Is 9 months the sweet spot for male athletes to return to sport after anterior cruciate ligament reconstruction?

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ABSTRACT

Objective Most studies examining the time to return to sport (RTS) after anterior cruciate ligament reconstruction (ACLR) do not account for the athlete's physical readiness. This study aimed to investigate the status of male athletes at 2 years after ACLR, the factors affecting a return to pivoting sports, and the association between time to RTS and subsequent knee injury risk for those athletes who met discharge criteria.

Methods We prospectively followed 530 male athletes (mean age 26.7±7.7 years) participating in pivoting sports throughout rehabilitation and at 2 years after ACLR. Pair-wise analyses were conducted to compare athletes who returned to pivoting sports and those who did not. We performed a Cox regression analysis to assess the association between subsequent non-contact or indirect contact knee injuries and time to RTS. Pearson's χ^2 test was used to compare athletes who RTS in ≤9 months to those who RTS in >9 months after ACLR.

Results In total, 379 (72%) athletes returned to pivoting sports at 2 years after ACLR. Athletes who completed rehabilitation and met discharge criteria (n=190) were almost 6 times more likely to return to their preinjury sport (OR 5.71; 95% CI 3.39 to 9.62). Of those who did not complete their rehabilitation (n=340), 132 (39%) did not return to pivoting sports. For athletes who met discharge criteria, time to RTS was not associated with the risk of new knee or ACL injury. There was no increased risk for new knee (HR 0.892, 95% CI 0.39 to 2.07, p=0.79) or ACL (HR 0.718, 95% CI 0.24 to 2.17, p=0.56) injury whether athletes returned before or after the 9-month mark following ACLR.

Conclusions Completing rehabilitation and meeting objective criteria significantly increased the odds for male athletes to return to pivoting sports. Time to RTS did not impact the risk for a new knee or ACL injury if athletes met objective criteria.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Clinicians are still using time as an important part of the return to sport (RTS) decision after anterior cruciate ligament reconstruction (ACLR), with 9 months (or even longer for younger athletes) typically being the cut-off.
⇒ Not meeting clinical discharge criteria before returning to sport is associated with a four times greater risk of graft rupture.

WHAT THIS STUDY ADDS

⇒ In a cohort of male athletes, adherence to the rehabilitation protocol had a significant impact on RTS rates, showing a dose–response relationship: the further athletes progress in their rehabilitation after ACLR, the greater their chances of returning to pivoting sports.
⇒ Athletes who met discharge criteria were six times more likely to return to pivoting sports compared with those who stopped attending.
⇒ Returning to sports in less than 9 months after surgery did not increase the risk of a new ACL or knee injury, provided athletes met the discharge criteria.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Decisions to RTS after ACLR should focus more on 'how' the athlete returns instead of 'when' the athlete returns. Time is necessary, but apparently not sufficient to ensure success.
⇒ In clinical practice, progression from phase to phase during rehabilitation and the decision to RTS should be dictated by relevant, objective criteria and individual athlete needs.
⇒ Further research into rehabilitation components and testing methods should complement the extensive research on surgical techniques to improve successful outcomes after ACLR.

INTRODUCTION

The debate over return to sport (RTS) timelines after anterior cruciate ligament (ACL) reconstruction (ACLR) has evolved over four decades. In the late 1990s, opinion favoured a 6-month wait.[1] However, a pivotal study by Grindem *et al*[2] showed that each additional month postsurgery decreased the likelihood of new knee injuries substantially and argued for an approach combining functional criteria and extended time leading to a generally accepted 9-month guideline. Further research suggests a sevenfold higher rate of ACL reinjury for patients who returned earlier than 9 months after surgery.[3] Some researchers advocate even longer delays, up to 12 months or even 2 years, to ensure ligamentisation of the new graft prior to RTS.[4 5]

Clinicians typically define success as preventing reinjuries, which heavily influences their recommendations on RTS timing.[6] In contrast, athletes often define success as returning to their sport as quickly as possible, raising the question of whether a rapid RTS can be achieved without increasing injury risk.

A combination of time-based and criteria-based RTS decision-making after ACLR has been

proposed. A substantial proportion of published research has used time alone as the RTS criterion, although this seems to be shifting towards including functional testing.[7] Still, there is substantial variation among clinicians, particularly around what should constitute criteria for returning to unrestricted sport.

Physiotherapists worldwide tend to use objective criteria, but opinions vary significantly on RTS timing depending on the country, with 22%–95% allowing RTS earlier than 9 months after ACLR.[8–12] Surgeons generally recognise the value of quantitative criteria, but acknowledge many barriers to their clinical implementation.[13] Time was stated as the most important criterion to evaluate readiness to RTS[14]; depending on the country, 25%–73% of surgeons would allow RTS earlier than 9 months.[13–15] Clinical guidelines conflict on whether time or objective criteria should dictate RTS.[16 17]

While time is crucial for graft maturation and functional restoration, its impact on reinjury risk is debated. Studies have focused on time and risk of future injuries, but all too often fail to control for rehabilitation compliance and the athlete's injury recovery status at the time of RTS. Piussi *et al*[18] found that patients who suffered a second ACL injury had returned to sport 25 days earlier than patients who did not. However, in professional athletes, there was no significant association between time to RTS and risk of new injury, possibly because of the higher quality/quantity of rehabilitation.[18] Additionally, the definition of reinjury often lacks consistency, especially regarding distinctions between contact and non-contact incidents as well as whether new injuries occur during rehabilitation or after RTS. Therefore, this study aimed to explore:

1. The status of athletes 2 years after ACLR and the factors influencing their return to pivoting sports, with a particular emphasis on the role of rehabilitation components—such as adherence, complications and the rehabilitation phase that athletes stopped/finished rehabilitation. We hypothesised that rehabilitation would significantly influence whether male athletes returned to pivoting sports.
2. The association between the time to RTS in male athletes who have met objective criteria and returned to pivoting sports and subsequent risk of injury.

METHODS

Study design and participants

This prospective observational study was conducted at the Riadh Assessment and Movement Analysis Lab (RAMAL) at Aspetar Orthopaedic and Sports Medicine Hospital. We included consecutive male athletes with preinjury participation in pivoting sports (football, basketball, handball, racket sports, alpine skiing, etc) at a recreational or competitive level (Tegner scale 6–10)[19] who underwent ACLR between 1 January 2017 and 30 April 2022. Athletes were excluded if they had associated posterior cruciate ligament injury and/or surgically treated injuries to the medial or lateral collateral ligament. Athletes who continued rehabilitation at another facility and those who could not be followed up because they left the country were also excluded. Out of 1010 athletes treated for ACL injuries during this period, 530 met the inclusion criteria (figure 1).

