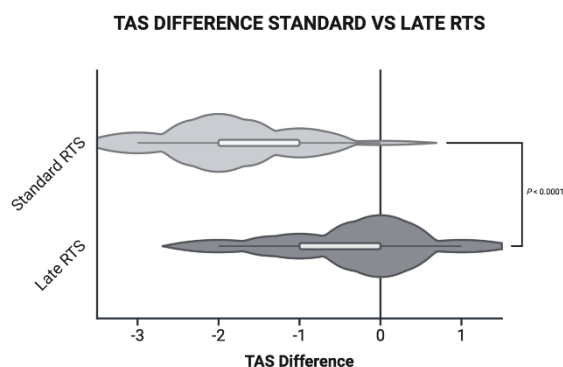


Fig. 2. TAS Difference Standard vs Late RTS.

ACL-RSI

The standard RTS group had a mean ACL-RSI score of 51.9 ± 16.4 (range: 18.3 to 84.6), indicating moderate psychological readiness to return to sport. The lower scores reflect ongoing concerns among patients about knee stability and fear of re-injury, which is common in shorter rehabilitation protocols. In contrast, the delayed RTS group demonstrated significantly better psychological readiness, with a mean ACL-RSI score of 85.6 ± 13.2 (range: 30.8 to 97.5) points (Fig. 3). A Mann-Whitney U test revealed a significant difference in ACL-RSI scores between the two groups ($p < 0.001$), with a median difference of 38.3 points favoring the delayed RTS group. The

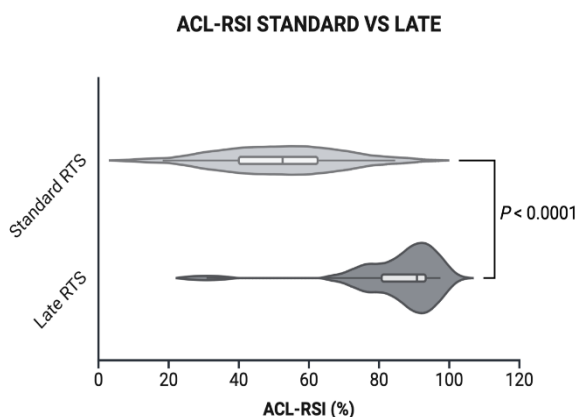


Fig. 3. ACL-RSI standard vs late RTS.

Shapiro-Wilk test showed non-normality in the delayed RTS group, but Levene's test indicated no significant difference in variance between groups ($p = 0.060$).

Risk of re-injury

For the event of re-injury, the data showed a pronounced difference in risk between the two groups. The Odds Ratio (OR) was found to be 6.5, meaning that the patients in the Standard RTS group were 6.5 times more likely to experience a relapse compared to those in the Late RTS group. This substantial difference indicates that the likelihood of ACL re-injury is dramatically increased with

an accelerated rehabilitation program. The Relative Risk (RR), calculated to be 7, further emphasizes this point by showing that patients in the Standard RTS group were seven times more likely to suffer a relapse than those in the Late RTS group.

Additionally, the Absolute Risk (AR) for relapse was 0.22, signifying a 22% higher chance of experiencing a relapse if a faster rehabilitation program was followed (Fig. 4).

