

Patient Characteristics and Predictors of Return to Sport at 12 Months After Anterior Cruciate Ligament Reconstruction

The Importance of Patient Age and Postoperative Rehabilitation

Peter K. Edwards,^{*†‡} MSc, Jay R. Ebert,^{†‡} PhD, Brendan Joss,[‡] PhD, Timothy Ackland,[†] PhD, FASMF, Peter Annear,[§] MBBS, FRACS, Jens-Ulrich Buelow,[§] MD, FRACS, and Ben Hewitt,^{||} MBBS, FRACS

Investigation performed at the Hollywood Functional Rehabilitation Clinic, Nedlands, and University of Western Australia, Perth, Western Australia, Australia

Background: Preventing and mitigating the risk of reinjury after anterior cruciate ligament reconstruction (ACLR) rest on variables including age, surgical restoration of knee stability, adequate physical function, and thorough and complete postoperative rehabilitation, but to what degree these factors influence return to sport is unclear.

Purpose: To investigate factors predictive of return to sport 12 months after ACLR. The factors specifically evaluated were strength, hop function, self-reported knee function, patient age, and quality of postoperative rehabilitation.

Study Design: Case-control study; Level of evidence, 3.

Methods: This study evaluated 113 patients approximately 12 months after ACLR using a rehabilitation grading tool, the subjective International Knee Documentation Committee (IKDC) form, and a return-to-sport battery consisting of maximal isokinetic quadriceps and hamstring strength and 4 functional hop tests. Mann-Whitney *U* tests and chi-square analyses were used to determine differences between patients who had or had not returned to sport. A subsequent binary logistic hierarchical regression determined the factors predictive of a patient's return to sport. In those patients who had returned to sport, relationships between either age or level of rehabilitation and passing the return-to-sport battery were also investigated.

Results: Complete rehabilitation (adjusted odds ratio [OR], 7.95; $P = .009$), age ≤ 25 years (adjusted OR, 3.84; $P = .024$), and higher IKDC scores ($P < .001$) were predictive of return to sport at 12 months. In participants who had returned to sport, 21% passed the return-to-sport battery compared with only 5% who did not. Of those who had returned to sport, 37% who underwent complete rehabilitation passed the return-to-sport battery as opposed to 5% who underwent incomplete rehabilitation. In patients aged ≤ 25 years, only 48% underwent complete rehabilitation, despite having returned to sport. Additionally, in this group of patients, 40% underwent complete rehabilitation and passed the physical performance battery as opposed to only 4% who did not undergo complete rehabilitation.

Conclusion: Younger patients and higher subjective IKDC scores were predictive of return to sport. Patients who completed 6 months of rehabilitation incorporating jumping and agility tasks had a higher rate of return to sport, suggesting that postoperative rehabilitation is important in predicting return to sport. Specialists and physical therapists alike should stress the importance of thorough postoperative rehabilitation and adequate neuromuscular strength and function to patients whose goals are to return to sport.

Keywords: anterior cruciate ligament injury; return to sport; rehabilitation; single-leg hop test

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Anterior cruciate ligament (ACL) ruptures are commonly sustained during sports involving cutting, jumping, landing, and pivoting activities. Unfortunately, ACL reconstruction (ACLR) does not guarantee that the patient

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returns to sport, with only 63% of patients resuming pre-injury levels of activity and only 44% returning to competition.⁶ A patient's return-to-sport status is a common measure of both surgical and rehabilitation success as well as a measure of patient satisfaction.³² While patients are often restricted from undertaking sport activities too soon, ACLR studies still indicate a high incidence of ACL reruptures and revision cases, with the retear risk being highest during the first 12 months after surgery. The reinjury rate in the first year after ACLR is over twice as frequent when compared with uninjured knees.[†] Despite this knowledge, patients are often cleared to return to sport before 12 months, and in some cases, they are released less than 6 months after surgery.⁷ An increased risk of secondary injuries appears to be associated with participating in cutting and pivoting sport activities, younger age, incomplete graft healing, and/or improper rehabilitation.⁵⁶ The incidence of reinjury in patients younger than 25 years has been reported to be as high as 23%, a 30 to 40 times greater risk compared with their noninjured counterparts.⁵⁶