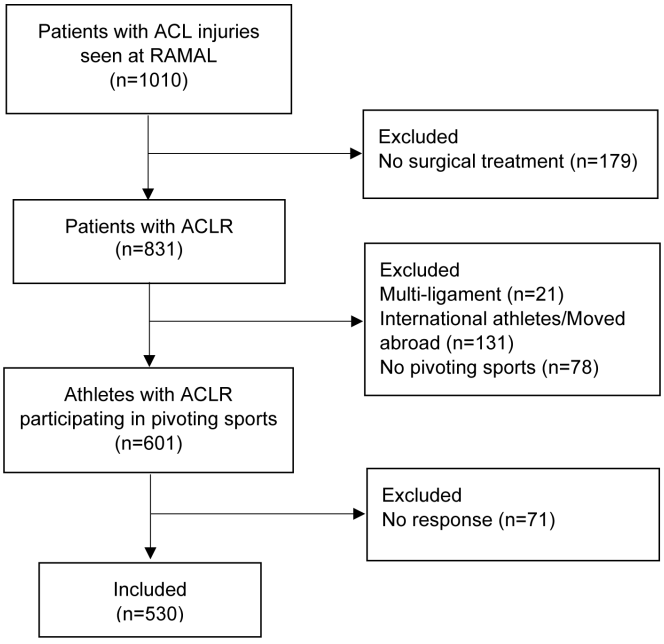

Figure 1 Study flow diagram. ACL, anterior cruciate ligament; ACLR, ACL reconstruction; RAMAL, Riadh Assessment and Movement Analysis Lab.

Demographics, surgery and rehabilitation

Graft selection was based on case history and surgeon preference. Extra-articular lateral augmentation was performed at the surgeon's discretion. Postsurgical restrictions (eg, bracing, weight-bearing status) were determined by the treating surgeon.

All athletes participated in a comprehensive rehabilitation programme overseen by a team of specialised sports physiotherapists dedicated exclusively to treating ACL injuries. The rehabilitation protocol was tailored to each athlete's specific treatment goals, monitored by regular, mandatory testing.

Most athletes participated in preoperative rehabilitation, with the primary objectives being to restore range of motion, reduce swelling, improve strength and prepare athletes for postoperative recovery. All athletes were referred to a postoperative rehabilitation programme immediately after surgery. Throughout the rehabilitation journey, athletes were taken through a structured protocol that included hydrotherapy, strengthening exercises, running retraining, proprioception drills, agility training, plyometrics, cardiovascular endurance workouts and sport-specific drills. The rehabilitation process was structured into three phases: (1) early, (2) intermediate and (3) advanced, and the progression through these phases was determined by objective criteria rather than a fixed timeframe. During the early phase, the focus was on managing swelling, restoring knee range of motion and activating the quadriceps and hamstring muscles. In the intermediate phase, the emphasis shifted to optimising muscle strength, proprioception and motor control. Towards the end of this phase, athletes were engaged in a running progression programme as well as plyometric training programme. Finally, in the advanced phase, rehabilitation focus was more sport-specific, with athletes beginning to undertake various sports-specific and position-specific drills.

Athletes underwent assessment at RAMAL every 6 weeks until they met the discharge criteria or stopped attending rehabilitation. Testing at RAMAL was an integral, mandatory component of the rehabilitation process, with progression through rehabilitation phases determined by objective test results. Independent testers, rather than the treating physiotherapists, conducted these assessments, which included clinical evaluations, strength and movement analyses and patient-reported outcomes. During their initial visit, we collected their demographic information, and at every time point, we conducted clinical, laxity, strength

and movement evaluations and collected patient-reported outcome measures. Surgical details, complications during rehabilitation and rehabilitation attendance were sourced from the electronic medical records of the institution. Athletes cleared to RTS from both the physiotherapy (RAMAL objective results) and surgical departments (documented in the athlete's medical record) were categorised as 'met discharge criteria', whereas those returning to sport without meeting criteria were categorised as 'not completed/stopped rehabilitation'. We further categorised athletes based on when they discontinued rehabilitation: those who stopped during the early phase (before progressing to running, reactive strength exercises and plyometric training), and those who stopped during the intermediate phase (after having undergone running, reactive strength exercises and plyometric training). The RTS meeting discharge criteria were decided on pain-free testing, >90% strength symmetry, >90% jump symmetry, completion of a sport-specific protocol, and education on prevention and maintenance.

Adherence was assessed using previously published methods[20] focusing on three key parameters: the total number of rehabilitation sessions, the number of sport-specific sessions and the weekly frequency of rehabilitation sessions. The cut-off values for adherence were set at 50 total sessions, 10 sport-specific sessions and 3 sessions per week. For each parameter, a score of 0 was assigned if the cut-off was not met and 1 if it was met. A total score of 0 or 1 indicated non-adherence ('no'), while a total score of 2 or 3 indicated adherence ('yes'). Complications during rehabilitation were defined as any issues persisting for more than 2 months that hindered the athlete's ability to complete the battery of tests at RAMAL. These complications included surgical complications, arthrofibrosis, arthrogenic muscle inhibition and persistent anterior knee pain.

Data collection for follow-up

Information on athletes' status 2 years postsurgery was collected using a survey and athletes' medical records. Athletes were contacted annually postsurgery to complete a survey, which included questions about their RTS: time to RTS, any new knee injury, and the mechanism of any new injury. The follow-up survey questions are reported as online supplemental file section 1. The time to RTS was defined as the time from the date of surgery to when athletes returned to unrestricted pivoting sporting activities, regardless of the type, level and intensity. Medical records were also reviewed for all athletes, and a subsequent ACL (ipsilateral or contralateral) or other acute knee injury was considered confirmed if diagnosed by physician's examination and confirmatory MRI.

The mechanism of ACL injury (primary and secondary) was categorised based on the athlete's self-report as non-contact, direct contact (to the injured knee) and indirect contact (elsewhere to the body, not the injured knee). Additionally, exacerbation was defined as an ACL reinjury that occurred when the index injury had not yet fully recovered (while the athlete was still undergoing rehabilitation).[21] Other knee injuries included any new acute meniscus, ligament or cartilage injury.

