

Primary Anterior Cruciate Ligament Reconstruction in Level 1 Athletes

Factors Associated With Return to Play, Reinjury, and Knee Function at 5 Years of Follow-up

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Background: Favorable outcomes after anterior cruciate ligament (ACL) reconstruction (ACLR) are often gauged by successful return to play (RTP), a low incidence of subsequent ACL injury, and positive patient-reported outcomes. Level 1 sports place the highest demands on the knee by requiring frequent pivoting, changes in direction, and jumping.

Purpose: To analyze the outcomes of primary ACLR in level 1 athletes and identify pre- and intraoperative factors associated with RTP, ipsilateral ACL reinjury, contralateral ACL injury, and International Knee Documentation Committee (IKDC) score at 5 years postoperatively.

Study Design: Cohort study; Level of evidence, 2.

Methods: A consecutive cohort of 1432 patients who underwent primary ACLR by 2 orthopaedic surgeons were prospectively evaluated. The RTP rate, incidence of ipsilateral/contralateral ACL injury, and IKDC score were analyzed at 5 years. Comparative analysis of clinical variables was performed between those who achieved favorable outcomes and those who did not. Outcomes at 5 and 2 years were also compared.

Results: The mean age was 24.3 ± 7.3 years (males: 75%, females: 25%). Gaelic football was the predominant sport (40%), followed by soccer (19%). The RTP rate was 87.4%, with 59.8% of athletes still playing at an equivalent or higher level at 5 years. The incidence of ipsilateral reinjury for athletes who resumed level 1 sport was 4.3% for bone–patellar tendon–bone (BPTB) autografts with screw fixation and 19.7% for hamstring tendon (HT) autografts with EndoButton and screw fixation. The incidence of contralateral ACL injury was 13.7%. The mean IKDC score at 5 years (86.6 ± 10.9) was comparable to that at 2 years (86.8 ± 10.1). Patients were more likely to RTP with each year of decreasing age (OR, 1.06; $P < .001$), with a higher preoperative Marx score (OR, 1.08; $P < .001$) or a higher 5-year IKDC score (OR, 1.06; $P < .001$). The risk of ipsilateral ACL reinjury increased each year of decreasing age (OR, 1.11; $P < .001$) or when an HT autograft was used (OR, 5.56; $P < .001$). Younger age was also associated with contralateral ACL injury (OR, 1.1; $P < .001$). Female sex, older age, concomitant meniscal/chondral injuries, and lower preoperative Anterior Cruciate Ligament Return to Sport after Injury scores were associated with lower IKDC scores at 5 years.

Conclusion: Most patients could return to level 1 sports, although their performance level was impacted. Those who returned to sport maintained their performance level over the 5 years. The ipsilateral reinjury rate for BPTB autografts with screws was significantly lower than that for HT autografts with EndoButton and screw fixation. Most ACL reinjuries occurred between 2 and 5 years of follow-up. Younger patients had an increased risk of a subsequent ACL injury to either knee, regardless of graft type. IKDC scores were lower in female patients, older patients, and those with concomitant meniscal/cartilage injuries.

Registration: NCT02771548 (ClinicalTrials.gov identifier).

Keywords: anterior cruciate ligament; level 1; 5-year outcomes; return to play; reinjury; contralateral injury; knee function; IKDC

wish to return to level 1 sports are recommended to undergo ACL reconstruction (ACLR).^{26,39,41} However, while modern surgical techniques proficiently restore knee stability, undergoing ACLR continues to have variable clinical outcomes.^{2,3,12}

The effectiveness of ACLR in athletes is often gauged by the rate of return to play (RTP), the incidence of a second ACL injury (to either the reconstructed limb or the contralateral limb), and patient-reported outcomes. However, the specific outcomes for athletes in level 1 sports are infrequently reported despite widespread acknowledgement that these patients are at a heightened risk of both graft reinjury and contralateral knee injury.^{19,20} Most studies also focus on the outcomes within 2 years after surgery, which may not fully capture the risk of resuming high-intensity sporting activities, given that the rehabilitation period consumes a significant portion of this time.⁶

This study elaborates on the outcomes reported for this patient cohort at 2 years of follow-up.¹⁷ The first objective was to determine the rate at which athletes return to level 1 sports and to assess their capacity to sustain participation in these sports 5 years after ACLR. Our second objective was to reanalyze the incidence of ipsilateral and contralateral ACL injuries, which allowed us to extend our survivorship analysis and evaluate the longer-term risk of reinjury with ongoing participation in high-intensity sports. Third, we compared the patient-reported outcomes at 2 and 5 years. Finally, we evaluated the influence of several preoperative and intraoperative factors on the 5-year outcomes to see if they were consistent with those identified at 2 years.

METHODS

A consecutive cohort of patients were prospectively enrolled from our institution between January 1, 2014, and September 30, 2016, from the caseload of 2 subspecialist orthopaedic knee surgeons (R.M. and M.J.). Patients were included if they were 13 to 45 years of age and were undergoing primary ACLR, including those with a previous contralateral injury. Participation in level 1 sports was categorized based on the type of sport and frequency of participation according to the Cincinnati Sports Activity Scale (CSAS). Specifically, individuals engaging in sports requiring jumping, hard pivoting, or

cutting 3 to 4 days per week (CSAS score of 100) or 1 to 2 days per week (CSAS score of 85) were classified as level 1 athletes. This classification also aligned with the definitions for level 1 sports previously established by Hefti et al¹³ and Daniel et al.⁵

All participants completed a preoperative questionnaire, which collected data regarding their age, sex, level of sports participation, intention to RTP after ACLR, primary mechanism of injury, Marx Activity Scale score²³ at the time of injury, and Anterior Cruciate Ligament Return to Sport after Injury (ACL-RSI) score.⁴⁴

Patients were excluded if they were undergoing revision ACLR or concurrent repair/reconstruction of other knee ligaments or were outside the specified age range. This study was registered at ClinicalTrials.gov under the identifier NCT02771548. Our local institutional review board granted ethics approval, and all participants provided informed consent before data collection was commenced.

The surgical procedures were conducted at our hospital by 2 knee surgeons, who used equivalent arthroscopic and surgical techniques utilizing either bone-patellar tendon-bone (BPTB) or hamstring tendon (HT) autografts. Graft selection was determined by the surgeons based on their assessment of patient characteristics and physical examination findings. BPTB autografts were predominantly used given the preference for this graft type in patients returning to high-demand sports. HT autografts were selected for patients with an open physis or a history of patellofemoral issues such as tendinopathy, Osgood-Schlatter disease, patella baja, patellar chondral pathology, bipartite patella, or those who expressed concern regarding the possibility of kneeling discomfort. Graft diameter for HT grafts was typically between 8 and 9.5 mm, and BPTB grafts were typically either 10 or 11 mm other than for pediatric patients.

