CURRENT CONCEPTS REVIEW

Return to Sport Activities and Risk of Reinjury Following Primary Anterior Cruciate Ligament Reconstruction

E. Carlos Rodriguez-Merchan, MD, PhD[1]; Leonard A. Valentino, MD[2]

Research performed at the Department of Orthopedic Surgery, La Paz University Hospital-IdiPaz, Madrid, Spain

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Abstract

This article examines the elements that affect the return to sport (RTS) and the risk and percentages of reinjury following a prior primary anterior cruciate ligament reconstruction (ACLR). The prevalence of RTS following ACLR ranges from 71% to 83%. Concerning elements affecting RTS, a limb symmetry index score of 90 or more duplicates the likelihood of RTS and triplicates it when the International Knee Documentation Committee (IKDC) score is 95 or more, irrespective of age. Other elements recognized to be preindicative of RTS at 1 year include complete rehabilitation, age ≤25, and higher IKDC scores. The prevalence of reinjury following ACLR ranges from 1.5% to 37.5% (between 9% and 29% in the majority of reports). It has been published that 1 in 5 individuals suffers reinjury to either knee, and that male individuals are more prone to reinjure following ACLR. The highest percentage of ACLR reinjury happens in younger male (<18 years), being substantially higher than in female of the same age. Passing a combination of functional tests with predetermined cut-off points utilized as RTS criteria are related diminished ACLR reinjury percentages.

Level of evidence: III

Keywords: Anterior cruciate ligament reconstruction, Primary, Return to sport

Introduction

Anterior cruciate ligament reconstruction (ACLR) is currently the gold standard of treatment for ruptures of the anterior cruciate ligament (ACL), with very good results in most individuals (1-9). On the other hand, many ACLR patients, especially younger patients, want to return to sport (RTS) as soon as possible and in the best possible condition after surgery. However, some ACLR patients experience reinjuries (1-9). It is therefore essential to understand the factors influencing RTS and reinjury after ACLR, and their presentation rates.

The aim of this paper is to review the most recent literature to try to find answers to the following questions: 1) What factors influence RTS after ACLR and what is the frequency of RTS? 2) What factors influence reinjury after ACLR and what is the incidence of reinjury following ACLR?

RETURN TO SPORT (RTS)

ACL return to sport (RTS) principles and criteria

In 2017 Davies et al described a functional testing algorithm (FTA) in the belief that it could help make decisions based on quantitative and qualitative testing and assessment; the goal of the FTA was to achieve RTS safely and without compromising patient performance (10). This algorithm includes numerous biopsychosocial assessments, impairment tests, strength and power tests, functional tests and patient-reported outcomes (PROs). Although the algorithm described by Davies et al did not have predictive validity, it provides practical guidelines to facilitate decision-making to achieve RTS and in choosing the most appropriate time for an athlete to return to competition which can have important safety and performance implications. The use of multifactorial FTA described by Davies et al could help us make the best

Corresponding Author: E. Carlos Rodriguez-Merchan, Department of Orthopedic Surgery, La Paz University Hospital, Madrid, Spain
Email: ecrmerchan@hotmail.com

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decision for the patient to achieve RTS (10).

Verification of a combined test for evaluation of readiness for return to sport (RTS) following ACLR

As stated by Blakeney et al in 2018, there was little information on the timing of RTS following an ACLR (11). Therefore, they developed a combined test to evaluate the patient's capacity to RTS following ACLR: the Knee Santy Athletic Return To Sport (K-STARTS) and tested this tool in a prospective comparative investigation enrolling 371 individuals who had experienced ACLR they compared the K-STARTS score to those from a control group of 39 healthy individuals. The K-STARTS score was determined by summing the scores of 7 tests (8 components), whose maximum value was 21 points. Construction validity, internal consistency, discriminant validity and sensitivity to change were utilized to validate this new assessment. The K-STARTS evaluation revealed an elevated completion percentage (100%), elevated reproducibility (intraclass correlation coefficient, 0.87; coefficient of variation, 7.8%), and elevated sensitivity to variation. There was a moderate correlation with the ACL Return to Sports after Injury (ACL-RSI) scale and hop evaluations. There were no ceiling or floor effects. There was a substantial difference in the K-STARTS scores of the participants who underwent ACLR at 6 months and 8 months after surgery (11.2 vs 17.1). The K-STARTS score in the control group was substantially greater than in the ACLR group (17.3 and 13.7, respectively). Therefore, it seems that K-STARTS is an objective test to assess functional amelioration following ACLR. Besides, in order to reduce the elevated peril of reinjury following ACLR, it is essential to determine the optimal timing of RTS (11).

Return to level 1 sports after ACLR: Assessment of age, sex, and readiness to return criteria

In 1989 Noyes et al reported four elements in the evaluation of knee function and sports activity that are paramount for correct analysis: a sports activity rating scale; return to or change in sports activities following injury/surgery**;** evaluation of specific knee functions (i. e. twisting, turning); and evaluation of the capacity to take part in specific types of sports (12).

In 2018, Webster and Feller determined the percentage of patients who returned to level 1 sport (jumping, hard pivoting, and cutting) less than 12 months following ACLR, as well as the RTS rates by age and sex (13). They also analyzed whether RTS was related to some usual result evaluation criteria. They assessed 1440 athletes (992 men, 448 women) who met the study inclusion criteria (primary ACLR, normal contralateral knee, no further surgery within the first 12 months following ACLR, and weekly participation in level 1 sports prior to injury). The following parameters were investigated: the proportion of patients who had restarted level 1 sport at 1 year following surgery, measurements of knee function (single-legged hop symmetry), anterior knee laxity (KT-1000 arthrometer), and the International Knee Documentation Committee [IKDC] subjective score. The following parameters were contemplated signs of successful recuperation from surgical operation: limb symmetry index scores of 90 or higher, difference from the contralateral knee in anterior laxity of 2 mm or less, and IKDC scores of 95 or higher. Level 1 RTS rates were substantially greater in patients aged 25 years or younger (48% return percentage) than in older patients (26-35 years, 32% return percentage [$p < 0.0001$]; ≥36 years, 19% RTS percentage [$p < 0.001$]). Men in the age cohorts of ≤25 and 26-35 years had substantially greater RTS rates than women (52% vs 39% and 37% vs 18%, respectively); however, no gender differences in RTS were observed after age 36. A substantially greater number of younger patients met the previously mentioned signs of satisfactory recuperation. Irrespective of age, patients were two times as likely to RTS when the limb symmetry index score was 90 or greater and three times as likely to RTS when the IKDC score was 95 or greater. Overall, nearly 50% of the younger patients (age ≤25) were able to RTS level 1 within the first 12 months of the ACLR (13).

