



Postoperative Pain Is Associated With Psychological and Physical Readiness to Return to Sports One-Year After Anterior Cruciate Ligament Reconstruction

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Purpose: To identify whether any patient factors, injury factors, or symptom severity scores are associated with either psychological or physical readiness to return to sport after anterior cruciate ligament reconstruction (ACLR). **Methods:** Consecutive patients with an ACL injury that required surgical treatment were included in this study. All patients completed the single-legged hop testing and the Anterior Cruciate Ligament Return to Sport Index (ACL-RSI) at 1 year postoperatively. Multivariable regression analysis models were used to determine whether an independent relationship existed between baseline patient factors (age, sex, BMI, preinjury Marx Activity Score), injury factors (meniscal tear and chondral injury), physical symptoms (Knee Injury and Osteoarthritis Outcome Score [KOOS] for pain and symptoms), and the dependent variables of physical and psychological readiness to return to sport (single-legged hop and ACL-RSI). **Results:** Of the 113 patients who were included, 37% were female, and the mean age of our population was 28.2 years (SD = 8.1). Multivariable regression models demonstrated that patient-reported pain symptoms at 1 year postoperatively, as measured by the KOOS pain subscale, was significantly associated with both ACL-RSI score (Beta estimate: 1.11 [95% CI: .62-1.60] $P < .001$) and the ability to pass the single-legged hop test (OR: 1.07 [95% CI: 1.004-1.142] $P = .037$). **Conclusions:** Patients with higher reported pain levels at 1 year following ACLR have lower psychological and physical readiness to return to sport. **Level of Evidence:** Level 3, retrospective cohort study.

Introduction

Anterior cruciate ligament (ACL) ruptures are common injuries in athletes, with an incidence of 38.9 (95% CI 30.7-49.3) per 100,000 person-years depending on the type of sports, level of sports participation, and gender.^{1,2} The highest ACL injury rates can be found in young active athletes participating in

high-risk sports that involve pivoting, shifting, and cutting movements.³ Although anterior cruciate ligament reconstruction (ACLR) may result in satisfactory long-term clinical outcomes for many, not every athlete will return to sports postoperatively.⁴ A meta-analysis by Ardern et al. in 2011 showed that 4 years after ACLR, only 63% of patients had returned to sports at their preinjury level, and only 44% had returned to competitive sport.⁵

In order to gauge which athletes are ready to safely return to sport, many physicians employ objective measurements of physical readiness, such as muscle strength measurements and single-legged hop tests.^{6,7} Often, these tests, in addition to clinical assessment and time-based restrictions, are used to provide clearance to athletes to initiate high-risk activities, such as pivoting and/or game play. In particular, the single-legged hop test has been validated as a predictor of safe return to sport at patients' preoperative level.⁸ Current recommendations suggest athletes achieve a distance of at least 90% of their uninjured leg in the best of three attempts to return to play after ACLR.⁹

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However, physical ability to return to sport alone does not adequately capture patient outcomes. Recently, studies have demonstrated the influence of psychological factors on patients' ability to return to sport.¹⁰⁻¹³ Because of the multifaceted and complex nature of psychological readiness to return to sport,¹⁴ many practitioners have reported feeling unprepared to evaluate their patients in this regard.¹⁵ Accordingly, many clinicians are using the Anterior Cruciate Ligament Return to Sport Index (ACL-RSI), a valid and reliable patient reported measure of psychological readiness to return to sport.¹⁶

The purpose of this study was to identify whether any patient factors, injury factors, or symptom severity scores, are associated with either psychological or physical readiness to return to sport after ACLR. We hypothesize that postoperative knee pain would interfere with psychological and physical readiness to return to sports.

Materials and Methods

Design

A retrospective review of prospectively collected data in patients who underwent ACLR by a fellowship-trained sports surgeon specialty group ($n = 4$) at a single academic center was performed. The study protocol was approved by the local ethics committee (study number: 2014-0006-B).

Participants

Patients with a unilateral ACL rupture between the ages of 16 to 55 years that required surgical reconstruction from 2013 to 2014 with one year of follow-up were included. All patients were diagnosed and deemed to require surgery through a combination of clinical history, examination, and magnetic resonance imaging.

Exclusion criteria included patients with a multiligament knee injury or revision ACLR, patients who declined to participate, and those who had follow-up but were unable to complete outcome questionnaires.