BPTB grafts were secured using metal interference screws (Softsilk; Smith & Nephew), while HT grafts were fixed using an EndoButton (CL Ultra; Smith & Nephew) for femoral fixation and a nonbioabsorbable screw (Biosure PK; Smith & Nephew) for tibial fixation. Tunnel positions were placed at the anatomic footprints of the original ACL, and femoral drilling was performed through an anteromedial portal. During the surgical procedure, routine arthroscopy was performed to address any coexisting intra-articular pathology. Meniscal tears were repaired when possible, with this decision based on location, pattern, and chronicity of the tear. Chondral pathology was treated

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nonoperatively or with chondroplasty as required. Lateral extra-articular tenodesis was performed for patients exhibiting significant laxity on clinical examination, regardless of graft type. This was performed using a 10-cm strip of the iliotibial band, which was tunneled under the LCL and secured to the femur with staple fixation.

Postoperatively, patients were immediately permitted to bear weight as tolerated without a brace. Crutches were used for approximately the first 2 weeks. Follow-up assessments were scheduled with the surgeons at 2 weeks, 3 months, 6 months, and 9 months after the surgery. Because of the geographical distribution of the participants, the majority underwent rehabilitation with a local physiotherapist. As part of the postoperative assessment, the participants underwent several physical tests to track their rehabilitation progress. The exact testing protocols have been previously described.¹⁶ During these follow-up assessments, the orthopaedic surgeon set minimum criteria for participants to focus on before returning to sport. These included the absence of joint effusion, restoration of quadriceps strength with effective control during single-leg squats, normal running patterns and a limb symmetry index of at least 90%. These criteria were not evaluated as part of a formal return-to-sport testing protocol. This study defined “return to play” as the unrestricted resumption of a patient’s preinjury sport in accordance with the 2016 consensus statement on return to sport.¹

During their follow-up, participants completed the International Knee Documentation Committee (IKDC) score, ACL-RSI, and Marx Activity Scale questionnaires. Additionally, a questionnaire was administered to record information regarding each participant’s ability to RTP, the timing of return, their level of performance, and any subsequent injuries to either the ACLR knee or the non-ACLR knee. After the supervised rehabilitation period, participants were followed up again via email and telephone for their 2-year and 5-year follow-ups. Participants who experienced a new ACL injury to either knee were identified during the follow-up period or if they returned to the clinic before the scheduled follow-up time with a confirmed diagnosis of ipsilateral or contralateral ACL injury on magnetic resonance imaging.

Statistical Analysis

Continuous variables are displayed as mean (standard deviation), whereas categorical variables are displayed as numbers and percentages. Patients were divided into outcome groups based on those who achieved the outcome and those who did not (ie, RTP vs no RTP, ipsilateral injury vs no injury, contralateral injury vs no injury, IKDC score >90 vs <80). For the RTP and ACL reinjury analyses, only patients who returned to a level 1 sport were included. For the IKDC analysis, patients were categorized into 2 groups: IKDC score >90 and IKDC score <80 to account for the standard error of measure for the IKDC, which ranges between 3.2 and 5.6 points.^{4,10} By establishing a minimum 10-point gap between the groups,

this approach offered a clear differentiation between optimal and suboptimal knee function (Figure 1).

Comparative analysis was conducted between outcome groups for preoperative and intraoperative variables using a chi-square contingency table. Means of nonparametric data were compared using the Mann-Whitney *U* test. A point biserial correlation coefficient was used to analyze the relationship between the binary outcomes and continuous independent variables. Odds ratios were calculated for variables that reached statistical significance to measure their strength of association with the outcome. Differences in the rates of ipsilateral and contralateral ACL injuries over time were explored using a Kaplan-Meier survivorship curve. Additionally, factors with $P < .10$ in the univariate analysis were used as candidate variables in the subsequent multiple regression analysis. A multivariable Cox proportional hazards regression analysis was conducted to assess the independent effect of each significant variable on RTP and ACL reinjury risk, adjusting for potential confounders. The threshold for statistical significance was set at a P value <.05. Data analysis and graphical presentation were performed using SPSS Version 29 (IBM Corp) and RStudio (Posit).

RESULTS

There were 1780 ACLRs performed by the 2 surgeons between January 1, 2014, and September 30, 2016. Of these, 1432 were primary ACLRs for patients between 13 and 45 years of age. Follow-up data was unavailable for 127 patients, giving an overall follow-up of 91.1% at 5 years (mean, 61.1 months; range, 60-72 months). The mean age was 24.3 ± 7.3 years (males: 75%, females: 25%). Gaelic football was the predominant sport (40%), followed by soccer (19%), hurling (15%), and rugby (11%). Preoperatively, 97% of participants anticipated returning to a similar or higher level of sport after ACLR. Most ACL injuries were noncontact (64.9%), with pivoting/side-stepping (47%) and jumping/landing (20%) being the most common actions leading to injury. The mean time from injury to surgery was 4.6 ± 10.7 months¹⁷ (Table 1).

Regarding graft choice, BPTB was the most common graft type (80%), followed by HT graft (20%) (Table 2). Graft diameter was most frequently 10 to 11 mm in the BPTB group and 8 to 9.5 mm in the HT group. Extra-articular tenodesis was performed in 2.2% of all patients, with no significant difference between graft types (2.4% with BPTB vs 1.7% with HT; $P = .51$). Surgeon 1 predominantly performed BPTB ACLR (93.2%; $n = 1104$) versus HT ACLR (6.8%; $n = 80$). Surgeon 2 predominantly performed HT ACLR (84.7%; $n = 210$) versus BPTB ACLR (15.3%; $n = 38$). Concerning medial meniscus injuries, 76% had no injury, 11% had a tear left in situ, 8% underwent partial meniscectomy, and 5% had a repair. Regarding lateral meniscus injuries, 62% of patients had no injury, 16% had a tear left in situ, 19% underwent partial meniscectomy, and 3% had a repair. The location and