Statistical analysis

Analyses were performed using SPSS software (V.26.0; SPSS) and JMP (V.17.0, SAS Institute). Initially, descriptive statistics were calculated for the demographic and intraoperative data for the cohort. Normality was assessed with the Kolmogorov-Smirnov test and Q-Q plots, and homogeneity of variances was assessed by Levene's test. The descriptive data were presented as mean (SD) or median (IQR) for continuous variables and as frequency (%) for categorical variables. Subsequent exploratory pair-wise analyses were conducted using the Mann-Whitney U test or Pearson χ^2 test to compare athletes who returned to play and those who did not for continuous and categorical variables, respectively. All expected cell counts for the χ^2 test were greater than 5. Where significant results were observed in the Mann-Whitney U test or Pearson χ^2 test, effect sizes and ORs were computed. Effect sizes were calculated using the pooled weighted SD.[22]

To accurately examine the effect of time, it is crucial to control for other key parameters, hence we included only athletes who returned to pivoting sports and completed rehabilitation meeting the discharge criteria. For new knee injuries (ipsilateral or contralateral), direct contact injuries were excluded, as they are likely not preventable by rehabilitation, surgical choices or meeting objective criteria. The Pearson's χ^2 test was used to compare athletes who RTS in less than 9 months and those who RTS later than 9 months after ACLR. Finally, an additional Cox regression model was used to assess the association between knee reinjuries and time to RTS as a continuous variable, considering the new knee injury as the dependent event, the months from RTS to new knee injury as the time event, and all the candidate risk factors as the independent variables. Analyses were separately conducted for new ACL injury and any new knee injury (including ACL and all other described knee injuries). Candidate risk factors were age, activity level, graft type, previous ACLR and time to RTS, but only age and activity level were included in the final model using criteria of $p<0.1$. Athletes who did not experience a new injury within 2 years after surgery were censored. A statistical significance level of $p<0.05$ was adopted.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Equity, diversity and inclusion

No potential participant was excluded based on race/ethnicity/nationality, socioeconomic level or as belonging to marginalised groups. Female athletes were not included as they represented only 2% of the total clinic patients and findings may not be applicable to female athletes. Participation of females in organised sports is still emerging in Qatar, leading to a limited number of female athletes with ACL injuries. Our author team consisted of one female (first author) and three male, junior, mid-career and senior researchers from different disciplines.

RESULTS

Baseline characteristics

The demographic details, preoperative and intraoperative data are reported in table 1. The study included 530 athletes engaged in pivoting sports prior to sustaining ACL injuries, with 220 classified as competitive athletes and 310 as recreational athletes, and results are presented accordingly in online supplemental file section 2. 'Competitive'-level athletes were participating in their sport in organised competition (professional or amateur) while 'recreational' athletes were not.

Two-year follow-up

Return to pivoting sports

72% of athletes returned to pivoting sports (table 2). Those who returned were younger, with lower body mass index (BMI), higher preinjury levels of activity and better adherence during

Table 1 Participant information (n=530)

	Mean±SD	Median	IQR
Age (years)*	26.7±7.7	25.4	21.3–30.8
Height (cm)*	175.5±7.6	175.0	170.0–180.0
Body mass (kg)*	79.6±14.1	79.0	70.0–88.0
Body mass index (kg/m^2)*	25.8±4.1	25.1	23.1–28.1
Tegner score preinjury*	7.8±1.2	7	7–9
Time from injury to ACLR (months)*	6.3±13.8	2.3	1.1–5.7
Rehabilitation duration (months)*	9.5±4.3	9.0	6.6–11.9

	n	%
Continental origin		
Asia	478	90.2
Africa	26	4.9
Europe	14	2.6
America	10	1.9
Oceania	2	0.4
Sport participation		
Football (soccer)	377	71.1
Handball	30	5.7
Volleyball	27	5.1
Basketball	23	4.3
Other	73	13.8
Mechanism of injury		
Non-contact	381	71.9
Contact direct	85	16.0
Contact indirect	64	12.1
Time between injury and ACLR		
<3 months	310	58.5
3–12 months	155	29.2
>12 months	65	12.3
Graft type		
Hamstring	312	58.9
BTB	198	37.3
Other	20	3.8
Lateral augmentation		
No	302	57.0
Lateral tenodesis	181	34.1
Antero-lateral ligament	47	8.9
Meniscus intervention		
No intervention	277	52.3
Repair	144	27.2
Meniscectomy	109	20.5
Cartilage debridement	11	2.0

*Non-normally distributed outcomes (Kolmogorov-Smirnov).
ACLR, anterior cruciate ligament reconstruction; BTB, bone-patellar-tendon-bone.

rehabilitation. Competitive athletes were five times more likely to return to pivoting sports, compared with recreational athletes. Previous ACL injury in either leg, injury mechanism, meniscus surgery and lateral augmentation were not significantly associated with return to pivoting sports.

Athletes with no complications during rehabilitation were 2.5 times more likely to return to pivoting sports (table 2). Those who had better adherence to the rehabilitation protocol were 3.7 times more likely to return to pivoting sports (table 2). Those who met criteria were 5.7 times more likely to return to pivoting sports. Among athletes who stopped early in rehabilitation, only half returned to pivoting sports. Among those who stopped at the advanced phase (after jump training), 70% returned to pivoting sports. Of those who met the criteria, 90% returned to pivoting sports (table 2).

New knee injuries

At 2 years after surgery, 456 athletes reported no new knee injury, 71 reported a new knee injury and 3 were still in rehabilitation. Out of the 71 new knee injuries, 48 were ACL injuries (9.1% of all included athletes), with 30 ipsilateral (5.7% of all included athletes) and 18 contralateral (3.4% of all included athletes). Seven new ACL injuries occurred during rehabilitation, including six exacerbations and one contralateral ACL injury.

Apart from ACL injuries, there were 23 cases (4.3% of all included athletes) with other acute knee injuries. On the ipsilateral knee, we recorded 20 new knee injuries (2 medial collateral ligament, 9 medial meniscus, 4 lateral meniscus, 1 trochlea cartilage, 1 medial cartilage and 1 lateral cartilage) and 3 injuries in the contralateral knee (1 medial meniscus, 1 lateral meniscus and 1 medial cartilage injury).

Among athletes who did not meet the discharge criteria, 208 (61%) returned to pivoting sports and 19 of them at a lower level (competitive to recreational). We recorded 34 new knee injuries, including 14 ipsilateral (2 direct contact) and 7 contralateral (2 direct contact) ACL injuries.