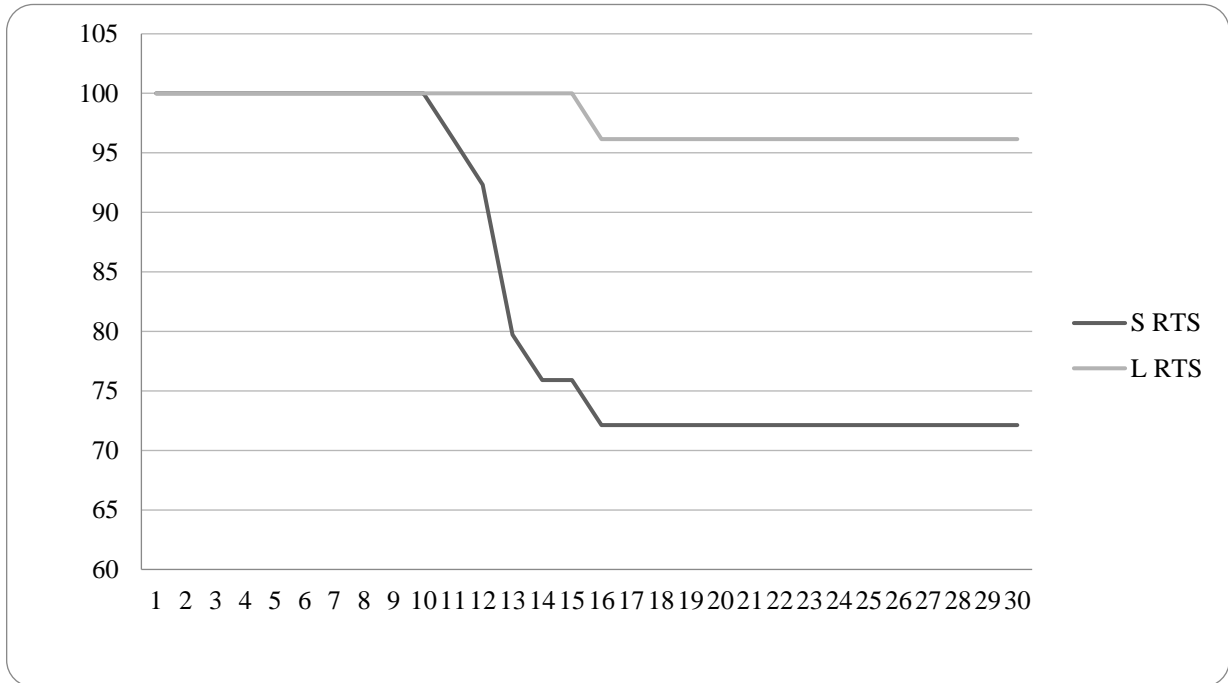


Fig. 4. Risk of re-rupture standard vs late RTS.

In contrast to re-injury, the risk of contralateral injuries was less pronounced but still noteworthy. The data showed an OR of 2.17, meaning that patients in the Standard RTS group were approximately twice as likely to experience a contralateral injury as those in the Late RTS group. The Relative Risk (RR) for contralateral injuries was calculated to be 2, indicating that the faster rehabilitation group had double the risk of sustaining a contralateral injury. The Absolute Risk (AR) for contralateral injuries was 0.07, reflecting a 7% increase in the absolute probability of developing a contralateral ACL injury in the Standard RTS group (Fig. 5).

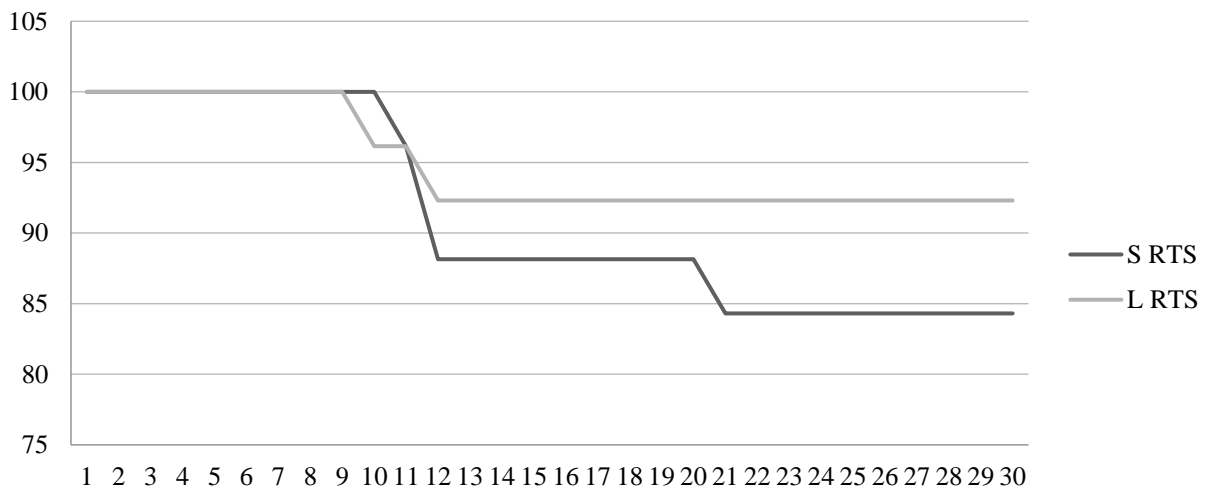


Fig. 5. Risk of contralateral injury standard vs late RTS.

Combined event (re-injury + contralateral ACL injury)

When considering the event of injury as both re-injury and contralateral ACL injuries, the overall risk remains elevated for the Standard RTS group. The Odds Ratio (OR) for this combined injury event was calculated to be 5.27, indicating that patients in the Standard RTS group were 5.27 times more likely to experience an injury (either relapse or contralateral) compared to those in the Late RTS group. The Relative Risk (RR) was 3.5, meaning that patients in the Standard RTS group were more than three times as likely to suffer from an injury, whether a relapse or contralateral injury. The Absolute Risk (AR) for the combined injury event was 0.29, signifying a 29% higher chance of encountering either a relapse or a contralateral injury when following a faster rehabilitation program.