Predictors of return to sport (RTS) at 1 year following ACLR

Edwards et al reported that the preclusion and mitigation of the peril of reinjury after ACLR depends on age, surgical reestablishment of knee stability, appropriate physical function, and complete and comprehensive postoperative rehabilitation; however, the extent to which these elements impact RTS was not clear at the time (14). Therefore, they investigated the factors that predict RTS at 12 months after ACLR by conducting a case-control study (level of evidence, 3) of 113 individuals analyzed about 1 year following ACLR to assess the value of a rehabilitation rating tool, the IKDC subjective form, and an RTS set that included a maximum isokinetic quadriceps and hamstring power, and 4 functional jumping tests. In individuals who had returned to sports, the relationship between age or rehabilitation level and the passage of the RTS battery was also studied. Complete rehabilitation, age ≤25 years, and greater IKDC scores were foretelling of RTS at 1 year. In individuals who had returned to sport, 21% passed the RTS set, compared to only 5% who did not. Of those who had returned to sport, 37% who experienced complete rehabilitation passed the RTS set, compared with 5% of those who experience incomplete rehabilitation. Among the individuals of ≤25, solely 48% experienced complete rehabilitation, in spite of having returned to sports. Furthermore, in this cohort of individuals, 40% experienced complete rehabilitation and passed the physical performance set, compared to solely 4% in the group that did not experience complete rehabilitation. The conclusion was that younger individuals and greater subjective IKDC scores were foretelling of RTS. Individuals who completed 6 months of rehabilitation integrating jumping and agility activities had a greater percentage of RTS. This suggested that postoperative rehabilitation is paramount in foretelling RTS. Complete postoperative rehabilitation and appropriate neuromuscular power and function are important for individuals to RTS (14).

Return to sport (RTS) and subsequent ACL injury

In order to establish the rate of return to play and the rate of secondary ACLR injuries among Australian Football League (AFL) players from 1999 to 2013, Lai et al conducted a case series study (level of evidence, 4) on a total of 158 AFL players who experienced an ACLR (15). The percentage of return to play following the initial ACL tear was 77% (121 of 158 players). Superior preinjury playing knowledge and earlier choice in the AFL draft were related to greater percentages of return to play. The percentage of secondary ACL injuries to either knee was 30% (48 of 158 players), with the rate being mainly elevated amid players under 21 years of age (23 of 46 players, 50%). Following secondary ACL injury, 34 of 48 players (71%) returned to play. In primary ACLR, the utilization of Ligament Augmentation and Reconstruction System (LARS) grafts resulted led to a quicker RTS but also a greater peril of secondary revision reconstruction. A family history of ACL injury was related to an augmented risk of secondary lesion to the contralateral ACL. The final opinion was that the majority of AFL players who experienced ACLR returned to play at least 1 AFL game (15).

Small percentages of return to sport (RTS) following bilateral ACLR

As published in 2019 by Webster et al, individuals with bilateral ACL ruptures tend to have poorer outcomes in terms of knee function and quality of life than those with a unilateral rupture (16). Considering that there was little information on RTS in this group, Webster et al. analyzed the RTS rates of patients operated on for bilateral ACLR and compared the results according to age and gender. They performed a case series study (level of evidence, 4) of 107 individuals (62 males, 45 females) operated for primary ACLR in both knees with a mean follow-up of 5 years (range, 2.5-10 years). They also assessed the IKDC subjective form, Marx Activity Scale, and Knee injury and Osteoarthritis Outcome Score-Quality of Life subscale. Rates of return to preinjury sport levels were estimated for the entire series; in addition, the series was divided by age (<25 vs. ≥25 years), gender, and period between reconstruction procedures (<3 vs. ≥3 years). The percentage of RTS after bilateral ACLR was 40%, compared with a RTS of 83% following the first reconstruction surgical technique. Even though not statistically significant, RTS percentages were greater in males than females (47% versus 31%) and in older versus younger individuals (45% versus 31%). Of those who returned to their pre-lesion sports levels following the second reconstruction, 72% considered they could carry out as well as prior to their ACL injury. However, solely 20% considered they could carry out as well if they returned to a lower level. Anxiety of reinjury was the main cause for not returning to sports following the second reconstruction. PROs were greater for those who returned to their preinjury sports levels, although they did not vary by gender and age. The final opinion was that RTS percentages decrease notably following a second reconstruction (that of the contralateral ACL); in fact, less than 50% of the series investigated returned to the preinjury sports level. In patients who undergo ACLR in both knees, RTS results were not ideal (16).

Length of time between ACLR and return to sport (RTS) does not foretell necessity for revision surgery

In 2019, Okoroha et al. attempted to find out whether the time between the primary ACLR and the RTS foretold the necessity to revise the ACLR in National Football League (NFL) athletes (17). They conducted a case-control study (level of evidence, 3) in which they identified all NFL players operated on for ACLR from 2009 to 2015. The day of the ACLR and the day of return to regular NFL season play following surgery were registered. In addition, the time between ACLR and RTS was compared for players who needed revision ACLR rand for patients who did not. They also assessed the relationship between early RTS and recurrent ACL injury. The records of 130 NFL players (mean age, 25.3 years) who had undergone ACLR surgery and returned to sport were analyzed . The mean time to RTS following ACLR was 49.7 weeks. Of the total number of players, 23 (18%) needed revision ACLR. There was no significant dissimilarity in the time between ACLR and RTS between players who did not require ACLR revision (50.2 weeks) and those who did (48.3 weeks). In patients who required revision ACLR, time to RTS did not correlate with time to reinjury. Fifty-six percent of the athletes suffered a reinjury within the first 10 weeks of returning to the NFL game. This investigation encountered that the time to RTS following ACLR was neither a substantial peril element for revision surgery nor did it correlate with time to reinjury in NFL athletes (17).