Persistent deficits in neuromuscular strength and altered limb-loading strategies during jumping and landing activities are key components of an increased secondary injury risk after ACLR.⁴³ Postoperative rehabilitation can address these deficiencies, thereby permitting a safe return to sport and/or physical activity.^{16,38,40,51} Before returning to sport, physical or functional performance tests (FPTs) should be undertaken to evaluate a patient's physical function and readiness to return to sport after ACLR.⁵⁰ FPTs assess the symmetry of lower extremity performance using single-leg hop tests,^{21,29,30,50} designed to simulate sport-related demands and neuromuscular control. These tests are often grouped in the form of a test battery. The results of individual tests are frequently reported as a limb symmetry index (LSI),⁵⁸ which aims to ensure that the operated limb reaches an acceptable level of strength or function to minimize the risk of overuse and/or further injuries when returning to sport or strenuous work.⁸ Recent ACLR studies have demonstrated an increased reinjury risk in patients not meeting a minimum 90% LSI on FPTs and strength tests.^{19,25}

Despite recent data, there still exists a low utilization of objective tests to assist in the return-to-sport decision-making process after ACLR, with time from surgery often the only variable considered.³⁴ Therefore, many patients may return to sport with persistent strength and performance impairments, which increase their risk of

reinjury.^{10,34} Existing research examining lower limb muscular strength and function after ACLR generally focuses on postoperative rehabilitation before returning to sport. What is not clear is how many of these patients returned to sport and whether they did so with adequate physical function.

The present study aimed to compare the physical profile of patients who had and had not returned to sport by 12 months after surgery. Second, it sought to investigate the factors predictive of return to sport within 12 months. Third, and specifically in those patients who had returned to sport, the current study sought to evaluate differences in strength, hop function, and self-reported knee function based on patient age as well as the duration and intensity of postoperative rehabilitation undertaken. We hypothesized that (1) the majority of patients who had returned to sport would demonstrate significantly better strength and hop function compared with those who had not returned to sport, (2) level of rehabilitation and patient age would be significant predictors of return to sport, and (3) in the subgroup of patients having returned to sport, the level of rehabilitation would play a significant role in determining whether a patient would pass a predetermined physical performance battery.

METHODS

Participants

A total of 113 patients (75 male and 38 female) who reported being involved in level I/II sports before an ACL injury were evaluated between 10 and 14 months after surgery. All patients underwent ACLR using a single-bundle hamstring autograft and were free of any concurrent musculoskeletal problems with their contralateral lower limb. Patients exhibiting a concomitant injury subsequent to the ACL injury were included in the analysis. Any patient with a history of surgery on the operated lower limb (including prior ACLR) or on the contralateral limb were excluded because of the potential influence that this may have on clinical outcomes. Given the retrospective nature of this study, patients did not follow a standardized rehabilitation protocol. Rather, they received guided rehabilitation from their local physical therapist, exercise physiologist, or independently at their own discretion. Patients were not given any specific criteria for return-to-sport clearance other than the generic advice provided from their surgeon at the last postoperative follow-up or verbal clearance from their physical therapist.

Participants were most commonly injured while playing high-risk sports (88%), which were defined as sports

[†]References 9, 17, 25, 27, 41, 46, 47, 50, 55.

*Address correspondence to Peter K. Edwards, MSc, School of Human Sciences, University of Western Australia, 35 Stirling Highway, Crawley, 6009, WA, Australia (email: peter.edwards@uwa.edu.au)(Twitter: @AEP_Pete).

[†]School of Human Sciences, University of Western Australia, Perth, Western Australia, Australia.

[‡]Hollywood Functional Rehabilitation Clinic, Nedlands, Western Australia, Australia.

[§]Perth Orthopaedic and Sports Medicine Centre, West Perth, Western Australia, Australia.

^{||}Orthology, West Perth, Western Australia, Australia.

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Ethical approval for this study was obtained from Hollywood Private Hospital (HPH382).