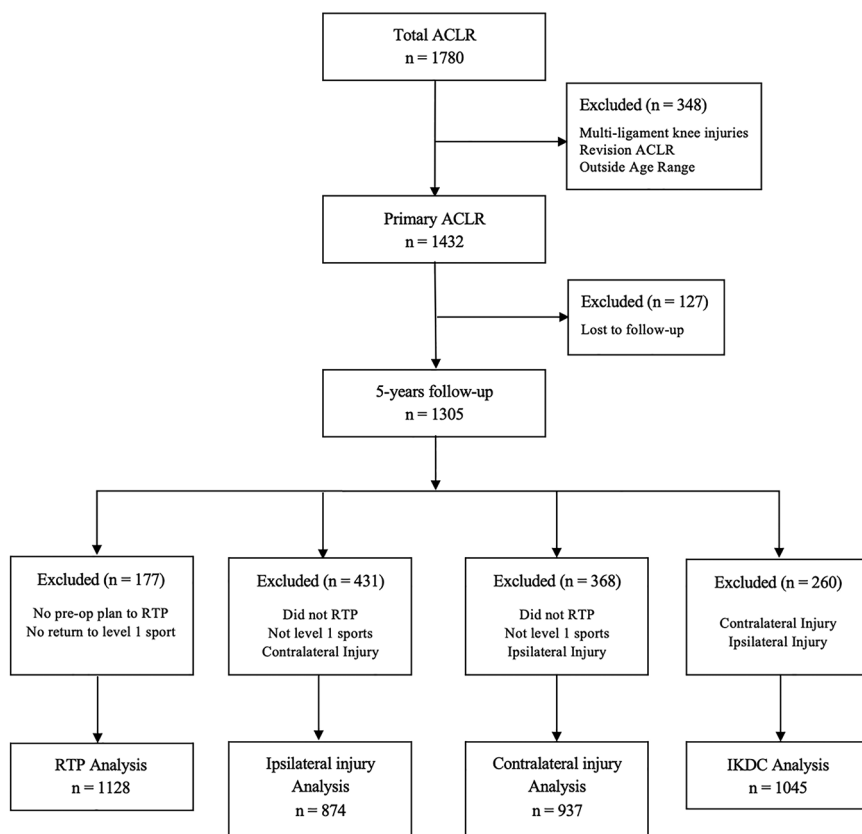


Figure 1. Flowchart of participant inclusion with each outcome measure. ACLR, anterior cruciate ligament reconstruction; IKDC, International Knee Documentation Committee; RTP, return to play.

graded severity of concomitant chondral injuries are detailed in Table 2.

Return to Play

For the RTP analysis, only patients who had a preoperative intention to RTP and those who participated in a level 1 sport were analyzed ($n = 1128$) (Figure 1). The overall rate of RTP at 5 years was 87.4% ($986/1128$) (Table 3). The median time from surgery to RTP was 10.6 months, with 92.5% of athletes who returned to play doing so within the first 2 postoperative years (Figure 2). The mean time from ACL injury to surgery for those who returned to play was slightly shorter than for those who did not return (4.1 ± 14 months vs 6.6 ± 14.5 months; $P < .001$).

Regarding the level of performance reported at 5 years of follow-up, 8.9% ($100/1128$) were participating at a higher level of play, 50.9% ($574/1128$) were playing at the same level, and 11.6% ($131/1128$) had transitioned to a lower level (Table 3). There were 16% ($181/1128$) patients who resumed their sporting activities but did not report their level of performance and 12.6% ($142/1128$) who did not RTP. These results were similar to those reported at 2 years of follow-up: 10.4% at a higher level, 54.9% at the same level, 12.2% at a lower level, and 7% who returned to sport but did not report the level of performance. Of

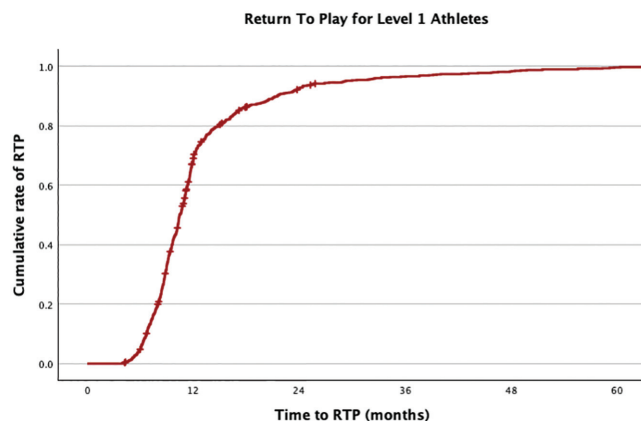


Figure 2. Probability and rate of return to play (RTP) for level 1 athletes over 5 years of follow-up. The median time to RTP was 10.6 months, and 7.5% of athletes returned to play after 2 years postoperatively.

note, there were 85 of 1128 (7.5%) patients who reported a subjective improvement in their level of sports performance between 2 and 5 years after surgery.

When the group who returned to play were compared with those who did not, we found that patients were

TABLE 1
Baseline Patient Characteristics and Preoperative Data^a

Characteristic	Total	BPTB	HT	P Value
Primary ACLR (13-45 y)	1432	1142	290	
Sex, male/female	1068:364	852:290	218:72	.84
Age, y	24.3 ± 7.3	24.5 ± 7.0	23.2 ± 7.9	<.001
Sport at the time of injury				
Gaelic football	569 (40)	472 (41)	97 (33)	.30
Soccer	266 (19)	201 (18)	65 (22)	
Hurling	209 (15)	166 (15)	43 (15)	
Rugby	158 (11)	125 (11)	33 (11)	
Snow sports	74 (5)	62 (5)	12 (4)	
Basketball	29 (2)	22 (2)	7 (2)	
Other	127 (9)	94 (8)	33 (11)	
Preoperative expected level of return to sport				.83
Higher level	329 (23)	262 (23)	67 (23)	
Same level	1062 (74)	850 (74)	212 (73)	
Lower level	15 (1)	11 (1)	4 (1)	
Other sport	20 (1)	14 (1)	6 (2)	
No return	6 (<1)	5 (<1)	1 (<1)	
Mechanism of primary injury				.38
Direct contact	284 (20)	225 (20)	59 (20)	
Indirect contact	219 (15)	183 (16)	36 (12)	
Noncontact	929 (65)	734 (64)	195 (67)	
Preoperative Marx score (74% patients)	10.9 ± 5.1	11.1 ± 5.0	10.5 ± 5.5	.35
Preoperative ACL-RSI score (86.4% patients)	47.8 ± 26.3	48.4 ± 26.4	45.3 ± 25.6	.12
Time from injury to surgery, mo	4.6 ± 10.7	4.4 ± 11	5.1 ± 9.1	<.001
Time to follow-up, mo	61.1 ± 3.0	61.1 ± 3.1	61 ± 2.6	.12

^aData are expressed as n (%) or mean ± SD. Bold P values indicate statistical significance. ACLR, anterior cruciate ligament reconstruction; ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury; BPTB, bone–patellar tendon–bone; HT, hamstring tendon.