Return to sport (RTS) and long-run involvement in pivoting sports following ACLR

Lindanger et al. studied the percentage and level of return to pivoting sports following ACLR, the time span of sports involvement, and the long-run repercussions of returning to pivoting sports (18). They analyzed all primary ACLR performed with autograft bone-patellar tendon-bone between 1987 and 1994 in 234 athletes participating in handball, basketball, or soccer teams (level of evidence study, 2). A long-run assessment (mean, 25 years) was carried out utilizing a set of questions concentrated on return to pivoting sports, time span of sports activity following surgery, subsequent contralateral ACL ruptures, revision surgery, and total knee arthroplasty (TKA). Individuals were divided into 2 groups according to the time elapsed between lesion and surgical procedure (early, <24 months; late, ≥24 months). A total of 93% of individuals (n = 217) responded to the set of questions. Even though 83% of individuals returned to pivoting sports following prompt (<24 months) ACLR, solely 53% returned to the pre-injury level. Comparable percentages of RTS were seen in men and women, although men had longer sports careers (mean, 10 years) than women (mean, 4 years). The prevalence of contralateral ACL injury after early ACLR was 28% among athletes who returned to sports, compared to 4% among athletes who did not return. The rate of re-injury after returning to the preinjury sport level was 41% (30%, contralateral lesions; 11%, revision

surgery). The prevalence of contralateral ACL injury was 32% in women versus 23% in men. The prevalence of revision surgery after returning to sport was 12% in women versus 7% in men. A late (≥24 months) ACLR was related to a greater peril of TKA (9% vs. 3%) than a prompt ACLR. The final opinion was that ACLR does not inevitably allow a return to pre-injury sports involvement. In addition, when returning to rotational or pivoting sports following an ACLR, athletes are at elevated peril of injury to the contralateral ACL (18).

ACLR utilizing autologous hamstrings augmented with the ligament augmentation and reconstruction system (LARS) gives good clinical scores, high levels of satisfaction and return to sport (RTS), and a low reinjury percentage at 2 years

The effectiveness of ACLR utilizing autologous hamstrings augmented with the LARS was analyzed by Ebert. They analyzed a case series (level of evidence, 4) of 65 individuals operated on arthroscopically assisted single-bundle ACLR utilizing hamstrings augmented with the LARS (19). Of these, 50 were attainable for evaluation at one and two years. PROs, the KT-1000 arthrometer test, knee range of motion (ROM), maximum isokinetic knee force test, and a 4-hop test battery were used. The Limb Symmetry Indices (LSIs) were also determined. Data were collected on return to preinjury sport level, reinjuries and re-operations. High PRO scores were found at one and two years. Prior to injury, 47 individuals (94%) were taking part in level 1 or 2 sports; at one and two years, respectively, 38 (76%) and 43 (86%) patients had returned to sports. Normal (<3 mm; 90%) or near-normal (3-5 mm; 10%) differences were observed in the KT-1000 arthrometer from side to side at 2 years. Aside from knee flexion, extension, and 6 m timed jump, there were no differences between the limbs at 12 months, and no dissimilarities in any objective measures at 24 months. The average LSIs in all measures was ≥90%. At 24 months, 84% to 90% of individuals had ≥90% in the hop tests, and 72% to 76% of individuals had ≥90% in extension and flexion force. Two reoperations were performed for meniscus tears (7 and 8.5 months), 1 individual (2%) had a reinjury at 7 months, and 2 individuals (3%) had a contralateral reinjury (at 8 and 12 months). The augmented ACLR method described gave good clinical results, an elevated percentage of RTS, and small percentages of secondary lesions and contralateral ACL ruptures at 24 months. Prudence should be exercised in explaining these outcomes, as 15 of the 65 individuals (23%) were not taken into account in the 24-month follow-up (19).

Current criteria for return to sport (RTS) following ACLR

In 2019, Flagg et al. reviewed rehabilitation protocols, tests and measurements, and criteria for RTS following ACLR, particularly in bone-tendon-bone (BTB) surgical techniques (1). They performed an evidence-based review of the literature, whose conclusions were contradictory and inconsistent. No strong evidence could be established on the precise qualities an individual should have in order to return to sport and at the same time minimize recurrence in the same knee or the occurrence of a new contralateral knee lesion. There seems to be little consensus on the test criteria for RTS after ACLR. In addition, there is a wide variation in ACLR rehabilitation protocols. What is now accepted is that for persons who participate in sports implicating side-to-side/pivoting maneuvers, ACLR is the favorite surgical technique, as it often allows them to return to the field following an ACL rupture (1).

Elements affecting return to sport (RTS) and second ACL rupture percentages

In order to analyze the impact of pre- and intra-operative variables on results after the ACLR, King et al conducted a cohort study (level of evidence, 3) of individuals experiencing primary ACLR operated on by 2 orthopedic surgeons and analyzed their results in a group of 1432 athletes in relation to RTS, a second ACL injury and IKDC scores (20). Follow-up was more than 2 years. The RTS rate was 81%; 1.3% of those who had a patellar tendon graft and 8.3% of those who had a hamstring graft suffered an ipsilateral rupture. The rate of contralateral ACL rupture was 6.6%. The IKDC score at follow-up was 86.8, with a higher amount of individuals with patellar tendon grafts achieving an IKDC score of <80. There was no correlation between RTS time and second ACL rupture. There was a moderate relationship between ACL-RSI score and RTS at follow-up. There were several dissimilarities in preoperative and intraoperative variables between cohorts for each result, but their ability to foretell results in level 1 athletes at 2 years follow-up was poor. Elevated percentages of RTS, lower percentages of reinjury with patellar tendon graft after 2 years of follow-up were observed in level 1 athletes, and no impact of RTS time on second ACL rupture. The data of this investigation suggested that after ACLR in level 1 athletes, preoperative and intraoperative variables should be taken into account to optimize results. However, to better predict outcomes after ACLR, future research is needed to assess other elements such as physical recuperation and psychological recovery (20).

Table 1 summarizes the available evidence on factors influencing RTS after ACLR. Table 2 summarizes the rates of RTS and the main factors influencing it after ACLR.