TABLE 1
Postoperative Rehabilitation Grading Scale

Grade	Description
0	No rehabilitation and sedentary
1	No supervised rehabilitation and reported self-managed return to light activity
2	Three months of supervised rehabilitation/physical therapy, followed by self-managed home exercises and return to light activity
3	Three months of supervised rehabilitation/physical therapy, followed by independent return to structured gym exercises and return to activity
4	Six months of supervised rehabilitation/physical therapy, followed by independent return to structured gym exercises and return to activity
5	Six months of supervised rehabilitation/physical therapy, including structured agility and landing exercises, followed by independent return to structured gym exercises and return to activity
6	Over 6 months of supervised rehabilitation/physical therapy as above, with supervised full return to sport

involving cutting, pivoting, or landing movements. These included Australian football (n = 25; 22%), soccer (n = 20; 18%), netball (n = 17; 15%), basketball (n = 15; 13%), and “other sports” (n = 36; 32%), which involved a variety of sports including martial arts, rugby, and surfing.

Patient-Reported Questionnaires

Two patient-reported outcome measures were completed. These included the International Knee Documentation Committee (IKDC) subjective knee evaluation form to measure knee symptoms, function, and sport activities^{23,24} and the Noyes Sports Activity Rating Scale (NSARS) to determine both individual functional limitations and an overall level of past and current activity/sport participation.³⁷ The NSARS was used to stratify patients based on their current activity/sport level, allowing an evaluation of lower limb strength/functional symmetry specifically in those patients who had already returned to higher risk activities. Return to sport was defined using the NSARS as those patients having returned to level I (participation 4-7 d/wk) or level II (participation 1-3 d/wk) activities that included jumping, hard pivoting, cutting, running, twisting, and/or turning sports, otherwise known to be “high risk.” While variations exist as to what constitutes a “successful” return to sport,^{2,7} it is well documented that the risk of ACL graft ruptures and contralateral injuries is associated with sports involving pivoting, landing, and cutting.^{42,53} Therefore, a return to these “high-risk” sports was included.

Postoperative Rehabilitation

Each participant was asked to rate his or her rehabilitation based on a 7-level scale (Table 1).¹³ This rehabilitation scale was discussed with patients, who were asked to select the most appropriate level of rehabilitation that they undertook from the time immediately after surgery until the day of assessment. Rehabilitation was then further categorized as either “complete” (grades 5 and 6) or “incomplete” (grades 0-4). Specifically, and consistent with the current literature,^{18,52} “complete” rehabilitation was defined as supervised rehabilitation for at least 6 months, which incorporated structured hopping, agility, and

landing exercises, followed by either an independent or facilitated return to structured gym exercises and return to activity supervised by an allied health professional. “Incomplete” rehabilitation was defined as rehabilitation that lasted less than 3 months and/or did not include any structured hopping, agility, and/or landing exercises.

Description of the Test Battery

All participants were evaluated by 2 examiners (P.K.E., J.R.E.). Before the physical evaluation, all patients completed a 6-minute walk test,¹⁴ which we deemed a standardized warm-up that prepared both the involved and noninvolved lower limbs, followed by an optional stretching period of 5 to 10 minutes, which was not standardized. The following FPTs as used in previous studies^{19,28,29,50} were then performed in order: single-leg hop for distance, timed 6-m hop, triple hop for distance, and triple crossover hop for distance. Participants completed the hop battery by undertaking 2 sets of each FPT, alternating between the nonoperated and operated legs. For the single-leg, triple, and triple crossover hop tests, hop distance was measured from the position of the stance toe before take-off to the position of the toe at final landing. A valid trial required the final hop to be completed with a stable landing, with the best trial selected for analysis. Patients were given a nonstandardized rest period and opportunity to stretch between trials to minimize fatigue. The LSI, in which the score for the operated limb was expressed as a percentage of that for the unaffected limb, was calculated for all hop tests.