more likely to RTP for each year of decreasing age (OR, 1.06) (Table 4). RTP was also more likely if patients had a higher preoperative Marx score (OR, 1.08), a higher preoperative ACL-RSI score (OR, 1.01), or a higher IKDC score (OR, 1.06) at 5 years of follow-up. Patients were less likely to RTP if they had undergone medial meniscectomy (OR, 0.46), meniscal repair (OR, 0.72), or had a MFC chondral injury grade 1 or 2 (OR, 0.65) or grade 3 or 4 (OR, 0.42) (Table 4). The operating surgeon did not influence the RTP rate (surgeon 1: 87.7% [820/935] vs surgeon 2: 86% [166/193]; $P = .519$). After inclusion in the multivariable Cox regression model, male sex (HR, 1.24; $P < .05$), decreasing age (HR, 1.02; $P < .001$), preoperative Marx score (HR, 1.03; $P < .001$), medial meniscus left in situ (HR, 1.34; $P < .01$), and preoperative ACL-RSI score (HR, 1.0003; $P < .05$) remained statistically significant.

Ipsilateral ACL Reinjury

The rate of ipsilateral ACL reinjury for athletes who resumed level 1 sport was 4.3% for BPTB autografts with screw fixation and 19.7% for HT autografts with EndoButton and screw fixation (Table 3). The mean time from surgery to ipsilateral reinjury was 28.8 ± 17.5 months. Importantly, 50.8% (33/65) of reinjuries occurred between 2 and 5 years postoperatively.

Comparative analysis between those who sustained an ipsilateral reinjury and those who did not indicated an

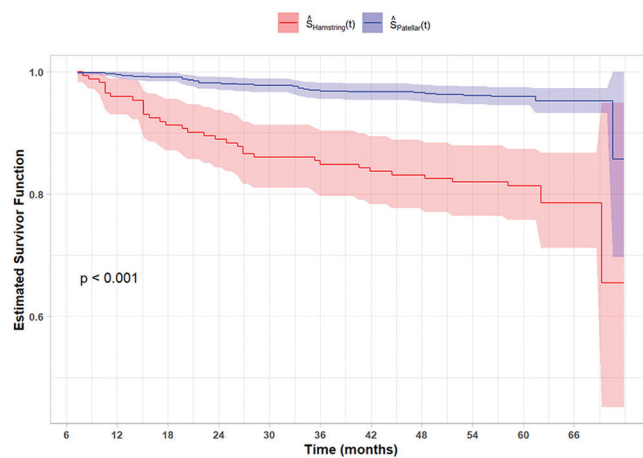


Figure 3. Kaplan-Meier plot demonstrating the probability of ipsilateral reinjury for level 1 athletes using bone–patellar tendon–bone autografts with screw fixation versus hamstring tendon autografts with EndoButton and screw fixation over 5 years of follow-up.

increased risk of injury for each year of decreasing age (OR, 1.11) and when an HT graft with EndoButton and screw fixation was used (OR, 5.56) (Table 5). There were similar rates of ipsilateral reinjury for both surgeons using

TABLE 2
Intraoperative Characteristics Including Meniscal and Chondral Surface Status During ACLR^a

Characteristic	Total	BPTB	HT	P Value
No. of patients	1432	1142	290	
Graft diameter, mm				<.001
7-7.5	25 (2)	0	25 (9)	
8-8.5	154 (11)	3 (<1)	151 (52)	
9-9.5	112 (8)	11 (1)	101 (35)	
10	401 (28)	388 (34)	13 (5)	
11	732 (51)	732 (64)	0	
12	8 (1)	8 (1)	0	
Extra-articular tenodesis	32 (2)	27 (2)	5 (2)	.51
Medial meniscus injury				<.001
Nil	1093 (76)	882 (77)	211 (73)	
Left in situ	159 (11)	137 (12)	22 (9)	
Meniscectomy	109 (8)	82 (7)	27 (9)	
Repair	71 (5)	41 (4)	30 (10)	
Lateral meniscus injury				.59
Nil	888 (62)	704 (62)	184 (63)	
Left in situ	233 (16)	183 (16)	50 (17)	
Meniscectomy	270 (19)	224 (20)	46 (16)	
Repair	41 (3)	31 (3)	10 (3)	
Medial femoral condyle				.46
Nil	1194 (83)	948 (83)	246 (85)	
Grade 1 or 2	171 (12)	138 (12)	33 (11)	
Grade 3 or 4	67 (5)	56 (5)	11 (4)	
Lateral femoral condyle				.243
Nil	1215 (85)	957 (84)	258 (89)	
Grade 1 or 2	196 (14)	168 (15)	28 (10)	
Grade 3 or 4	21 (1)	17 (1)	4 (1)	
Medial tibial plateau				<.001
Nil	1420 (99)	1139 (100)	281 (97)	
Grade 1 or 2	8 (1)	1 (<1)	7 (2)	
Grade 3 or 4	4 (<1)	2 (<1)	2 (1)	
Lateral tibial plateau				.004
Nil	1421 (99)	1137 (100)	284 (98)	
Grade 1 or 2	9 (1)	5 (<1)	4 (1)	
Grade 3 or 4	2 (<1)	0	2 (1)	
Patella				<.001
Nil	1399 (98)	1132 (99)	267 (92)	
Grade 1 or 2	28 (2)	8 (1)	20 (7)	
Grade 3 or 4	5 (<1)	2 (<1)	3 (1)	
Trochlea				.023
Nil	1417 (99)	1134 (99)	283 (98)	
Grade 1 or 2	9 (1)	5 (<1)	4 (1)	
Grade 3 or 4	6 (<1)	3 (<1)	3 (1)	

^aData are expressed as n (%). Bold P values indicate statistical significance. ACLR, anterior cruciate ligament reconstruction; BPTB, bone–patellar tendon–bone; HT, hamstring tendon.

BPTB autografts with screw fixation (4.3% vs 3.9%; $P = .905$) and HT autografts with EndoButton and screw fixation (18.9% vs 20.0%; $P = .862$).

Survival analysis also revealed a statistically significant difference between the BPTB and HT cohorts at all time points over 5 years of follow-up (Figure 3). Younger age and HT autografts were associated with an increased risk of reinjury, regardless of whether reinjury occurred before 2 years or between 2 and 5 years postoperatively (Table 5). Multivariable analysis revealed that decreasing age (HR, 1.08; $P < .01$) and graft type (HR, 4.4; $P < .001$) remained statistically significant.