REINJURY AFTER ACLR

Reinjury rate in younger patients

In 2016 Webster and Feller conducted a cohort study (level of evidence, 3) to define the percentages of graft rupture and contralateral ACL injury in young athletes (21). They also analyzed the influence of sex and age (<18 years vs 18-19 years at the time of surgery) on the peril of further ACL rupture. A total of 354 individuals under 20 years of age who experienced their first primary hamstring autograft ACLR were analyzed. After a median follow-up of 5 years, the amount of further ACL lesions (graft rupture or contralateral injury of the native ACL) was obtained. Descriptive statistics were estimated for

Table 1. Summary of the available evidence on factors influencing return to sport (RTS) after anterior cruciate ligament reconstruction (ACLR)

AUTHORS	YEAR	TYPE OF STUDY	POPULATION	RATE OF RTS	OUTCOME MEASURES	FACTORS INFLUENCING RTS	COMMENTS
Davies et al (10)	2017	Review of the best current evidence to support a functional testing algorithm (FTA)	NA	NA	Biopsychosocial assessments, impairment testing, strength and power testing, functional testing and patient-reported outcomes (PROs)	The algorithm described has no predictive validity	These authors provided some practical guidelines that can facilitate the decision-making process for RTS
Blakeney et al (11)	2018	Prospective comparative diagnostic study, with level 3 evidence	410 patients: 371 ACLR procedures versus a control group of 39 healthy participants	NA	Development of a composite test to evaluate the patient's capacity for RTS after ACLR: the Knee Santy Athletic Return To Sport (K-STARTS)	K-STARTS is an objective test to assess functional improvement after ACLR.	There was a moderate correlation with the ACL Return to Sports after Injury (ACL-RSI) scale and hop tests. There was a significant difference between K-STARTS scores at 6 and 8 months postoperatively (11.2 ± 2.7 vs 17.1 ± 3.2; *P < 0.001*). The K-STARTS score in the control group was significantly higher than that of the ACLR group (17.3 ± 2.1 and 13.7 ± 3.8, respectively; *P < 0.001*).
Webster and Feller (12)	2018	Case series study (level of evidence, 4)	1440 athletes (992 men, 448 women) in level I sports (jumping, hard pivoting, and cutting)	42% in patients under 25; 32% in patients aged 25-36	Proportion of patients who had resumed level I sport 12 months after surgery, measurements of knee function (single-legged hop symmetry), anterior knee laxity (KT-1000 arthrometer) and the International Knee Documentation Committee [IKDC] subjective score	Limb symmetry index scores of 90 or greater, difference from the contralateral knee in anterior laxity of 2 mm or less, and IKDC scores of 95 or greater	Regardless of age, patients were twice as likely to have RTS when the limb symmetry index score was 90 or higher (*P ≤ 0.0001*) and three times as likely to have RTS when the IKDC score was 95 or higher (*P < 0.0001*).
Edwards et al (13)	2018	Case-control study (level of evidence, 3).	113 patients	NA	A rehabilitation classification tool, the IKDC subjective form, and an RTS battery consisting of a maximum isokinetic quadriceps and hamstring force, and 4 functional jump tests.	Complete rehabilitation (adjusted odds ratio [OR], 7.95; P = 0.009), age ≤25 years (adjusted OR, 3.84; P = 0.024), and higher IKDC scores (P < 0.001) were predictive of RTS at 12 months.	Among the participants who had returned to the sport, 21% passed the RTS battery, compared to only 5% who did not. Of those who had returned to sport, 37% who underwent complete rehabilitation passed the RTS battery, compared to 5% who underwent incomplete rehabilitation. Among the patients of ≤25, only 48% underwent complete rehabilitation, despite having returned to sports. Furthermore, in this group of patients, 40% underwent complete rehabilitation and passed the physical performance battery, compared to only 4% who did not undergo complete rehabilitation.
Lai et al [9]	2018	Case series study (level of evidence, 4)	158 players from the Australian Football League (AFL)	77%	NA	Greater preinjury playing experience and earlier selection in the AFL draft were associated with higher RTS rates.	The rate of subsequent ACL injuries in either knee was 30% (48 out of 158 players), and was especially high among players under 21 years of age (23 out of 46 players, 50%). After subsequent ACL injury, 34 of 48 players (71%) returned to play.

Table 1. Continued

Webster et al (15)	2019	Case series study (level of evidence, 4)	Bilateral ACL reconstruction: 107 patients (62 male, 45 female)	The rate of return to preinjury sport after bilateral ACLR was 40% (95% CI, 31%-50%), as compared with an 83% (95% CI, 74%-88%) return rate after the first reconstruction procedure.	International Knee Documentation Committee subjective form, Marx Activity Scale, and Knee injury and Osteoarthritis Outcome Score-Quality of Life subscale.	NA	RTS rates decrease significantly after a second reconstruction (that of the contralateral ACL); in fact, less than half of the series investigated returned to the pre-injury sport level.
Okoroha et al (16)	2019	Case-control study (level of evidence, 3)	130 National Football League (NFL) players	Of the total number of players, 23 (18%) required an ACLR review	The date of the ACLR and the date of return to regular season NFL play after surgery were recorded. In addition, the time between ACLR and RTS was compared for players who required ACLR review and for patients who did not. These authors also assessed whether players who had early RTS had a recurrent ACL injury before the others.	Time of RTS after ACLR was not a significant risk factor for revision surgery in NFL athletes. Nor was time for RTS shown to correlate with time to re-injury.	The average time to the RTS after the ACLR was 49.7 weeks. Of the total number of players, 23 (18%) required an ACLR review. There was no significant difference in the time between ACLR and RTS between players who did not require ACLR review (50.2 ± 10.1 weeks) and those who did (48.3 ± 11.0 weeks, *P=0.40*).
Lindanger et al (17)	2019	Cohort study (level of evidence, 2).	234 athletes participating in handball, basketball or soccer teams.	83% of patients returned to pivoting sports after early ACLR, only 53% returned to the preinjury level	Questionnaire focusing on return to pivoting sports, duration of sports activity after surgery, subsequent contralateral ACL injuries, revision surgery and knee replacement surgery.	ACLR does not necessarily allow a return to pre-injury sports participation. In addition, when returning to rotational sports after an ACLR, athletes are also at high risk for a contralateral ACL injury.	The rate of reinjury after returning to the preinjury sports level was 41% (30%, contralateral injuries; 11%, revision surgery).
Ebert et al (18)	2019	Case series study (level of evidence, 4)	50 patients were treated with arthroscopically assisted single-bundle ACLR using hamstrings augmented with the LARS (Ligament Augmentation and Reconstruction System)	Before the injury, 47 patients (94%) were actively participating in level 1 or 2 sports; at one and two years, respectively, 38 (76%) and 43 (86%) patients had returned to sports.	Patient-reported outcomes (PROs), KT-1000 arthrometer test, knee range of motion, maximum isokinetic knee force test and a battery of 4 hop tests, and Limb Symmetry Indices (LSIs)	NA	Normal (<3 mm; 90%) or near-normal (3-5 mm; 10%) differences were observed in the KT-1000 arthrometer from side to side at 2 years. Apart from knee flexion (*P<0.0001*), extension (*P=0.001*), and 6 m timed jump (*P=0.039*), there were no differences between limbs at 1 year, and no differences in any objective measures at 2 years (all *P>0.05*). The mean LSIs in all measures was ≥90%. At 2 years, 84% to 90% of patients had ≥90% in the hop tests, and 72% to 76% of patients had ≥90% in extension and flexion strength.
Flagg et al (1)	2019	Evidence-based literature review	NA	NA	Analysis of rehabilitation protocols, tests and measurements, and criteria for RTS after ACLR, especially in bone-tendon-bone (BTB) procedures	No strong evidence could be established on the specific qualities a patient should have for RTS while minimizing recurrence in the same knee or the occurrence of a new contralateral knee injury.	What is currently accepted is that for individuals who participate in sports involving side-to-side/pivoting movements, ACLR is the preferred surgical technique, as it can often allow them to return to the field after an ACL injury.
King et al (19)	2020	Cohort study (level of evidence, 3).	1432 athletes from a single center	81%	NA	NA	There was a moderate correlation between ACL-Return to Sport After Injury score and RTS at follow-up (*P < 0.001*, rho = 0.46).