After the hop tests, isokinetic strength of the quadriceps and hamstring muscle groups was assessed using an isokinetic dynamometer (Isosport International). Patients were seated in the dynamometer chair so that the hips and knees were at 90°. The trunk and thigh were stabilized using rigid straps, and the apparatus was adjusted to accommodate the individual thigh and leg lengths. Concentric knee extension and flexion strength were measured through a range of 0° to 90° of knee flexion at an angular velocity of 90 deg/s. Each trial consisted of 4 repetitions: 3 low-intensity repetitions of knee extension and flexion, immediately followed by 1 maximal effort. Three trials on each lower limb were undertaken, alternating between the operated and

nonoperated limbs, with the first trial always undertaken on the nonoperated side. During each test effort, patients were asked to perform to their maximal muscle strength, while standardized verbal encouragement was also provided. Similar to the hop-based assessments, patients were given adequate rest time between trials to minimize fatigue. For all knee extension and flexion efforts, the peak torque value (N·m) was obtained. An LSI was calculated for all strength measures by dividing the peak values on the operated limb by those recorded on the nonoperated limb.

Pass/Fail Criteria

To “pass” the test battery, participants were required to achieve an LSI $\geq 90\%$ on the operated limb for the 4 hop tests and peak isokinetic quadriceps and hamstring strength. Participants were classified as “pass” on LSIs $\geq 90\%$ on all 6 measures or “fail” on LSIs $< 90\%$ on 1 or more measure.

Statistical Analysis

Statistical analysis was conducted using SPSS version 23.0 (IBM). Descriptive statistics were calculated for all demographic, subjective, and functional data between patients who had or had not returned to sport. Between-group differences were assessed using Mann-Whitney *U* tests and chi-square analyses where applicable. Means, standard deviations, and proportions were calculated for all variables, and statistical significance was calculated at an alpha of 0.05. Significant differences between the 2 groups with the Mann-Whitney *U* tests and chi-square analyses for categorical variables were subsequently included in a binary logistic hierarchical regression to determine which factors were best predictive of a patient returning to level I/II sports. Predictor variables were entered in order of non-modifiable factors of age (grouped as ≤ 25 and > 25 years) and body weight, followed by rehabilitation (complete or incomplete) and finally the IKDC score, which was entered as a continuous variable. A pass/fail on the physical performance battery was entered last to examine whether this variable would significantly predict return to sport after accounting for the rehabilitation variable. The final model included all variables that had a significant association with return to sport. In a subgroup of patients who had returned to sport, the patients who passed the performance battery were stratified by age (≤ 25 and > 25 years) and rehabilitation (complete or incomplete). Odds ratios (ORs) and 95% CIs were used to determine whether relationships existed between either age or level of rehabilitation and passing the return-to-sport battery.

RESULTS

Of the 113 patients included in this study, 72 (64%) had returned to level I or II sport by the time of their clinical evaluation. The remaining 41 (36%) were either sedentary or had returned to light sport and activities with a low risk of ACL injuries. Table 2 shows a comparison of the anthropometric and injury characteristics between those patients

TABLE 2
Demographics in Patients Who Had or Had Not Returned to Level I/II Sports^a

	Returned to Sport (n = 72)	Not Returned to Sport (n = 41)	<i>P</i> Value
Age, mean \pm SD	22.9 \pm 6.4	31.1 \pm 8.3	<.001
≤ 25 y	48	11	
> 25 y	24	30	
Sex			.360
Male	50	25	
Female	22	16	
Height, mean \pm SD, m	1.76 \pm 0.1	1.76 \pm 0.1	.879
Weight, mean \pm SD, kg	75.5 \pm 13.9	81.1 \pm 15.3	.039
Concomitant injury/procedure			.260
None	36	16	
Yes	36	25	
Meniscectomy	22	25	
Meniscus repair	3	1	
Chondral defect	1	2	
MCL/LCL injury	4	3	
Injury mechanism			.703
Contact	12	8	
Noncontact	60	33	
Months from ACLR to assessment, mean (range)	12.2 (10-14)	12.4 (10-14)	.370

^aData are shown as No. unless otherwise specified. Bolded *P* values indicate significant between-group differences ($P < .05$). ACLR, anterior cruciate ligament reconstruction; LCL, lateral collateral ligament; MCL, medial collateral ligament.

who had and had not returned to sport. Of the concomitant injuries included, these were largely meniscus injuries, which were either excised or repaired using the Fast-Fix method (Smith & Nephew). Other concomitant injuries included medial collateral ligament sprains and chondral defects, all of which were treated conservatively. The breakdown of concomitant injuries between the 2 groups is shown in Table 2.