Contralateral ACL Injury

For the contralateral injury analysis, 937 patients were evaluated, including only those who returned to a level 1 sport and excluding those who sustained an ipsilateral ACL reinjury (Figure 1). The overall contralateral injury rate was 13.7% at 5 years. There was no statistically significant difference between BPTB autografts with screw fixation (13.8%) and HT autografts with EndoButton and screw fixation (12.8%; $P = .725$) (Table 3). There were similar rates of contralateral injury for both surgeons (13.9% vs 12.6%; $P = .685$). Contralateral injuries occurred later

TABLE 3
Outcomes of ACLR for Level 1 Athletes at 5 Years of Follow-up^a

Outcome	Value
Total primary ACLR	1432
Primary ACLR with 5 years of follow-up	1305 (91.1)
Return to level 1 sport at 5 years (n = 1128)	986 (87.4)
Higher level	100 (8.9)
Same level	574 (50.9)
Lower level	131 (11.6)
Returned to sport but level unknown	181 (16.0)
No return to sport	142 (12.6)
Ipsilateral ACL reinjury	
BPTB autograft	30/696 (4.3)
HT autograft	35/178 (19.7)
Mean time from surgery to ipsilateral ACL reinjury, mo	28.8 ± 17.5
Contralateral ACL injury	
BPTB autograft	107/773 (13.8)
HT autograft	21/164 (12.8)
Mean time from surgery to contralateral ACL injury, mo	34.5 ± 17.7
IKDC score (80.1% patients)	86.6 ± 10.9
Marx score (82.5% patients)	8.9 ± 5.4

^aData are expressed as n (%) or mean ± SD. ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; BPTB, bone–patellar tendon–bone; HT, hamstring tendon; IKDC, International Knee Documentation Committee.

than ipsilateral reinjuries at a mean time from surgery of 34.5 ± 17.7 months. Of note, 64.8% (83/128) of contralateral ACL injuries occurred between 2 and 5 years postoperatively. There was no statistically significant difference in the survivorship rates between graft types concerning the incidence of contralateral ACL injury (Figure 4).

Comparative analysis between those who sustained a contralateral injury and those who did not indicated an increased risk of injury for each year of decreasing age (OR, 1.1) and for those with a higher preoperative Marx score (OR, 1.07) (Table 6). This was slightly different from the results at 2 years of follow-up, when only younger age was associated with contralateral injury.

IKDC Score

The mean IKDC score at 5 years of follow-up for level 1 athletes was 86.6 ± 10.9 points, which was equivalent to the results at 2 years of follow-up (86.8 ± 10.1 points) (Table 3). Comparative analysis identified that there was a significantly higher proportion of females who had an IKDC score <80 points compared with males (OR, 1.5) (Table 7). Less favorable IKDC scores were also associated with each year of increasing patient age (OR, 1.07), lower preoperative Marx scores (OR, 1.06), and lower preoperative ACL-RSI scores (OR, 1.01). The presence of a medial meniscus injury and cartilage injuries to either femoral condyle also influenced the IKDC scores at 5 years (Table 7). Unlike at 2 years, there was no statistically significant relationship found between the use of BPTB grafts and lower IKDC scores at 5 years of follow-up. The details of the comparative analysis between those with an IKDC score >90 and those with an IKDC score <80 can be found in Table 7.

DISCUSSION

The most important finding of this study was the significant difference in ipsilateral ACL reinjury rate between BPTB autografts with screw fixation (4.3%) and HT autografts with EndoButton and screw fixation (19.7%) in athletes who returned to level 1 sports. Another observation was that the majority of both ipsilateral and contralateral ACL injuries occurred between 2 and 5 years postoperatively. This indicates the importance of ongoing injury prevention and the need for extended follow-up to fully appreciate the outcomes of those participating in pivoting sports. Importantly, while many athletes could return to demanding sports, a significant proportion did not recover their preinjury performance level. Nevertheless, once athletes returned, they maintained their performance level for 5 years and reported satisfactory knee function, despite ongoing participation in high-intensity activities.

Our study demonstrated an 87.4% rate of return to level 1 sports at 5 years. These results expand on the 2-year outcomes of this cohort, which demonstrated an RTP rate of 82%, with 65.3% reporting a performance level higher/equivalent to their preinjury level.¹⁷ More specifically, this cohort demonstrated satisfactory RTP rates for athletes regardless of sex, graft choice, or preoperative sporting level. We find these results reassuring given that rates of RTP frequently fall below patient expectations, especially in sports that involve pivoting and hard cutting.^{7,20,27} Ardern et al³ demonstrated that only 55% of athletes return to competitive sports after ACLR, with approximately 65% of these achieving their preinjury performance level. Similarly, Lindanger et al²⁰ noted that although 83% of patients returned to level 1 sport after ACLR, only 53% returned to their preinjury level. Another

TABLE 4
Comparative Analysis Between Groups (RTP vs No RTP) at 5 Years of Follow-up^a

	RTP	No RTP	Statistic	P Value	OR (95% CI)
Sex					
Male	792 (88)	105 (12)	3.10	.078	
Female	194 (84)	37 (16)			
Age, y	22.9 ± 6.2	25.5 ± 7.2	−0.14	<.001	1.06 (1.03-1.08)
Preoperative Marx score	11.7 ± 4.9	9.4 ± 5	0.15	<.001	1.08 (1.05-1.12)
Injury mechanism					
Jumping/landing	189 (89)	23 (11)	0.959	.916	
Sidestep/pivot	466 (87)	71 (13)			
Tackling	81 (88)	11 (12)			
Being tackled	202 (87)	29 (13)			
Other	48 (86)	8 (14)			
Injury contact					
Direct	207 (87)	30 (13)	0.250	.882	
Indirect	158 (86)	25 (14)			
Noncontact	621 (88)	87 (12)			
Graft type					
BPTB	793 (88)	113 (12)	0.057	.812	
HT	193 (87)	29 (13)			
Extra-articular tenodesis					
Yes	23 (77)	7 (23)	3.23	.72	
No	963 (88)	135 (12)			
Medial meniscus treatment					
Nil	767 (87)	110 (13)	13.24	.004	
Left in situ	125 (94)	8 (6)			2.24 (1.13-5.10)
Meniscectomy	48 (76)	15 (24)			0.46 (0.25-0.87)
Repair	45 (83)	9 (17)			0.72 (0.36-1.6)
Lateral meniscus treatment					
Nil	599 (88)	82 (12)	3.73	.292	
Left in situ	161 (83)	32 (17)			
Meniscectomy	200 (89)	24 (11)			
Repair	25 (86)	4 (14)			
Chondral pathology MFC					
Nil	851 (88)	111 (12)	8.13	.017	
Grade 1 or 2	100 (83)	20 (17)			0.65 (0.40-1.0)
Grade 3 or 4	35 (76)	11 (24)			0.42 (0.21-0.88)
Chondral pathology LFC					
Nil	851 (88)	113 (12)	4.53	.104	
Grade 1 or 2	121 (82)	26 (18)			
Grade 3 or 4	14 (82)	3 (18)			
Preoperative ACL-RSI score	49.9 ± 26.4	41.2 ± 25.1	0.11	<.001	1.01 (1.00-1.02)
IKDC score at 5 y	88.5 ± 9.2	80.1 ± 14	0.28	<.001	1.06 (1.04-1.08)