NA = Nonavailable; CI = Confidence interval

Table 2. Rates of return to sport (RTS) and main factors influencing it after anterior cruciate ligament reconstruction (ACLR)
Overall between 71% and 83%; 42% in patients under 25; 32% in patients aged 25-36.
Regardless of age, when the limb symmetry index score is 90 or higher the probability of RTS doubles; and triples when the IKDC score is 95 or higher.
A complete rehabilitation, age ≤25, and higher IKDC scores are predictive of RTS at 12 months.
Greater preinjury playing experience and being selected earlier in the Australian Football League (AFL) draft are associated with higher RTS rates.

IKDC = International Knee Documentation Committee

the time of ACL graft rupture and contralateral ACL lesion. The overall follow-up percentage was 89% (316/354). In 57 individuals (18%), graft ruptures occurred within an average time of 1.8 years following surgery. 47% happened in the first postoperative year, and 74% in the first 2 years. The greatest rate of graft rupture, which was 28.3%, was recorded in younger men (<18 years) and was substantially greater than in women of the same age (12.9%), as well as in men over 18 years (13.8%). In 56 patients (17.7%), contralateral ACL injuries occurred within an average of 3.7 years following surgery. There were no substantial differences based on age or gender for contralateral ACL ruptures. The total number of individuals who had at least one additional ACL rupture following primary surgery was 110 (35%). The elevated percentage of further ACL rupture in younger patients was proved. Early graft ruptures were more frequent in individuals who had surgery when they were younger than 18 years old. Men had greater percentages of graft rupture than women, with younger men (<18 years) having the greatest peril of rupture (21).

Female soccer players with ACLR have an elevated peril of new knee ruptures and quit soccer to a greater grade than knee-healthy controls

In 2019 Faltstrom et al published the results of a prospective group of female soccer players with primary unilateral ACLR and compared them with matched knee-healthy controls from the same soccer teams with respect to: 1) the percentage of new traumatic and non-traumatic knee and other lesions, 2) the amount of players who dropped out of soccer, and 3) the activity level and satisfaction with the activity level and knee function of the players (level of evidence, 2) (22). A total of 117 active female soccer players (mean age 19.9 years) were followed prospectively then assessed 18.9 months after the ACLR and compared to 119 paired female soccer players with healthy knees (19.5 years) The results focused on new knee lesionss, other injuries, soccer playing level, activity level on the Tegner Activity Scale, and satisfaction with activity level and knee function. Women players with unilateral ACLR had a greater percentage of new ACL injuries (n = 29 vs 8; 19 vs 4 per 100 years of play), other traumatic knee lesions (29 vs 16 per 100 years of play), and nontraumatic knee lesions (33 vs 9 per 100 player years) compared to the control group who had never experienced unilateral ACLR. There was no dissimilarity in the percentage of other (non-knee) lesions (43 vs 48 per 100 player years). During the 24-month follow-up, 72 (62%) players with ACLR stopped playing soccer compared to 43 (36%) in the control group. The mean Tegner Activity Scale score diminished in both cohorts but more in the ACLR cohort. These authors concluded that the female soccer players with ACLR had a nearly 5-fold increased rate of new ACL injuries and a 2 to 4-fold increased percentage of other new knee lesions and stopped playing soccer to a greater extent, reducing their activity level more than those in the control group (22).

The relationship between passing return to sport (RTS) criteria and second ACL rupture risk

In 2019 Losciale et al attempted to determine whether decisions based on RTS criteria were associated with a lower peril of second ACL lesion (either graft failure or contralateral ACL lesion) (2). In this systematic review with meta-analysis (level 2a evidence), the Losciale et al calculated the combined peril dissimilarity (approved versus failed RTS criteria), the prevalence rate of injury, and the diagnostic exactness of each RTS guideline. Overall, 42.7% of individuals passed the RTS guidelines, and 14.4% of those who passed the guidelines had a second ACL lesion (graft rupture or contralateral ACL lesion). There was a nonsignificant 3% reduction in the peril of a second ACL lesion after passing RTS guidelines. The level of evidence of the Grading of Recommendations Assessment, Development and Evaluation scale was "very low quality", due to the inaccuracy and heterogeneity of the estimation of the combined risk difference. The conclusion was that the approval of the RTS guidelines did not demonstrate a statistically significant relationship with the peril of a second ACL lesion (2).

Psychological predisposition to return to sport (RTS) is related to second ACL lesions

The impact of psychological preparation and predisposition on the ability to RTS and likelihood of second ACL rupture was determined by McPherson et al in a cohort study (level of evidence, 2) (23). Participants operated on for primary ACLR between June 2014 and June 2016 finished the ACL-RSI scale (short version) prior to their ACLR and at 1 year following surgery in order to evaluate their psychological predisposition to return to sport. Individuals were also followed for a minimum of 24 months following surgery to establish if more injuries occurred following ACLR. A relationship was found between ACL-RSI scores and the prevalence of a second ACL lesion. In 329 individuals who returned to sport following the ACLR, 52 (16%) suffered a second ACL lesion. There was no dissimilarity from the

preoperative psychological situation, but individuals who suffered a second lesion tended to have less psychological preparation at 12 months than uninjured patients (60.9 vs 67.2 points). Younger injured individuals (≤20 years) had substantially less psychological preparation for RTS than younger, non-injured individuals (60.8 vs 71.5 points), although no dissimilarity was encountered in older individuals (60.9 vs 64.6 points). In younger individuals, receiver operating characteristic curve study showed a cut-off score of 76.7 points with 90% sensitivity to recognize those who suffered a second ACL lesion. The conclusion was that younger individuals with less psychological preparation are at greater peril of suffering a second ACL lesion following RTS (23).