Time to RTS

Among the 190 athletes meeting discharge criteria, 171 (90%) returned to pivoting sports. Three new direct contact ACL injuries (one ipsilateral and two contralateral) were excluded from the analyses. Of the 168 athletes, 71 returned within 9 months postsurgery and 97 returned after this time frame (table 3). Three athletes returned to a lower level (competitive to recreational). Competitive athletes were three times more likely to complete rehabilitation within 9 months. There was no increased risk for new knee or ACL injuries whether athletes returned before or after the 9-month mark.

The average time to RTS was 9.9±3.5 (range: 5.2–23.8, median: 9.0, IQR: 7.5–11.4) and 11.6±3.6 (range: 6.7–19.6, median: 10.9, IQR: 8.8–13.9) months after surgery for the competitive and recreational athletes, respectively. All participants were followed for a minimum of 2 years post-ACLR, with those who did not experience reinjury being censored. The average time from RTS to a new knee injury was 13.3±4.4 (range: 0.6–18.8, median: 14.5, IQR: 11.5–16.3) and 11.3±4.3 (range: 1.2–17.4, median: 12.7, IQR: 7.6–15.0) months after surgery for the competitive and recreational athletes, respectively.

The average age of athletes who sustained a new ACL injury was 21.8±4.7 (range: 14.6–31.8, median: 21.3, IQR: 18.3–23.6) and the age of athletes who did not sustain a new ACL injury was 24.8±6.9 (range: 14.2–56.1, median: 23.9, IQR: 19.7–27.9).

There was no increased risk for new knee injury (HR 0.892, 95% CI 0.39 to 2.07, p=0.79) or new ACL injury (HR 0.718, 95% CI 0.24 to 2.17, p=0.56) whether athletes returned before or after the 9-month mark (figure 2). There was no significant association with new knee or ACL injury when these analyses were performed for: only competitive athletes, only competitive athletes with no previous ACL surgery, when the time to event considered was from surgery to injury (figure 3) (instead of time from RTS to injury) or when time to RTS was analysed as a continuous variable (online supplemental file section 3 tables S2–S10).

Table 2 Factors associated with return to pivoting sports (n=530)

	Yes=379			No=151				
	Mean±SD	Median	IQR	Mean±SD	Median	IQR	P value	Effect size
Age (years)	25.7±7.1	24.7	21.0–29.1	29.0±8.9	27.7	22.8–34.0	**<0.001**	0.45
Height (cm)	175.7±7.7	175.0	170–180	174.8±7.2	175.0	170.0–180.0	0.49	
Body mass (kg)	77.7±13.4	77.0	68.8–85.5	84.3±14.8	83.6	75.0–93.1	**<0.001**	0.50
Body mass index (kg/m^2)	25.1±3.9	24.5	22.6–27.1	27.5±4.2	27.4	25.0–30.4	**<0.001**	0.63
Tegner score preinjury	8.1±1.2	9.0	7–9	7.2±0.9	7.0	7–7	**<0.001**	0.80
Time from injury to ACLR (months)	5.3±9.8	2.0	0.9–5.1	8.8±20.5	3.1	1.7–7.0	**0.044**	0.26
Rehabilitation duration (months)	9.6±3.8	9.1	7.0–11.9	9.2±5.3	8.8	5.0–12.1	0.08	
Rehabilitation sessions/week	2.4±1.2	2.2	1.6–3.2	1.8±0.9	1.7	1.3–2.3	**<0.001**	0.53
	n	%		n	%	P value	χ^2	OR: RTS (95% CI)
Activity level						**<0.001**	48.56	4.77 (3.00 to 7.57)
Competitive	193	87.7		27	12.3			
Recreational	186	60.0		124	40.0			
Previous ipsilateral ACL						0.99		
Yes	45	71.4		18	28.6			
No	334	71.5		133	28.5			
Previous contralateral ACL						0.76		
Yes	44	69.8		19	30.2			
No	335	71.7		132	28.3			
Graft type						**0.001**	13.59	
Hamstring	205	65.7		107	34.3			
BTB	160	80.8		38	19.2			BTB:HS 2.20 (1.44 to 3.36)
Other	14	70.0		6	30.0			Other:HS 1.21 (0.46 to 3.26)
Meniscus intervention						0.62		
No intervention	202	72.9		75	27.1			
Repair	103	71.5		41	28.5			
Meniscectomy	74	67.9		35	32.1			
Lateral augmentation						0.18		
Yes	170	74.6		58	25.4			
No	209	69.2		93	30.8			
Mechanism of injury						0.34		
Non-contact	268	70.3		113	29.7			
Contact	111	74.5		38	25.5			
Sessions/week						**<0.001**	17.69	3.06 (1.78 to 5.25)
≥3	111	86.0		18	14.0			
<3	268	66.8		133	33.2			
Sport-specific sessions						**<0.001**	46.91	4.89 (3.02 to 7.91)
≥10	182	88.3		24	11.7			
<10	197	60.8		127	39.2			
Total sessions						**<0.001**	20.57	2.54 (1.69 to 3.84)
≥50	301	76.8		91	23.2			
<50	78	56.5		60	43.5			
Adherence						**<0.001**	38.31	3.70 (2.41 to 5.68)
Yes	200	85.1		35	14.9			
No	179	60.7		116	39.3			
Stopped rehabilitation						**<0.001**	73.02	
Early phase	60	46.2		70	53.8			
Intermediate phase	148	70.5		62	29.5			Intermediate:early 2.78 (1.77 to 4.39)
Met criteria	171	90.0		19	10.0			Met criteria:early 10.5 (5.84 to 18.87)
Complications during rehabilitation						**<0.001**	19.26	2.49 (1.65 to 3.76)
No	303	76.5		93	23.5			
Yes	76	56.7		58	43.3			
Met discharge criteria						**<0.001**	49.70	5.71 (3.39 to 9.62)
Yes	171	90.0		19	10.0			
No	208	61.2		132	38.8			

Bold indicates statistically significant differences.
ACLR, anterior cruciate ligament reconstruction; BTB, bone-patellar-tendon-bone; RTS, return to sport.

Table 3 Time to return to sport, after meeting criteria (n=168)

	≤9 months n=71		>9 months n=97				
	n	%	n	%	P value	χ^2	OR ≤9 months (95%CI)
Activity level					**0.004**	8.25	2.73 (1.36 to 5.49)
Competitive	56	50.0	56	50.0			
Recreational	15	26.8	41	73.2			
New knee injuries					0.95		
No	61	42.4	83	57.6			
Yes	10	41.7	14	58.3			
New ACL injuries					0.46		
No	66	43.1	87	57.6			
Yes	5	33.3	10	66.7			

Bold indicates statistically significant differences.
ACL, anterior cruciate ligament.