^aData are expressed as n (%) or mean ± SD. Bold *P* values indicate statistical significance. ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury; BPTB, bone–patellar tendon–bone; HT, hamstring tendon; IKDC, International Knee Documentation Committee; LFC, lateral femoral condyle; MFC, medial femoral condyle; RTP, return to play.

study by Øiestad et al²⁷ highlighted that ACLR often forced those involved in high-intensity sports to change discipline. In their study of level 1 athletes, they found that although 71% of patients returned to sport, only 52% returned to a pivoting sport. The high RTP rate in our cohort indicates that most athletes could resume level 1 sports after ACLR.

Our results demonstrated that 59.8% of athletes maintained a level of performance that was higher than or equivalent to their preinjury level at 5 years of follow-up. It is important to note that another 16% of those who returned to play did not provide data regarding their

performance level. Athletic performance is thought to decrease slightly after ACLR, although most athletes achieve a level of performance comparable to a matched cohort who have not undergone ACLR.^{6,11} Yet, this is contingent on the level of sport, position played, and the evaluation criteria. For example, Pinheiro et al³² evaluated a cohort of professional soccer players over 5 years and discovered that only 30% of athletes regained their preinjury performance level at 2 years, which decreased to 22% at 5 years. Results of National Football League players reported an RTP rate of 55.8%, with only 28.5% remaining in the league 3 years after injury. This study found

TABLE 5
Comparative Analysis Between Groups (Ipsilateral ACL Reinjury vs No Injury) at 5 Years of Follow-up^a

	Ipsilateral Reinjury	No Injury	Statistic	P Value	OR (95% CI)
Sex					
Male	56 (8)	656 (92)	1.02	.312	
Female	9 (6)	153 (94)			
Age, y	20.2 ± 5.2	23.6 ± 6.4	−0.14	<.001	1.11 (1.06-1.17)
Preoperative Marx score	11.6 ± 5.2	11.6 ± 5	0.004	.921	
Injury mechanism					
Jumping/landing	15 (9)	152 (91)	2.41	.661	
Sidestep/pivot	32 (8)	380 (92)			
Tackling	5 (7)	68 (93)			
Being tackled	9 (5)	170 (95)			
Other	4 (9)	39 (91)			
Injury contact					
Direct	11 (6)	177 (94)	1.05	.590	
Indirect	10 (7)	132 (93)			
Noncontact	44 (8)	500 (92)			
Graft type					
BPTB	30 (4)	666 (96)	48.53	<.001	5.56 (3.23-9.09)
HT	35 (20)	143 (80)			
Extra-articular tenodesis					
Yes	0 (0)	22 (100)	1.81	.178	
No	65 (8)	787 (92)			
Medial meniscus treatment					
Nil	51 (8)	626 (92)	3.31	.347	
Left in situ	6 (6)	103 (94)			
Meniscectomy	6 (13)	39 (87)			
Repair	2 (5)	40 (95)			
Lateral meniscus treatment					
Nil	38 (7)	497 (93)	2.52	.472	
Left in situ	13 (9)	125 (91)			
Meniscectomy	11 (6)	167 (94)			
Repair	3 (14)	19 (86)			
Chondral pathology MFC					
Nil	56 (7)	698 (93)	1.43	.488	
Grade 1 or 2	8 (9)	78 (91)			
Grade 3 or 4	1 (3)	33 (97)			
Chondral pathology LFC					
Nil	55 (7)	702 (93)	.257	.879	
Grade 1 or 2	9 (9)	95 (91)			
Grade 3 or 4	1 (8)	12 (92)			
Preoperative ACL-RSI score	51.3 ± 29.3	49.5 ± 26.3	0.02	.593	

^aData are expressed as n (%) or mean ± SD. Bold *P* values indicate statistical significance. ACL, anterior cruciate ligament; ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury; BPTB, bone–patellar tendon–bone; HT, hamstring tendon; LFC, lateral femoral condyle; MFC, medial femoral condyle.

a significant decrease in performance, games played, and approximate value for all positions, particularly running backs, defensive linemen, and linebackers.²⁴ While detailed metrics for amateur sporting performance are challenging to quantify, our study suggests that ACLR does affect an athlete's ability to return to their preoperative level. However, once an athlete returns, they can maintain their performance level for at least 5 postoperative years.

Consistent with the current literature, we found that decreasing age, higher preoperative activity levels, higher preoperative psychological readiness, and higher IKDC scores at 5 years were associated with an increased likelihood of RTP. The effect of age on RTP rates in level 1

athletes was previously recognized by Webster et al,⁴³ who reported that almost half of patients aged <25 years had returned by 1 year postoperatively, compared with one-third of those aged 26 to 35 years and one-fifth of those >36 years. Preoperative fear of reinjury and confidence have also previously been shown to be major determinants of RTP.^{3,42} The need to undergo medial meniscectomy or medial meniscus repair and a cartilage injury to the medial femoral condyle decreased the likelihood of RTP, which was also consistent with previous studies.³¹ Unsurprisingly, these factors were similar to those identified in this cohort at 2 years of follow-up given that 92.5% of athletes had achieved RTP by this time.

Ipsilateral ACL Reinjury

Previous research has shown that after ACLR, those who return to level 1 sports face up to 3.9 times the risk of ipsilateral reinjury and 5 times the risk of contralateral ACL injury compared with those who resume less demanding sports.⁴⁵ A systematic review by Wiggins et al⁴⁶ specifically analyzed patients <25 years of age who returned to a high-risk sport and found an ipsilateral reinjury rate of 10% and contralateral reinjury rate of 12% at a mean follow-up of 51 months. Similarly, Lindanger et al²⁰ followed a cohort of athletes who returned to pivoting sport over a 25 years, demonstrating an 11% revision ACLR rate and a 30% contralateral ACL injury rate. In our study, the rate of BPTB graft reinjury in those who returned to a level 1 sport was 1.9% at 2 years and 4.3% at 5 years of follow-up. This compares favorably to the rates previously reported in the literature.⁴⁷

One of the most striking results from this study was the significant difference in the rate of ipsilateral reinjury between BPTB autografts with screw fixation (4.3%) and HT autografts with EndoButton and screw fixation (19.7%). It is also important to note that the reinjury rate for HT grafts in our cohort is consistent with other reports in the literature. For instance, the reinjury rate for HT grafts at 2 years in our cohort of level 1 athletes (11.9%) was comparable to the 11% reinjury rate for isolated HT grafts using EndoButton and screw fixation in the Stability I randomized trial, which analyzed another high-risk cohort of patients who underwent ACLR. The addition of lateral extra-articular tenodesis in the Stability I trial reduced HT graft reinjury rates to 4% at 2 years, comparable to our rate of BPTB graft reinjury at 5 years of follow-up (4.3%).⁸ Another case series of 1000 HT autografts in Australian soccer players reported a 10% reinjury rate at 5 years, despite only 70% of patients returning to sport, which was identified as a risk factor for graft reinjury.²¹ The substantial difference in ipsilateral reinjury rates in our cohort suggests that intention to return to a level 1 sport may serve as a relative indication for BPTB use.