Screening for second ACL lesion in younger individuals who return to sport (RTS) by means of clinical tests

A common clinical scenario is detecting and identifying patients at augmented peril of second ACL lesion. To address these questions, Webster and Feller investigated the relationship between usually registered clinical outcomes and second ACL lesion in a group of young, active patients in a cohort study (level of evidence, 2) which included 329 athletes (200 men, 129 women) under the age of 20 who had undergone ACL surgery and had afterward returned to sports (24). Clinical examination included knee ROM (passive flexion and extension deficiencies), anterior knee laxity, and single- and triple-crossover hop for distance. Individuals also finished the subjective IKDC form. Individuals were assessed for a minimum of 3 years to establish the prevalence of secondary ACL lesion. A total of 95 individuals (29%) suffered a second ACL lesion following RTS. There were 50 graft breaks and 45 contralateral ACL lesions. Individuals with a bending deficiency of 5° were more than 2 times more likely to have graft rupture, and individuals with a side-to-side dissimilarity in anterior knee laxity of 3 mm or more were more than 2 times more likely to have contralateral ACL lesion. Overall, 29% (94 of 329) of individuals met the threshold for satisfactory function on all 6 clinical measures; these individuals had a 33% decrease in the peril of a second ACL lesion compared to those who did not meet all clinical thresholds. The final opinion was that clinical measures of knee flexion and stability might be useful in detecting and identifying patients at augmented peril of second ACL lesion (24).

The probability of repetitive ACL lesions is related to the level of competition but not related gender or timing of game play

In 2019, Slater et al. published the descriptive characteristics (gender, level of sports participation, and playing time (i.e., early versus late in the game) of individuals with repetitive ACL injuries among National Collegiate Athletic Association (NCAA) and high school athletes compared to primary ACL injuries (25). Athletic coaches reported the occurrence and characteristics of ACL injuries in college athletes during the 2009-2010 to 2016-2017 academic years and in high school athletes during the 2011-2012 to 2013-2014 academic years. The amount of ACL lesions and ratios were estimated by gender, level of competition, and playing time. Outcomes were also categorized according to the mechanism of injury with regards to physical contact, excessive use, or surface contact. A total of 705 ACL lesions were found, including 644 primary lesions and 61 repetitive lesions. When noncontact ACL lesions were investigated, 416 (373 primary and 43 repetitive lesions) were found. The likelihood of repetitive ACL injury versus new lesion in NCAA student-athletes was 4.6 times greater than that of high school student-athletes. When investigating noncontact ACL lesions, the likelihood of a repetitive versus new ACL lesion during the postseason and preseason was 4.5 and 2.8 times that of the regular season, apiece. Athletes in limited-contact and non-contact sports were more likely to have a repetitive lesion than athletes playing football and other contact and collision sports. There was no substantial dissimilarity in the likelihood of repetitive ACL lesion by gender or playing time. The final opinion was that the likelihood of repetitive ACL injury is related to level of competition, but not with gender or playing time (25).

Return to sport (RTS) tests' prognostic usefulness for reinjury risk

To evaluate the impact of a combination of functional tests on reinjury peril and RTS following ACLR, Ashigbi et al collected self-reported data on function and functional tests to determine their prognostic usefulness (3). The study was a systematic review of previous level 2 publications. They found 276 potential studies, although eight studies (moderate to high quality) involving 6140 individuals were included in the final investigation. The recurrence percentage found ranged from 1.5% to 37.5%. Four reports showed a combination of isokinetic quadriceps power at different percentages and some hop tests as foretelling. One report stated that the isokinetic hamstring to quadriceps ratio was foretelling. Another study showed that kinetic and kinematic measures during vertical drop jumps (VDJ) were foretelling of new lesion and/or future revision surgery. The final opinion was that passing a combination of functional tests with predetermined cut-off points, using it as RTS guidelines, was related to reduced reinjury percentages. Therefore, a combination of isokinetic power and hop tests was advised in the course of RTS testing (3).

NFL athletes with a history of successful ACLR prior to being drafted show augmented peril of further ACL lesion when compared with a control group consisting of players of comparable positions and draft class

In 2019 Stulhman et al reported a cohort investigation (level of evidence, 3) in which they conducted orthopedic assessments of NFL Combine participants from 2006 to 2012 to recognize players who entered the NFL draft with a history of successful ACLR (26). A control group was constructed at a 2:1 ratio, consisting of players matched by position and draft class. Of the 2016 players summoned to the NFL Combine in the course of the investigation interval, 100 met the inclusion criteria. A

total of 26 ACL reinjuries (12 ipsilateral, 14 contralateral) happened in 25 players (25%) while playing in the NFL; these lesions occurred on average 22.1 months following the NFL draft. By comparison, 18 of the 200 (9%) players in the control group (with no history of previous ACL injuries) suffered a new ACL lesion during the same time interval. The final opinion was that NFL athletes with a history of successful ACLR prior to being recruited into the NFL have a substantially greater percentage of subsequent ACL reinjury while playing in the NFL than players without a previous ACL injury (26).

Soccer players that return to sport have a substantially greater risk of suffering further ACL lesion

The risk of subsequent knee injury remains a concern for players and plays heavily into the decision regarding the timing for return to play In 2020, Sandon et al provided insight into this question by reporting on 10 year follow-up of soccer players following primary ACLR surgery to determine the amount of players who RTS, what affected their resolution, and whether there was any difference in additional ACL lesions (graft failure and/or contralateral ACL injury) between those who returned to play and those who did not (27). This retrospective case-control cohort study (level of evidence, 3) consisted of 1661 soccer players from the Swedish National Knee Ligament Registry. A set of questions was dispatched to each player concerning his RTS and additional knee lesions that might have happened in the 10 years following primary ACLR. The outcomes were based on 684 players who responded to the survey. Data was collected on age, gender, surgical procedures, associated lesions patient-reported outcomes (PROMs), and additional knee surgical procedures. In this study, the RTS rate was 51% and for those who could not RTS, the primary cause was knee-related (65.4% of cases). The most frequent knee-related reasons for not being able to RTS were pain and/or instability (50%; n = 109), followed by anxiety of reinjury (32%; n = 69). Players who RTS were at substantially greater peril of additional ACL lesion: 28.7% had additional ACL lesion, 9.7% had graft failure, and 20.6% had contralateral ACL lesion. The final opinions were that solely 50% of the soccer players were able to RTS following the ACLR, knee-related concerns were cited by the two-thirds who could not RTS, and those players who did RTS had a substantially greater peril of subsequent ACL lesion. The high risk of additional knee injury continues to be a major concern for players and should be taken into account when deciding to return to play (27).