DISCUSSION

Adherence to the rehabilitation protocol had a significant impact on RTS rates, showing a dose–response relationship: the further athletes progress in their rehabilitation after ACLR, the greater their chances of returning to pivoting sports. At 2 years post-surgery, 72% of the athletes participating in pivoting sports had returned to pivoting sports. Nearly 90% of those who met the criteria returned to pivoting sports and were almost six times more likely to do so compared with those who stopped rehabilitation early. Among those who stopped at the advanced phase, 70% returned to pivoting sports, while only 50% of those who stopped early did so. The time to RTS might not impact the risk of a new knee or ACL injury.

Rehabilitation, adherence, objective criteria

The success or failure of rehabilitation post-ACLR depends on both the content of the prescribed programme and the athlete's adherence to it.[20 23 24] The results presented here reinforce these findings, revealing significant differences in RTS rates associated with adherence levels; only 50% returned to pivoting sports among those who chose to stop rehabilitation early, whereas 70% returned after exposure to advanced phases, including explosive and reactive strength training, and 90% returned to previous pivoting sports after completing the rehabilitation and meeting discharge criteria.

We suggest that objective testing throughout rehabilitation and at the time of RTS is vital for achieving successful outcomes. Four systematic reviews examined the impact of discharge criteria on secondary injury rates with inconclusive findings.[25–28] Meeting discharge criteria, although important, does not guarantee that an athlete will avoid future injury. To date, there is no screening test available to predict sports injuries with adequate test properties.[29] Still, the effect of meeting discharge criteria on performance is still unclear—specifically, whether athletes

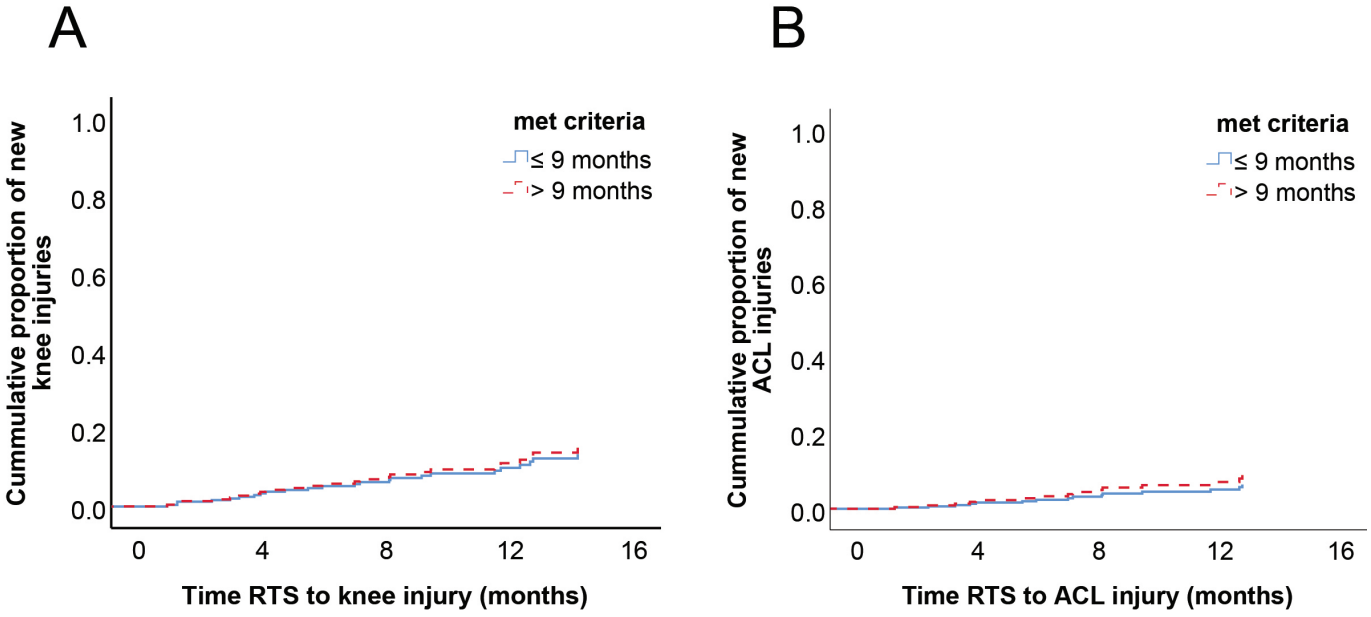

Figure 2 Cox regression model of the cumulative prevalence of new knee injuries (A) and new ACL injuries (B) in those who met criteria for RTS in ≤9 (blue, continuous line) and >9 months (red, dashed line). Time 0 was defined as the time to RTS, to account for more exposure in athletes who returned earlier. Age was included as a factor for knee injuries, and age and activity level were included as factors in the model for ACL injuries. No significant difference was seen for either new ACL or any knee injury for those who returned in ≤9 or >9 months. ACL, anterior cruciate ligament; RTS, return to sport.