Our results contradict the meta-analyses performed by Xie et al⁴⁸ and Mohtadi et al,²⁵ which both found no difference in re-rupture rate between these autografts. Conversely, results from the Norwegian registry indicated that HT grafts were associated with twice the risk of revision compared with BPTB grafts.²⁹ Another study from the Norwegian registry noted that the method of HT autograft fixation influenced revision rates, although no combination of HT fixation had revision rates as low as those for BPTB grafts.³⁰ These conflicting results from large, heterogeneous patient cohorts emphasize the need for more detailed studies on specific subsets of patients who undergo ACLR.

Another important finding of this study was the sustained risk of ACL reinjury between 2 and 5 years of follow-up. Our results demonstrate that 50.8% of ipsilateral ACL injuries occurred during this time. This is often underappreciated given the shorter-term follow-up of many studies and highlights the prolonged risk of exposure to pivoting sports. We also identified younger age and the use of HT autograft as risk factors for reinjury, regardless of whether reinjury occurred before 2 years or between 2

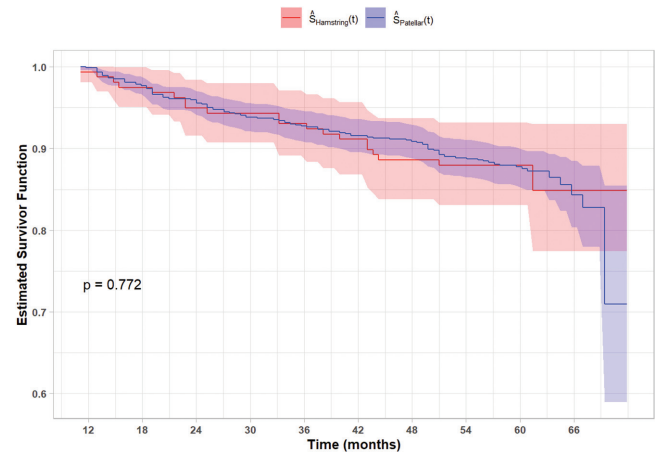


Figure 4. Kaplan-Meier plot demonstrating the probability of contralateral injury for level 1 athletes using bone–patellar tendon–bone autografts with screw fixation versus hamstring tendon autografts with EndoButton and screw fixation over 5 years of follow-up.

and 5 years postoperatively. Age is a well-established predictor of ACL reinjury, with studies demonstrating that patients <20 years have a 6-fold graft re-rupture risk and a 3-fold contralateral injury risk.^{36,43}

Contralateral ACL Injury

The rate of contralateral ACL injury in athletes who returned to level 1 sport was 13.7% at 5 years of follow-up. This is consistent with the rates reported in the literature, which are often cited as high as 2-fold the risk of graft reinjury.⁹ Specifically, studies have reported overall rates between 8.2% and 16%, with a pooled percentage of 11.8% at 5 years of follow-up.⁴⁷ Our results also identified that younger patient age and a higher preoperative Marx score were risk factors for contralateral ACL injury. This is also in keeping with the current literature.^{28,47} Our current understanding is that an increased risk of contralateral ACL injury is associated with postsurgical biomechanical changes in movement technique, which redistributes some of the loading from the reconstructed knee to the contralateral knee.^{15,40} It is also likely that patients who sustain an ACL injury have inherent predisposing factors that elevate their risk of subsequent ACL injuries.^{37,38} However, these factors are often challenging to quantify, and the extent of their effect is difficult to accurately measure. Regardless, the frequency of contralateral injuries highlights the importance of considering both knees during rehabilitation and maintaining strict criteria when implementing RTP guidelines.

IKDC Scores

The mean IKDC scores for this cohort at 2 and 5 years of follow-up were comparable (86.8 and 86.6 points,

TABLE 6
Comparative Analysis Between Groups (Contralateral ACL Injury vs No Injury) at 5 Years of Follow-up^a

	Contralateral Injury	No Injury	Statistic	P Value	OR (95% CI)
Sex					
Male	95 (13)	656 (87)	3.28	.070	
Female	33 (18)	153 (82)			
Age, y	20.3 ± 4.3	23.6 ± 6.4	-0.18	<.001	1.1 (1.07-1.14)
Preoperative Marx score	12.9 ± 4.0	11.6 ± 5.0	0.09	.006	1.07 (1.01-1.13)
Injury mechanism					
Jumping/landing	25 (14)	152 (86)	.525	.971	
Sidestep/pivot	63 (14)	380 (86)			
Tackling	9 (12)	68 (88)			
Being tackled	25 (13)	170 (87)			
Other	6 (13)	39 (87)			
Injury contact					
Direct	23 (12)	177 (89)	1.81	.404	
Indirect	18 (12)	132 (88)			
Noncontact	87 (15)	500 (85)			
Graft type					
BPTB	107 (14)	666 (86)	0.123	.725	
HT	21 (13)	143 (87)			
Extra-articular tenodesis					
Yes	1 (4)	22 (96)	1.73	.188	
No	127 (14)	787 (86)			
Medial meniscus treatment					
Nil	101 (14)	626 (86)	1.78	.62	
Left in situ	17 (14)	103 (86)			
Meniscectomy	7 (15)	39 (85)			
Repair	3 (7)	40 (93)			
Lateral meniscus treatment					
Nil	71 (13)	497 (88)	2.58	.461	
Left in situ	26 (17)	125 (83)			
Meniscectomy	27 (14)	167 (86)			
Repair	4 (17)	19 (83)			
Chondral pathology MFC					
Nil	109 (14)	698 (86)	1.78	.410	
Grade 1 or 2	16 (17)	78 (83)			
Grade 3 or 4	3 (8)	33 (92)			
Chondral pathology LFC					
Nil	108 (13)	702 (87)	1.34	.512	
Grade 1 or 2	19 (17)	95 (83)			
Grade 3 or 4	1 (8)	12 (92)			
Preoperative ACL-RSI score	50.1 ± 26.4	49.5 ± 26.3	0.007	.862	