Kaplan-Meier survival analysis

To better understand the long-term impact of the rehabilitation protocols, Kaplan-Meier survival curves were employed to compare the injury-free survival between the Standard RTS and Late RTS groups over a 30-month follow-up period. The Kaplan-Meier analysis showed a significant divergence between the two groups, with the Late RTS group maintaining a considerably higher probability of remaining injury-free throughout the 30 months compared to the Standard RTS group.

In the Standard RTS group, the survival curve showed a steep decline early in the follow-up period, indicating a higher frequency of injuries (both relapses and contralateral injuries) soon after the return to sport. In contrast, the Late RTS group exhibited a more gradual decline in the survival curve, with far fewer injuries observed over the same period.

DISCUSSION

The findings of this study indicate that delaying return to sport (RTS) beyond nine months after anterior cruciate ligament (ACL) reconstruction significantly enhances functional outcomes and reduces the risk of reinjury compared to a standard rehabilitation timeline of 5–7 months. These results support the growing body of evidence advocating for extended, criterion-based rehabilitation protocols to optimize patient recovery.

The results of the present study align closely with the recommendations of the Delaware-Oslo ACL cohort study, which emphasized that delaying RTS until certain functional milestones are achieved can substantially reduce the risk of re-injury.

Grindem et al. (16) found that each additional month of rehabilitation up to nine months decreased the reinjury rate by 51%, and patients who met specific strength and hopping criteria before RTS had an 84% lower risk of a second ACL injury compared to those who did not meet these criteria. This underscores the importance of not only time but also the quality of rehabilitation in ensuring safe RTS.

Similarly, the Multicenter Orthopaedic Outcomes Network (MOON) group has developed guidelines that stress the importance of individualized, criterion-based progression through rehabilitation phases (8, 17). The MOON guidelines recommend that patients achieve specific functional benchmarks—such as quadriceps strength symmetry and successful completion of hop tests—before considering RTS. Our delayed RTS group, which adhered more closely to these principles by allowing an average of 9.9 months for rehabilitation, demonstrated significantly better Lysholm Knee Scores and ACL-RSI scores, suggesting both better physical function and psychological readiness.

The superior functional outcomes observed in the delayed RTS group are consistent with the findings of Kyritsis et al. (18), who reported that patients not meeting specific discharge criteria before RTS were at a fourfold greater risk of graft rupture. This study highlights the critical role of objective functional assessments in determining RTS readiness. The delayed RTS group's longer rehabilitation period likely allowed for a more comprehensive recovery of muscle strength, proprioception, and neuromuscular control, which are essential for knee stability and function.

Psychological readiness is another crucial factor influencing RTS outcomes. Ardern et al. (8) emphasized that psychological responses significantly impact the likelihood of returning to preinjury levels of sport. The higher ACL-RSI scores in the delayed RTS group suggest that extended rehabilitation may provide additional time for patients to rebuild confidence in their knee function, reducing fear of reinjury—a common barrier to successful RTS.

The markedly lower rates of ACL re-rupture and contralateral injuries in the delayed RTS group have important clinical implications. Paterno et al. (19) demonstrated that young athletes who returned to high-risk sports had a significantly higher incidence of second ACL injuries within 24 months post-reconstruction. Our study's findings reinforce

the need for cautious progression through rehabilitation and suggest that accelerated RTS protocols may inadequately prepare patients for the demands of competitive sports.

Moreover, the Kaplan-Meier survival analysis in our study illustrates a clear divergence in injury-free survival between the two groups over 30 months, favoring the delayed RTS group. This long-term benefit supports the notion that extended rehabilitation improves immediate postoperative outcomes and contributes to sustained knee health and function.

While the study provides valuable insights, several limitations must be acknowledged. The retrospective design may introduce selection bias, and the sample size of 54 patients, although adequate for detecting significant differences, limits the generalizability of the results. Additionally, the study did not control for potential confounding variables such as the exact rehabilitation protocols followed, patient adherence, or the presence of concomitant injuries. Future studies should employ a prospective, randomized, controlled design to validate these findings and account for these variables.

The results advocate for a shift towards more conservative, individualized rehabilitation timelines, as recommended by both the MOON guidelines and the Delaware-Oslo study. Clinicians should consider incorporating objective functional tests and psychological assessments into their RTS criteria.

CONCLUSIONS

This study provides robust evidence that delaying return to sport (RTS) after ACL reconstruction leads to significantly better outcomes compared to standard, accelerated rehabilitation protocols. The delayed RTS group demonstrated superior results across all measured outcomes. Future research should focus on identifying specific biological and functional markers that indicate readiness for return to sport, as well as developing and validating standardized, evidence-based protocols for extended ACL rehabilitation. Additionally, long-term follow-up studies are needed to assess the impact of delayed RTS on career longevity and the development of post-traumatic osteoarthritis.

In conclusion, this study provides strong evidence in favor of delaying return to sport following ACL reconstruction to optimize functional outcomes and minimize re-injury risk.

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