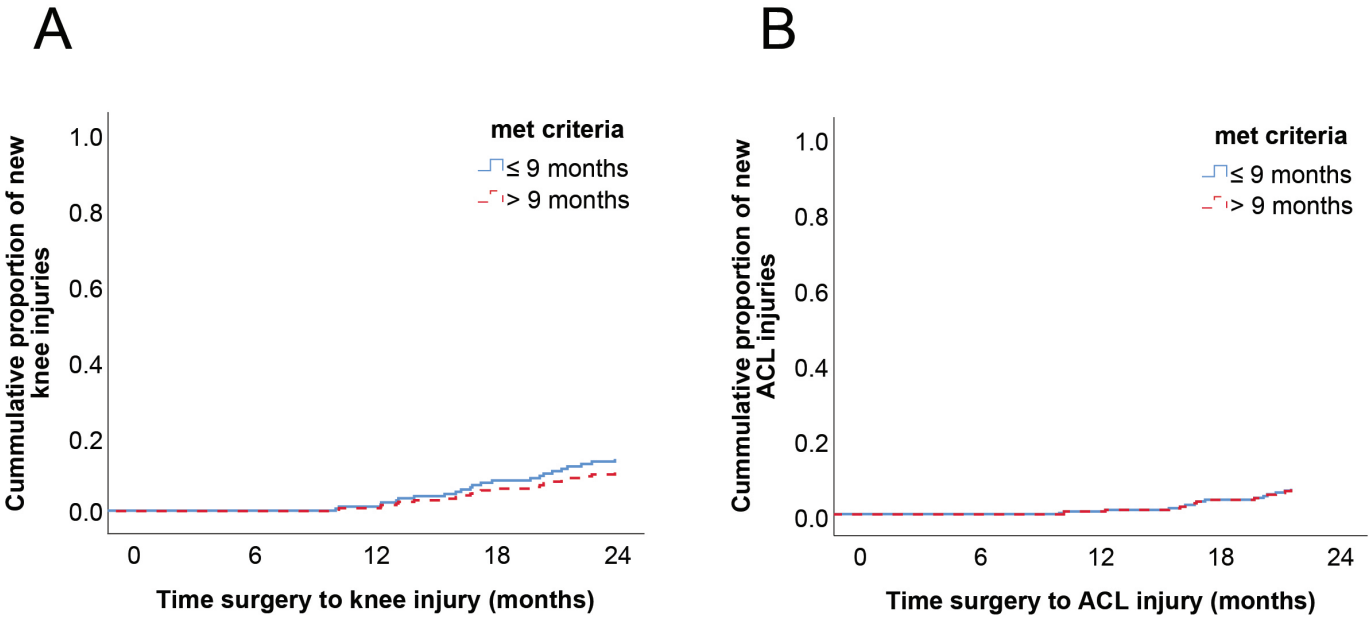

Figure 3 Cox regression model of the cumulative prevalence of new knee injuries (A) and new ACL injuries (B) in those who met criteria for return to sport in ≤9 (blue, continuous line) and >9 months (red, dashed line). Time 0 was defined as the time of the ACLR. Age and activity level were included as factors in the model. No significant difference was seen for either new ACL or any knee injury for those who returned in ≤9 or >9 months. ACLR, anterior cruciate ligament reconstruction.

return to their sport sooner or at a level closer to their preinjury performance. We suggest that the objective of the testing process is to inform the entire rehabilitation process by documenting the patient's status at all stages, thereby informing rehabilitation.[7] When comparing the current results to the ACL reinjury rates from the same institution during the period 2008–2015,[30] using identical methods and inclusion criteria, we observed a significant reduction in reinjury rates—by half. The primary difference between these two periods is the implementation of mandatory regular testing and progress monitoring during rehabilitation.

It should be noted, however, that these criteria and the methods of measurement have evolved and likely will continue to do so. Ongoing research aims to understand the relative contributions of the different domains and parameters to outcome goals (eg, performance, reinjury) and further refine the process.

Younger age, lower BMI and higher preinjury Tegner score are factors often cited as contributing to early return to play and meeting criteria.[31–33] In the current study, these same factors were favourably associated with return rates to pivoting sports. Intraoperative decisions appeared less strongly associated with RTS. We noticed higher RTS rates for those with a bone-patellar-tendon-bone graft compared with those with hamstring graft; however, a greater percentage of competitive athletes received this graft type (online supplemental file section 4).

Time

The results of the current study suggest that there might not be a difference between the risk of new knee injuries among athletes by returning to pivoting sports before 9 months compared with after 9 months, provided they met discharge criteria. In our research, competitive athletes returned to their sport at approximately 10 months postsurgery, while recreational athletes returned about 2 months later, although the range was considerable, spanning 5.2–24 months. Each athlete's journey is unique, influenced by factors including age, motivation, surgical and rehabilitation complications, and individual adherence.

The literature presents conflicting findings regarding the relationship between the time taken to RTS and the risk of new ACL injury. Importantly, many studies have overlooked the athlete's status at the time of RTS, complicating the interpretation of results and hindering definitive conclusions. Grindem *et al*[2] demonstrated a 50% reduction in knee reinjury risk for each month that return was delayed, until 9 months after ACLR. However, multiple injuries occurred in athletes who RTS as early as 3–4 months after surgery, and only a quarter of the athletes in that cohort met functional RTS criteria before resuming activities. Kyritsis *et al*[30] found that professional football players failing to meet criteria were four times more likely to experience ACL graft rupture, indicating the importance of assessing knee function alongside time since operation. King *et al*[34] reported no survival distribution differences among athletes returning to sports at varying intervals post-surgery, suggesting that strict timeline-based restrictions on RTS beyond 6 months may not be warranted. Della Villa *et al*[35] reported that professional elite male football players have a high rate of second ACL injury; however, the time to return to training was not associated with these injuries. Recent systematic reviews and studies shed further light on this topic. Piussi *et al*[18] found that patients who suffered a second ACL injury had returned to sport 25 days earlier than patients who did not. However, the evidence supporting this finding was of very low certainty and did not apply to professional athletes. For professional athletes, there was no difference in time to RTS between those who suffered a second ACL injury and those who did not. Cronström *et al*[36 37] reported no elevated odds of sustaining an ipsilateral or contralateral ACL injury with an RTS ≤6 months post-primary ACLR compared with >6 months.

Younger age is a reported factor in the literature for increased risk of new ACL injury.[38–40] A study[41] examined the rates of subsequent ACL injuries in younger patients who were advised to delay returning to competitive sports until 12 months after surgery, compared with those who did not delay. The findings

showed no significantly different results between the two groups with high rates of ACL injuries, even for patients who delayed their return until 12 months after surgery.[41]

We suggest that the current study's findings are in accordance with previous research cited here when viewed through the prism of 'when' the athlete returns being less important than 'how' the athlete returns. Sufficient time is necessary, but apparently not adequate to ensure success alone. We argue for a shift towards greater focus on individual patient needs and assessment of associated competencies through repeated evaluation during rehabilitation, with less attention to time.

RTS is a continuum, not simply a decision taken in isolation at the end of the recovery and rehabilitation process.[6] Accordingly, each step on this continuum should have objective criteria to inform progress.[17]

Methodological considerations

This study has key strengths, including a standardised, single-institution rehabilitation protocol, thorough monitoring of athletes' progression and comprehensive documentation of RTS status. Standardised discharge criteria further reduce outcome variability, while the study setting enhances accuracy by registering all ACL graft ruptures.