^aData are expressed as n (%) or mean ± SD. Bold *P* values indicate statistical significance. ACL, anterior cruciate ligament; ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury; BPTB, bone–patellar tendon–bone; HT, hamstring tendon; LFC, lateral femoral condyle; MFC, medial femoral condyle.

respectively), demonstrating that IKDC scores remained stable after multiple seasons of returning to level 1 sport. Similar to our findings, Randsborg et al³⁴ found that patient-reported outcome measures were maintained 7 years after ACLR. They also found that a chondral lesion >2 cm was the strongest predictor of a poor outcome. Interestingly, there is also evidence to suggest that athletes who returned to level 1 sports had better self-reported function in activities of daily living and lower odds of osteoarthritis at 15 years.²⁷ Overall, this sustained, good functional outcome at 5 years after surgery is encouraging for athletes who wish to resume high-demand sports after ACLR.

There was no relationship between graft type and IKDC score <80 at 5 years of follow-up, which differed from the results of this cohort at 2 years of follow-up. The occurrence of anterior knee pain is often associated with BPTB autografts, although the specific origin of this symptom is unknown, and it has been suggested that this pain improves over time.^{18,22} For example, Rousseau et al³⁵ showed no discernible difference in knee symptoms between HT and BPTB groups at 2 years of follow-up despite more patients reporting anterior knee pain at the 1-year follow-up. A recent review of the New Zealand ACL Registry demonstrated that although BPTB grafts were associated with kneeling pain, they did not result in

TABLE 7
Comparative Analysis Between Groups (IKDC Score >90 vs IKDC Score <80) at 5 Years of Follow-up^a

	IKDC Score >90	IKDC Score <80	Statistic	P Value	OR (95% CI)
Sex					
Male	433 (75)	146 (25)	4.65	.031	1.50 (1.03-2.2)
Female	115 (67)	58 (34)			
Age, y	23.6 ± 6.5	27.7 ± 8	-0.25	<.001	1.07 (1.05-1.10)
Preoperative Marx score	11.3 ± 5.1	9.5 ± 5.6	0.14	<.002	1.06 (1.03-1.10)
Injury mechanism					
Jumping/landing	100 (74)	36 (26)	3.95	.412	
Sidestep/pivot	255 (71)	103 (29)			
Tackling	43 (74)	15 (26)			
Being tackled	115 (78)	32 (22)			
Other	35 (66)	18 (34)			
Injury contact					
Direct	128 (76)	40 (24)	2.06	.357	
Indirect	83 (75)	27 (25)			
Noncontact	337 (71)	137 (29)			
Graft type					
BPTB	442 (72)	170 (28)	0.703	.402	
HT	106 (76)	34 (24)			
Extra-articular tenodesis					
Yes	10 (63)	6 (38)	0.890	.346	
No	538 (73)	198 (27)			
Medial meniscus treatment					
Nil	430 (76)	135 (24)	25.56	<.001	
Left in situ	66 (75)	22 (25)			0.94 (0.57-1.62)
Meniscectomy	25 (48)	27 (52)			0.29 (0.16-0.52)
Repair	26 (57)	20 (43)			0.41 (0.22-0.76)
Lateral meniscus treatment					
Nil	349 (72)	134 (28)	5.29	.151	
Left in situ	75 (67)	37 (33)			
Meniscectomy	113 (80)	29 (20)			
Repair	10 (71)	4 (29)			
Chondral pathology MFC					
Nil	470 (76)	151 (24)	17.97	<.001	
Grade 1 or 2	57 (65)	31 (35)			0.59 (0.37-0.96)
Grade 3 or 4	21 (49)	22 (51)			0.31 (0.16-0.58)
Chondral pathology LFC					
Nil	475 (74)	171 (26)	9.64	<.008	
Grade 1 or 2	69 (73)	25 (27)			0.99 (0.62-1.65)
Grade 3 or 4	4 (33)	8 (67)			0.18 (0.05-0.58)
Preoperative ACL-RSI score	50.0 ± 26.6	41.3 ± 25.2	0.14	<.001	1.01 (1.00-1.02)

^aData are expressed as n (%) or mean ± SD. Bold P values indicate statistical significance. ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury; BPTB, bone-patellar tendon-bone; HT, hamstring tendon; IKDC, International Knee Documentation Committee; LFC, lateral femoral condyle; MFC, medial femoral condyle.

a more symptomatic knee overall compared with HT grafts.³³

The other factors we identified to be associated with lower IKDC scores have been highlighted in other studies, namely older age and female sex.¹⁹ As previously reported, medial meniscus pathology and femoral chondral defects also influenced the IKDC score.¹⁴

There are limitations to this study. All long-term evaluations are subject to a certain degree of recall bias. However, these data were collected prospectively at several time points to minimize this. Furthermore, RTP was defined as the unrestricted resumption of a patient's preinjury sport, although this may be influenced by individual

interpretation. Similarly, performance level was based on each participant's subjective assessment of their ability compared with their preoperative level. Each graft type used a different fixation method, and graft selection was not randomized, introducing an element of selection bias. There were 25 (1.7%) patients who did not intend to return to sport preoperatively who we excluded from our RTP analysis limiting our ability to compare directly with studies that do not apply this criterion. Lateral extra-articular tenodesis was performed in too small a subset of patients to comment on its influence on patient outcomes. Finally, we used ACL graft re-rupture as our definition of failure, and while this is superior to using revision surgery alone, it

may not account for patients with atraumatic, clinical failures such as increased graft laxity or an asymmetrical, symptomatic pivot shift.

CONCLUSION

This study prospectively reports the 5-year outcomes of a large cohort of level 1 athletes with 91.1% follow-up. Our results suggest that most level 1 athletes could RTP and maintain their level of performance for 5 years after ACLR. We also found that the risk of ipsilateral reinjury in patients who return to pivoting sports is significantly lower using BPTB autografts with screw fixation compared with HT autografts with EndoButton and screw fixation. Interestingly, most ipsilateral and contralateral ACL injuries occurred beyond 2 years postoperatively, highlighting the importance of ongoing injury prevention efforts and longer-term monitoring of patients after ACLR. Overall, the IKDC score was high, indicating maintained knee function over 5 years during high-intensity activities. Of note, the IKDC score was generally lower in female patients, older patients, and when concomitant meniscal/cartilage injuries were present.

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