Second ACL lesions following ACLR in professional sumo wrestlers

Additional insights into this question regarding subsequent ACL injuries after ACLR comes from the 2020 publication of Shimizu et al who investigated second ACL lesions following ACLR in sumo wrestlers (28). This case study (evidence level 4) was conducted between 1988 and 2015 when a total of 139 primary ACLRs were carried out in professional sumo wrestlers. After excluding cases of multiple ligament knee reconstruction and individuals in whom the contralateral ACL had been previously damaged, the study included 110 individuals. The amount of second lesions, the time from primary reconstruction to second lesion, the system of treatment and the variation in official sumo classification following second lesions were investigated. Among the 110 wrestlers who underwent ACLR, 22 (20%) had second injuries after the primary ACLR. Among them, 14 individuals (12.7%) had an ipsilateral reinjury, 11 (10%) a contralateral lesion, and 3 a combination of reinjury and contralateral lesion. Regarding surgical treatment, 5 ACLRs were carried out for ipsilateral reinjury (35.7%), and 7 ACLRs for contralateral lesions (63.6%). In the remaining cases, no surgical treatment was performed. Wrestlers who were treated by revision or contralateral ACLR following the second lesion were demoted in rank for 3 or 4 tournaments but outperformed the nonsurgical management cohort in the rankings for 2 years after the operation; all athletes were initially demoted in rank following the second lesion. The rates of ipsilateral reinjury and contralateral ACL injury following ACLR in professional sumo wrestlers were somewhat greater than those published in previous reports and performance, evidence by ranking was diminished (28).

One in 5 athletes experience reinjury upon return to high-risk sports following ACLR

In order to determine if the application of objective testing criteria before RTS correlated with a smaller reinjury percentage, Barber-Westin and Noyes performed a systematic review of the literature (level of evidence, 4) examining the RTS rate, the impact of participation in elevated-risk sports, gender, and graft type on ACL reinitiation percentages (4). They included reportss on transphyseal ACLR in <20 year old athletes with a minimum mean follow up of 24 months that collected reinjury percentages, amount of RTS, and type of sport. A total of 1239 individuals from 8 reports were analyzed; 87% RTS and 80% restarted elevated-peril activities. Of the individuals, 18% had a new ACL graft injury and/or contralateral ACL. 9% of patellar autografts and 15% of hamstring autografts failed. Of the reinjuries, 90% happened in elevated-peril sports. Males patients had a substantially greater percentage of ACL graft failure than females. Contralateral ACL injuries were not related to gender. Only one report mentioned objective criteria for RTS. The final opinion of this study was that an elevated rate of athletes can RTS, although 1 in 5 suffer reinjuries to either knee. Men were more likely than women to re-injure their ACL graft. Objective criteria for RTS were infrequently cited or not specified. It remains critical that knee stability, power, neuromuscular control, agility, and psychological measures be analyzed in young athletes before evaluating RTS (4).

Table 3 summarizes the available evidence on factors influencing reinjury after ACLR. Table 4 summarizes the rates of reinjury and the main factors influencing it after ACLR.

In conclusion, RTS after ACLR rates range from 71% to

Table 3. Summary of the available evidence on factors influencing reinjury after anterior cruciate ligament reconstruction (ACLR)

AUTHORS	YEAR	TYPE OF STUDY	POPULATION	RATE OF REINJURY	OUTCOME MEASURES	FACTORS INFLUENCING REINJURY	COMMENTS
Webster and Feller (20)	2016	Cohort study (level of evidence, 3)	354 patients younger than 20 years	18%	The number of subsequent ACL injuries (graft rupture or a contralateral injury to the native ACL) was determined at a mean follow-up of 5 years (range, 3-10 years).	The highest rate of graft rupture, which was 28.3%, was recorded in younger men (<18 years) and was significantly higher than in women of the same age (12.9%), as well as in men over 18 years (13.8%).	Contralateral ACL injuries occurred in 17.7%.
Fältström et al (21)	2019	Cohort study (level of evidence, 2)	117 active female soccer players	NA	Tegner Activity Scale, and satisfaction with activity level and knee function	Female soccer players with ACLR had nearly a 5-fold-higher rate of new ACL injuries and a 2- to 4-fold-higher rate of other new knee injuries, quit soccer to a higher degree, and reduced their activity level to a greater extent as compared with knee-healthy controls.	Players with ACLR had a higher rate of new ACL injuries, other traumatic knee injuries, and nontraumatic knee injuries as compared with controls.
Losciale et al (2)	2019	Systematic review with meta-analysis (prognosis, level 2a of evidence)				42.7% of patients who passed the TRS criteria, and 14.4% of those who passed suffered a second ACL injury (ruptured graft or contralateral ACL injury).	There was a nonsignificant 3% reduction in the risk of a second ACL injury after passing the RTS criteria (risk difference, -3%).
McPherson et al (22)	2019	Cohort study (level of evidence, 2)	329 patients who returned to sport after ACLR	16%	ACL-Return to Sport after Injury (ACL-RSI) (short version) scale	Younger patients with lower psychological readiness were at higher risk for a second ACL injury after return to sport.	In younger patients, receiver operating characteristic curve analysis revealed a cutoff score of 76.7 points with 90% sensitivity to identify younger patients who sustained a second ACL injury.
Webster and Feller (23)	2019	Cohort study (level of evidence, 2).	329 athletes (200 males, 129 females) younger than 20 years	29%. There were 50 graft ruptures and 45 contralateral ACL injuries.	Flexion deficit, side-to-side difference in anterior knee laxity.	Clinical measures of knee flexion and stability may have utility to screen for and identify patients who are at greater risk for a second ACL injury	Patients with a flexion deficit of 5° had over 2 times the odds of sustaining a graft rupture (OR, 2.3; $P < 0.05$), and patients with a side-to-side difference in anterior knee laxity of 3 mm or greater had over 2 times the odds of sustaining a contralateral ACL injury (OR, 2.4; $P < 0.05$).
Slater et al (24)	2019	Descriptive epidemiology study	705	8.6%	The number of ACL injuries, proportions, and ORs were calculated by sex, competition level, and time in game played. Results were also classified according to injury mechanism: noncontact, overuse, or surface contact.	The odds of recurrent ACL injuries are associated with the level of competition but not associated with sex or timing of game play	Logistic regression was used to estimate ORs and 95% CIs for recurrent versus first-time ACL injury.
Ashigbi et al (3)	2019	Systematic review on level 2 studies	6140 patients	From 1.5% to 37.5%.	NA	Passing a combination of functional tests with pre-determined cut-off points used as RTS criteria is associated with reduced re-injury rates.	A combination of isokinetic strength and hop tests were recommended during RTS testing.
Stuhlman et al (25)	2019	Cohort study (level of evidence, 3).	100 National Football League (NFL) players	25%	Detailed orthopedic evaluations	NFL athletes with a history of successful ACLR before being drafted into the NFL have a significantly higher rate of subsequent ACL reinjury while playing in the NFL when compared with a carefully matched cohort of players without a history of prior ACL injury.	A total of 26 subsequent ACL reinjuries (12 ipsilateral, 14 contralateral) occurred in 25 players (25%) while playing in the NFL, with injuries occurring at a mean of 22.1 months after the NFL draft. In comparison, 18 of the 200 (9%) carefully matched cohort players without history of prior ACL injury sustained a new ACL injury during this time period ($P<0.001$).