Patients who had returned to level I/II sports were not only significantly younger than those who had not returned to sport, but a significantly higher proportion of patients who returned to sport were also ≤ 25 years of age (Table 2). Half (51%) of the patients who had returned to sport had done so after incomplete rehabilitation. Furthermore, a significantly higher proportion of patients who had undertaken complete rehabilitation had returned to sport and had passed all components of the physical performance battery. In the cohort of patients who had returned to sport, 15 of 72 (21%) passed the return-to-sport clearance battery by achieving LSIs $\geq 90\%$ for all 6 strength and functional measures, as opposed to 2 of 41 patients (5%) who had not returned to sport. Significantly greater subjective IKDC scores, LSIs in all hop categories, and strength were observed in patients who returned to level I and II sports compared with those who had not (Table 3).

Logistic regression analysis revealed that complete rehabilitation (adjusted OR, 7.95; $P = .009$), patient age ≤ 25

TABLE 3
Subjective and Objective Group Differences in Patients Who Had or Had Not Returned to Level I/II Sports^a

	Returned to Sport (n = 72)	Not Returned to Sport (n = 41)	P Value
Postoperative rehabilitation, n			<.001
Complete	35	3	
Incomplete	37	38	
Pass/fail, n	15/57	2/39	.023
Single-leg hop LSI, %	94.2 ± 8.2	77.1 ± 17.6	<.001
6-m timed hop LSI, %	94.0 ± 8.8	78.4 ± 18.6	<.001
Triple hop LSI, %	94.6 ± 8.9	77.9 ± 19.1	<.001
Crossover triple hop LSI, %	94.0 ± 8.2	76.4 ± 20.7	<.001
Peak quadriceps torque LSI, %	88.1 ± 14.0	71.9 ± 23.5	<.001
Peak hamstring torque LSI, %	95.5 ± 14.5	84.7 ± 16.1	.001
IKDC score	88.4 ± 8.6	73.4 ± 12.3	<.001

^aData are shown as mean ± SD unless otherwise specified. Bolded *P* values indicate significant between-group differences ($P < .05$). IKDC, International Knee Documentation Committee; LSI, limb symmetry index.

TABLE 4
Significant Predictors of Returning to Level I/II Sports^a

	Returned to Sport ^b	Not Returned to Sport ^b	Adjusted Odds Ratio	95% CI	P Value
Complete rehabilitation	35 (49)	3 (7)	7.95	1.63-38.77	.009
Age ≤25 y	48 (67)	11 (27)	3.84	1.19-12.30	.024
IKDC score	88.4	73.4	1.13	1.07-1.20	<.001

^aBolded *P* values indicate significant between-group differences ($P < .05$). IKDC, International Knee Documentation Committee.

^bData are shown as n (%) or mean.

TABLE 5
Physical Performance Test Results in Patients Who Had Returned to Level I/II Sports, Stratified by Postoperative Rehabilitation^a

	Complete Rehabilitation (n = 35)	Incomplete Rehabilitation (n = 37)	P Value
Single-leg hop for distance	97.57 ± 8.32	91.46 ± 7.49	.020
6-m timed hop	96.45 ± 9.48	91.33 ± 7.28	.009
Triple hop for distance	97.26 ± 9.72	92.00 ± 7.35	.011
Triple crossover hop for distance	96.44 ± 8.62	93.19 ± 6.73	.035
Knee extension peak torque	91.87 ± 15.57	82.30 ± 10.24	.030
Knee flexion peak torque	99.54 ± 17.75	90.62 ± 11.28	.072
Pass, n (%)	13 (37)	2 (5)	.001

^aData are shown as mean ± SD unless otherwise specified. Bolded *P* values indicate significant between-group differences ($P < .05$).

years (adjusted OR, 3.84; $P = .024$), and higher 12-month IKDC scores ($P < .001$) were predictive of return to sport at the time of the clinical assessment (Table 4). As indicated in Table 5, 35 of 72 patients (49%) who had returned to sport undertook complete rehabilitation, defined as supervised rehabilitation beyond 6 months in duration and incorporating agility, landing, and hop-based exercises as part of the program. In a subgroup analysis of the 72 patients who had returned to sport, 13 of the 35 patients (37%) who underwent complete rehabilitation successfully passed the physical performance battery, as opposed to 2 of the 37 patients (5%) who underwent incomplete rehabilitation (OR, 10.34; $P = .001$) (Table 5).