Several methodological aspects should be kept in mind when interpreting the results. First, we included athletes with previous ACLR for two main reasons: to address our research question comprehensively and to include the effect of previous surgery on outcomes. Our findings suggest that prior ACLR does not affect an athlete's likelihood of returning to pivoting sports.[42–44] Second, the definition of reinjury lacks consistency, especially concerning contact versus non-contact incidents. We argue that analysing direct (knee) contact injuries separately is essential, as they are likely not preventable by rehabilitation, surgical choices or meeting objective criteria. Third, the rehabilitation protocol, progression and discharge criteria were not constant over the 7 years of the study's duration. Instead, they evolved and were adjusted based on research updates; however, the core philosophy remained the same: standardised rehabilitation, regular mandatory testing and objective criteria for progression and discharge. Although the specific tests and metrics for discharge criteria changed over time, they consistently focused on the same fundamental aspects: restoration of clinical, motor control and strength as well as functional testing, evaluation of psychological readiness and comprehensive sport-specific training. This evolution has led to our current rehabilitation and testing protocol (version 2023, which can be downloaded from the following link https://aspetar.com/en/professionals/aspetar-clinical-guidelines). We expect this process to evolve further as new evidence is presented.

Several limitations should be acknowledged. Surgery type and rehabilitation duration were not randomised; rather, they were at the discretion of the medical team and the participants. Regarding the association between time to RTS and subsequent injury risk, we did not include data on athlete exposure after RTS, focusing only on whether athletes returned to a competitive or recreational level. Future research should prospectively record the number of hours athletes spend in their sport to more accurately assess and account for risk exposure. Although there was considerable variability in the time between injury and surgery, this factor was not significantly associated with the return to pivoting sports in our study. The mechanism of ACL injury (primary and secondary) was categorised based on the athlete's self-report. Female athletes were excluded from the current study, due to their very low representation (2% of the sample) compared with males. The recruitment of only males from a single site suggests caution should be applied before extrapolating these results to females and other populations. We recommend that future studies include female athletes to determine if the findings of the current study are applicable to females. None of our participants met the discharge criteria earlier than 5.2 months after surgery; hence, we were unable to include injuries as early as 3–4 months after surgery. However, we suggest that it is unlikely many athletes can meet strict discharge criteria this early after surgery. Additionally, the rehabilitation was exclusively conducted in-person and this regimen may not be easily applicable worldwide, especially in countries where physiotherapy visits covered by insurance are limited. Finally, the small number of ACL-reinjured athletes highlights the need for further research with larger cohorts to draw more robust conclusions. We acknowledge that the study was not powered to detect small differences in reinjury risk between RTS before versus after 9 months, and this limitation should be considered when interpreting the findings.

CONCLUSIONS

Adherence to a structured rehabilitation protocol, progression based on objective criteria and meeting discharge criteria were associated with low reinjury rates and high likelihood of returning to pivoting sports irrespective of surgery type or comorbidities. Time to RTS might not impact the occurrence of new knee injuries provided athletes met RTS criteria. These findings underscore the importance of personalised rehabilitation programmes in optimising outcomes for athletes after ACLR.