Table 3. Continued

Sandon et al (26)	2020	Case-control study (level of evidence, 3)	684 soccer players	28.7%	Questionnaire regarding RTS and additional knee injuries that may have occurred 10 years after primary ACL	The most common knee-related reasons for not RTS were pain and/or instability (50%), followed by fear of reinjury (32%). Players who return to soccer have a significantly higher risk of additional ACL injury. Of the players who RTS, 28.7% had additional ACL injury, 9.7% had a graft failure and 20.6% had a contralateral ACL injury.	51% of players could RTS. For those who did not RTS, the primary reason was knee related (65.4% of the cases).
Shimizu et al (27)	2020	Case series study (level of evidence, 4).	110 professional sumo wrestlers	20%	Number of second injuries, time from primary reconstruction to second injury, treatment method, and change in official sumo ranking after second injuries.	The incidences of ipsilateral reinjury and contralateral ACL injury after ACLR in professional sumo wrestlers were relatively higher than those reported in previous studies.	Among 110 wrestlers who underwent ACLR, second injuries after primary ACLR occurred in 22 cases (20.0%). Among them, 14 cases (12.7%) entailed ipsilateral reinjury, 11 (10.0%) entailed contralateral injury, and 3 involved combined re-rupture and contralateral injury. As for surgical treatment, 5 revision ACLR were performed for ipsilateral reinjury (35.7%), and 7 ACLR were performed for contralateral injury (63.6%). Surgical treatment was not performed for the remaining cases.
Barber-Westin and Noyes (4)	2020	Systematic review of the literature (level of evidence, 4)	1239 patients	18% reinjured the ACL graft and/or the contralateral ACL	RTS rates; the effect of participation in high-risk sports, sex, and graft type on ACL reinjury rates; and objective test criteria before RTS.	1 in 5 suffered reinjuries to either knee. Male patients were more likely to reinjure the ACL graft.	Of reinjuries, 90% occurred during high-risk sports. Male patients had a significantly higher rate of ACL graft failure than female patients (OR, 1.64; $P = 0.01$). There was no sex-based effect on contralateral ACL injuries.

OR = Odds ratio; CI = Confidence interval

Table 4. Rates of reinjury and main factors influencing it after anterior cruciate ligament reconstruction (ACLR)

From 1.5% to 37.5% (in most studies between 9% and 29%)
The highest rate of graft rupture occurs in younger men (<18 years), being significantly higher than in women of the same age (12.9%).
Female soccer players with ACLR have nearly a 5-fold-higher rate of new ACL injuries and a 2- to 4-fold-higher rate of other new knee injuries, quit soccer to a higher degree, and reduced their activity level to a greater extent as compared with knee-healthy controls.
42.7% of patients who passed the RTS criteria, and 14.4% of those who passed suffered a second ACL injury (graft rupture or contralateral ACL injury).
Younger patients with lower psychological readiness are at higher risk for a second ACL injury after return to sport.
Patients with a flexion deficit of 5° have over 2 times the odds of sustaining a graft rupture, and patients with a side-to-side difference in anterior knee laxity of 3 mm or greater had over 2 times the odds of sustaining a contralateral ACL injury.
The odds of recurrent ACL injuries are associated with the level of competition but not associated with sex or timing of game play.
Passing a combination of functional tests with pre-determined cut-off points used as RTS criteria is associated with reduced re-injury rates.
NFL athletes with a history of successful ACLR before being drafted into the NFL have a significantly higher rate of subsequent ACL reinjury while playing in the NFL when compared with a carefully matched cohort of players without a history of prior ACL injury.
1 in 5 patients suffer reinjuries to either knee. Male patients are more likely to reinjure the ACL graft.

ACL = Anterior cruciate ligament; ACLR = Anterior cruciate ligament reconstruction; RTS = Return to sport. NFL = National Football League

83%. The probability of RTS, regardless of the patient's age, doubles when the limb symmetry index score is 90 or more the probability of RTS; and triples when the IKDC score is 95 or more. A complete rehabilitation, age ≤25, and higher IKDC scores are predictive of RTS at 12 months. Reinjury rates after ACLR range from 1.5% to 37.5%. Patients with a flexion deficit of 5° have over 2 times the odds of sustaining a graft rupture, and patients with a side-to-side difference in anterior knee laxity of 3 mm or greater had over 2 times the odds of sustaining a contralateral ACL injury. Passing a combination of functional tests with pre-determined cut-off points used as RTS criteria is associated with reduced re-injury rates. 1 in 5 patients suffer reinjuries to either knee. Male patients are more likely to reinjure the ACL graft.

E. Carlos Rodriguez-Merchan MD PhD[1]
Leonard A. Valentino MD[2]
1 Department of Orthopedic Surgery, La Paz University Hospital, Madrid, Spain
2 Rush University. Chicago, Illinois, USA

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