As reported in Table 2, 81% of participants aged ≤25 years had returned to level I/II sports at 12 months after surgery. Despite having returned to sport, only 23% of these patients met all of the criteria required to pass the physical performance battery. Furthermore, less than half (48%) of patients aged ≤25 years undertook complete rehabilitation, despite having returned to sport. In these participants aged ≤25 years and without having undergone complete rehabilitation, only 1 patient (4%) passed the physical performance battery. In contrast, 40% of patients aged ≤25 years who completed rehabilitation passed the physical performance battery (OR, 14.67; $P = .003$).

DISCUSSION

This study evaluated the patient characteristics, including postoperative rehabilitation, return-to-sport status, and physical function, of 113 patients who were engaged in nonelite sports before their ACL injury. At 12 months after surgery, 63% of the patient sample had returned to their preinjury level of sport, which is consistent with previous research by Ardern et al,⁶ who reported that 63% of patients resumed participation at their preinjury level of activity by 12 months after surgery. The factors that were more likely to predict return to sport at 12 months were younger patient age, complete rehabilitation, and higher subjective IKDC scores. Previous research has found sex-based differences in outcomes after ACLR, with female patients demonstrating poorer subjective and functional outcomes, including a reduced ability to return to sport.⁴⁹ No sex differences were observed in return-to-sport outcomes at 12 months in this study.

When looking at the physical function of patients, only 17 of 113 patients who had been involved in level I/II sports before their injury met the 6 physical performance criteria making up the return-to-sport clearance battery at 10 to 14 months after surgery. Alarming, only 21% of patients who had returned to sport passed the return-to-sport clearance battery by achieving LSIs $\geq 90\%$ across all 6 strength and functional measures. This suggests that over three-quarters of patients who had returned to high-risk sports were doing so without having met the 6 physical elements of our return-to-sport battery and thus being at an elevated risk of graft ruptures or contralateral injuries.

The low proportion of patients not meeting the performance criteria suggests that this battery may be too stringent for patients to pass before returning to sport. In fact, the same criteria used in this study have been reported to be some of the most demanding in the literature and in clinical practice.^{1,54} However, our clearance battery was similar to the one used by Kyritsis et al,²⁵ who reported that athletes who did not meet the required clearance criteria before returning to sport had a 4-fold greater risk of sustaining an ACL graft rupture compared with those who had met the criteria. It is also the same battery used by Grindem et al,¹⁹ who reported an estimated 84% lower knee reinjury rate in patients who passed return-to-sport criteria within 2 years of ACLR. Conversely, Wellsandt et al⁵⁴ reported that achieving limb symmetry in quadriceps strength and the single-leg hop test after ACLR overestimates knee function, potentially clearing patients to return to sport when they are not functionally ready. This suggests that the return-to-sport criteria used in this study, and indeed in clinical practice after ACL injuries, are not stringent enough to provide a safe clearance to return to sport.

While a number of factors may influence lower limb strength and function after ACLR, postoperative rehabilitation is considered critical. In this study, complete rehabilitation was defined as an exercise rehabilitation program that incorporated movements and activities that clinically replicate conditions experienced during sport, such as hopping, jumping, and landing, given that these tasks have been suggested to facilitate a successful return to sport and

reduce the reinjury risk.^{12,32,35} We demonstrated that rehabilitation was the strongest predictor of return to sport at 10 to 14 months after surgery. Those patients who reported undertaking complete rehabilitation were almost 8 times more likely to return to sport compared with those who did not. However, even among those patients who had returned to sport, only 49% undertook complete rehabilitation. In a subgroup analysis of the 72 patients who returned to level I/II sports, 37% of those who reported undertaking complete rehabilitation successfully passed all components of the physical performance battery, compared with 5% of patients who passed the test battery but had not undertaken complete rehabilitation. Essentially, for patients who had already returned to sport, those who embarked on a more thorough rehabilitation regimen were 10 times more likely to perform better. This improved physical function may better meet the demands of high-risk sports and potentially reduce the reinjury risk. However, it is important to note that this study does not imply that passing functional tests correlates with return to sport. In fact, in our regression analysis, we showed that this was not the case. It is also not known if additional rehabilitation can correct the deficits if they are below the criteria. Future research is needed to see if later stage training could correct these deficits.