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REFERENCES

1 Campbell JD. The evolution and current treatment trends with anterior cruciate, posterior cruciate, and medial collateral ligament injuries. *Am J Knee Surg* 1998;11:128–35.
2 Grindem H, Snyder-Mackler L, Moksnes H, *et al*. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *Br J Sports Med* 2016;50:804–8.
3 Beischer S, Gustavsson L, Senorski EH, *et al*. Young Athletes Who Return to Sport Before 9 Months After Anterior Cruciate Ligament Reconstruction Have a Rate of New Injury 7 Times That of Those Who Delay Return. *J Orthop Sports Phys Ther* 2020;50:83–90.
4 Capin JJ, Khandha A, Zarzycki R, *et al*. Gait mechanics and second ACL rupture: Implications for delaying return-to-sport. *J Orthop Res* 2017;35:1894–901.
5 Nagelli CV, Hewett TE. Should Return to Sport be Delayed Until 2 Years After Anterior Cruciate Ligament Reconstruction? Biological and Functional Considerations. *Sports Med* 2017;47:221–32.
6 Ardern CL, Glasgow P, Schneiders A, *et al*. 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern. *Br J Sports Med* 2016;50:853–64.
7 Burgi CR, Peters S, Ardern CL, *et al*. Which criteria are used to clear patients to return to sport after primary ACL reconstruction? A scoping review. *Br J Sports Med* 2019;53:1154–61.
8 Aquino CF, Ocarino JM, Cardoso VA, *et al*. Current clinical practice and return-to-sport criteria after anterior cruciate ligament reconstruction: a survey of Brazilian physical therapists. *Braz J Phys Ther* 2021;25:242–50.
9 Dingenen B, Billiet B, De Baets L, *et al*. Rehabilitation strategies of Flemish physical therapists before and after anterior cruciate ligament reconstruction: An online survey. *Phys Ther Sport* 2021;49:68–76.
10 Ebert JR, Webster KE, Edwards PK, *et al*. Current perspectives of Australian therapists on rehabilitation and return to sport after anterior cruciate ligament reconstruction: A survey. *Phys Ther Sport* 2019;35:139–45.
11 Greenberg EM, Greenberg ET, Albaugh J, *et al*. Rehabilitation Practice Patterns Following Anterior Cruciate Ligament Reconstruction: A Survey of Physical Therapists. *J Orthop Sports Phys Ther* 2018;48:801–11.
12 Korakakis V, Kotsifaki A, Korakaki A, *et al*. Current perspectives and clinical practice of physiotherapists on assessment, rehabilitation, and return to sport criteria after anterior cruciate ligament injury and reconstruction. An online survey of 538 physiotherapists. *Phys Ther Sport* 2021;52:103–14.
13 Glattke KE, Tummala SV, Goldberg B, *et al*. There Is Substantial Variation in Rehabilitation Protocols Following Anterior Cruciate Ligament Reconstruction: A Survey of 46 American Orthopaedic Surgeons. *Arthroscopy* 2023;39:578–89.
14 Koc BB, Schotanus MGM, Jansen EJP. Preferences in anterior cruciate ligament reconstruction and return to sport: A survey among surgeons in the Netherlands. *J Clin Orthop Trauma* 2021;12:183–6.
15 Marshall NE, Keller RA, Dines J, *et al*. Current practice: postoperative and return to play trends after ACL reconstruction by fellowship-trained sports surgeons. *Musculoskelet Surg* 2019;103:55–61.
16 Andrade R, Pereira R, van Cingel R, *et al*. How should clinicians rehabilitate patients after ACL reconstruction? A systematic review of clinical practice guidelines (CPGs) with a focus on quality appraisal (AGREE II). *Br J Sports Med* 2020;54:512–9.
17 Kotsifaki R, Korakakis V, King E, *et al*. Aspetar clinical practice guideline on rehabilitation after anterior cruciate ligament reconstruction. *Br J Sports Med* 2023;57:500–14.
18 Piussi R, Simonson R, Zsidai B, *et al*. Better Safe Than Sorry? A Systematic Review with Meta-analysis on Time to Return to Sport After ACL Reconstruction as a Risk Factor for Second ACL Injury. *J Orthop Sports Phys Ther* 2024;54:161–75.
19 Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res* 1985;1985:43–9.
20 Della Villa F, Andriolo L, Ricci M, *et al*. Compliance in post-operative rehabilitation is a key factor for return to sport after revision anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2020;28:463–9.
21 Bahr R, Clarsen B, Derman W, *et al*. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). *Br J Sports Med* 2020;54:372–89.
22 Hedges L, Olkin I. *Statistical Methods for Meta-Analysis*. Academic press, 2014.
23 Grindem H, Granan LP, Risberg MA, *et al*. How does a combined preoperative and postoperative rehabilitation programme influence the outcome of ACL reconstruction 2 years after surgery? A comparison between patients in the Delaware-Oslo ACL Cohort and the Norwegian National Knee Ligament Registry. *Br J Sports Med* 2015;49:385–9.
24 Han F, Banerjee A, Shen L, *et al*. Increased Compliance With Supervised Rehabilitation Improves Functional Outcome and Return to Sport After Anterior Cruciate Ligament Reconstruction in Recreational Athletes. *Orthop J Sports Med* 2015;3:2325967115620770.
25 Ashigbi EYK, Banzer W, Niederer D. Return to Sport Tests' Prognostic Value for Reinjury Risk after Anterior Cruciate Ligament Reconstruction: A Systematic Review. *Med Sci Sports Exerc* 2020;52:1263–71.
26 Hurley ET, Mojica ES, Haskel JD, *et al*. Return to play testing following anterior cruciate reconstruction - A systematic review & meta-analysis. *Knee* 2022;34:134–40.
27 Losciale JM, Zdeb RM, Ledbetter L, *et al*. The Association Between Passing Return-to-Sport Criteria and Second Anterior Cruciate Ligament Injury Risk: A Systematic Review With Meta-analysis. *J Orthop Sports Phys Ther* 2019;49:43–54.
28 Webster KE, Hewett TE. What is the Evidence for and Validity of Return-to-Sport Testing after Anterior Cruciate Ligament Reconstruction Surgery? A Systematic Review and Meta-Analysis. *Sports Med* 2019;49:917–29.
29 Bahr R. Why screening tests to predict injury do not work-and probably never will…: a critical review. *Br J Sports Med* 2016;50:776–80.
30 Kyritsis P, Bahr R, Landreau P, *et al*. Likelihood of ACL graft rupture: not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture. *Br J Sports Med* 2016;50:946–51.
31 Paterno MV, Rauh MJ, Schmitt LC, *et al*. Incidence of Second ACL Injuries 2 Years After Primary ACL Reconstruction and Return to Sport. *Am J Sports Med* 2014;42:1567–73.
32 Shelbourne KD, Gray T, Haro M. Incidence of subsequent injury to either knee within 5 years after anterior cruciate ligament reconstruction with patellar tendon autograft. *Am J Sports Med* 2009;37:246–51.
33 Sousa PL, Krych AJ, Cates RA, *et al*. Return to sport: Does excellent 6-month strength and function following ACL reconstruction predict midterm outcomes? *Knee Surg Sports Traumatol Arthrosc* 2017;25:1356–63.
34 King E, Richter C, Jackson M, *et al*. Factors Influencing Return to Play and Second Anterior Cruciate Ligament Injury Rates in Level 1 Athletes After Primary Anterior Cruciate Ligament Reconstruction: 2-Year Follow-up on 1432 Reconstructions at a Single Center. *Am J Sports Med* 2020;48:812–24.
35 Della Villa F, Hägglund M, Della Villa S, *et al*. High rate of second ACL injury following ACL reconstruction in male professional footballers: an updated longitudinal analysis from 118 players in the UEFA Elite Club Injury Study. *Br J Sports Med* 2021;55:1350–6.
36 Cronström A, Tengman E, Häger CK. Risk Factors for Contra-Lateral Secondary Anterior Cruciate Ligament Injury: A Systematic Review with Meta-Analysis. *Sports Med* 2021;51:1419–38.
37 Cronström A, Tengman E, Häger CK. Return to Sports: A Risky Business? A Systematic Review with Meta-Analysis of Risk Factors for Graft Rupture Following ACL Reconstruction. *Sports Med* 2023;53:91–110.
38 Magnussen RA, Lawrence JTR, West RL, *et al*. Graft size and patient age are predictors of early revision after anterior cruciate ligament reconstruction with hamstring autograft. *Arthroscopy* 2012;28:526–31.
39 Maletis GB, Inacio MCS, Funahashi TT. Risk factors associated with revision and contralateral anterior cruciate ligament reconstructions in the Kaiser Permanente ACLR registry. *Am J Sports Med* 2015;43:641–7.
40 Webster KE, Feller JA, Leigh WB, *et al*. Younger patients are at increased risk for graft rupture and contralateral injury after anterior cruciate ligament reconstruction. *Am J Sports Med* 2014;42:641–7.
41 Webster KE, Feller JA, Klemm HJ. Second ACL Injury Rates in Younger Athletes Who Were Advised to Delay Return to Sport Until 12 Months After ACL Reconstruction. *Orthop J Sports Med* 2021;9:2325967120985636.
42 Andriolo L, Filardo G, Kon E, *et al*. Revision anterior cruciate ligament reconstruction: clinical outcome and evidence for return to sport. *Knee Surg Sports Traumatol Arthrosc* 2015;23:2825–45.
43 Glogovac G, Schumaier AP, Grawe BM. Return to Sport Following Revision Anterior Cruciate Ligament Reconstruction in Athletes: A Systematic Review. *Arthroscopy* 2019;35:2222–30.
44 Grassi A, Zaffagnini S, Marcheggiani Muccioli GM, *et al*. After revision anterior cruciate ligament reconstruction, who returns to sport? A systematic review and meta-analysis. *Br J Sports Med* 2015;49:1295–304.