It is well known that younger age serves as a significant risk factor for secondary injuries after ACLR. Paterno et al⁴² reported that 29.5% of athletes under 25 years of age suffered a second ACL injury within 24 months of return to sport, with 20.5% sustaining a contralateral injury and 9.0% reinjuring the graft. In a systematic review, Wiggins et al⁵⁶ identified younger patients (<25 years) and those who returned to a high level of activity, especially in high-risk sports, to be at an increased risk; the secondary ACL injury rate was 23%, with an ipsilateral reinjury rate of 10% and a contralateral injury rate of 12%. The reasons for the increased risk are likely to be multifactorial, as younger age most likely represents a proxy for other factors.⁵³ First, younger patients are more likely to return to high-risk sports that involve cutting, jumping, and pivoting movements. In the current study, younger age was a significant predictor of return to sport, with 81% of patients aged ≤ 25 years having already returned to level I/II sports at the time of the clinical evaluation. Second, neuromuscular and physical impairments have been shown to be predictive of second ACL injuries in young athletes^{41,42}; therefore, incomplete neuromuscular maturation may also be an age-related risk factor. Alarming, in this study, we observed that over half (52%) of the patients aged ≤ 25 years who were back playing sport had done so without having undertaken complete rehabilitation, potentially putting them at an increased reinjury risk. Furthermore, in younger patients, those who completed proper rehabilitation were almost 15 times more likely to pass the physical performance battery. This suggests that rehabilitation is important, certainly in younger athletes, and could be a critical factor in potentially reducing the reinjury risk.

Our study was limited in that it focused solely on strength and performance symmetry. A range of variables including psychological factors (fear of reinjury and confidence) has also been shown to influence physical

performance and return to sport but was not included in the analysis.^{3-5,11,26,31,48} To better standardize the cohort, all study participants had undergone ACLR utilizing hamstring grafts. While the hamstring remains a common ACLR graft choice,^{15,36,57} these results cannot be generalized across all reconstruction techniques. The patient evaluation in this study did not include objective knee laxity. Greater anterior laxity has been previously shown to affect strength and hop test function after ACLR,⁴⁵ so it is possible that greater knee laxity may have confounded some of the results.

Regarding our return-to-sport battery, the LSI is currently the most commonly reported method of presenting strength and function outcomes,^{20,50,51} although it does not account for potential deconditioning of the nonoperated side.⁵¹ As described above, Wellsandt et al.⁵⁴ found that postoperative LSIs may indeed overestimate function, and therefore, future research may consider using what the authors termed the “estimated preinjury capacity,” in which limb symmetry is determined by comparing involved limb measurements at a time point postoperatively with the uninvolved limb measurements before ACLR. In addition, LSIs of hop test performance may present well in the absence of sound hopping and landing biomechanics, so we recommend that future research evaluate “biomechanical symmetry” in addition to “performance symmetry,” which may be associated with ACL injuries.^{22,33,39}

Finally, we endeavored to minimize fatigue by giving patients adequate rest time during tests, although all hop and strength assessments were performed in the same test session for patient convenience. The hop tests used in this study have previously demonstrated test-retest reliability,⁴⁴ and some researchers have encouraged the undertaking of these tests in a fatigued state, suggesting that it better replicates game settings.^{8,20,50}

CONCLUSION

Younger patient age, a higher subjective IKDC score, and postoperative rehabilitation indicated that patients were more likely to have returned to sport by 12 months. Furthermore, despite their return to sport, many patients did not meet the required physical criteria to do so, potentially elevating the risk of reinjury. Postoperative rehabilitation was significantly associated with greater physical function, particularly in younger patients, and may be highly influential in restoring physical function before returning to sport, potentially lowering the risk of reinjury.

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