Treatment and Rehabilitation

All participants should have presented with adequate range of motion and minimal swelling prior to surgery. The ACL was reconstructed with a single-bundle, bone-patellar, tendon-bone (BTB) autograft using the antero-medial portal for femoral tunnel drilling. All surgeons used interference screws for fixation of the graft. The need for adjunct meniscal and/or cartilage procedures at the time of ACLR was determined by the treating surgeon and documented. All patients were instructed to be weight-bearing as tolerated postoperatively, and began a standardized rehabilitation program on postoperative day 1.¹⁷ Patients with meniscus repair and chondral interventions were kept touch weight-bearing

for 6 weeks. Return to the preinjury level of sport was targeted for low-risk sporting activities between 6 and 9 months postoperatively, and high-risk sporting activities involving pivoting and cutting between 9 months and 1 year.

Readiness to Return to Sport Outcomes

The single-leg-hop test was used to measure functional hop performance at baseline and 12 months post-ACLR¹⁸. Patients were standing on one leg and being instructed to jump straight ahead as far as possible and to land on the same leg. This test was considered successful if the landing was stable and considered unsuccessful in cases in which the patients lost their balance, touched down with the contralateral limb, or took additional hops after landing. A total of three trials were performed and the best trial was used for analysis. The ratio between the injured and uninjured contralateral leg was calculated as the limb symmetry index (LSI), with those who obtained a distance greater than or equal to 90% of the contralateral leg considered to pass the test, with less than 90% being considered a fail.¹⁹

Patients were also asked to complete the ACL-RSI scale at the one-year visit. The ACL-RSI is a 12-item scale designed to evaluate psychological readiness to return to sports after ACLR or injury.¹⁶ This scale consists of three specific domains: emotions, confidence in performance, and risk appraisal, and is scored on a scale from 0 to 100, with higher scores indicating greater readiness for return to sports.

Covariates

Covariates for inclusion in our statistical models were determined a priori on the basis of previous literature identifying factors that influence outcomes of ACLR.²⁰⁻²⁴

Demographic and patient factors, including age, sex, BMI, and preinjury activity level (Marx Activity Score) were recorded at the patient's first visit.

Injury factors and related treatments were assessed and recorded at the time of surgery. Concomitant injuries to the menisci (lateral versus medial, both) were noted and, if necessary, treated with meniscus repair or with partial meniscectomy where appropriate. Cartilage lesions of the knee were documented using the International Cartilage Regeneration and Joint Preservation Society Score (ICRS).²⁵ Cartilage lesions grade I-II were considered as low grade, and grade III-IV lesions were considered as high-grade injuries. Symptomatic high-grade cartilage lesions (ICRS grade III/IV) were treated with debridement and microfracture.

Patient symptoms were evaluated using the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire, a reliable, valid, and responsive outcome measure in patients with ACLR.²⁶ The KOOS consists of

a total of five domains: pain, symptoms, activities of daily living, sports and recreation, and knee-related quality of life.²⁷ To investigate the relationship between patient symptoms and readiness to return to sport, the KOOS Pain and Symptoms subscales at 1 year following surgery subscales were included as covariates.

To determine whether physical readiness to return to sport had independent influence on psychological readiness, and vice versa, the single-legged hop test was included as a covariate for psychological readiness (ACL-RSI). Inversely, ACL-RSI score was included as a covariate for physical readiness (single-legged hop test).

Analysis Plan and Statistical Analysis

Descriptive data are presented as means (\pm SD), medians (interquartile range [IQR]) for continuous variables, and number (percentage) for categorical variables as appropriate. Single-legged hop test results at 1 year were dichotomized into passing and failing as described above. KOOS subscale scores were compared from baseline to 1 year using two-sided paired *t*-tests. A multivariable linear regression analysis was used to model the relationship between included covariates and ACL-RSI score, producing beta estimates and 95% confidence intervals. To assess adjusted associations between covariates and single-legged hop outcome, a multivariable logistical regression model was constructed. To prevent overparameterization in the setting of this categorical outcome, a univariate logistic regression screen was performed, and covariates with a *P* value of less than .25 were retained within the final model. This multivariable logistic regression model was used to determine association, odds ratios, and 95% confidence intervals for each included covariate with single-legged hop outcomes. Key modeling assumptions were tested for all models, including graphical inspection for influential outliers, assessment of model fit for logistic regression models using Hosmer Lemeshow tests, and assessment for normality of residuals, straight line relationship, and homoscedasticity for linear regression models. All assumptions were confirmed. The level of significance was set at *P* < .05. All statistical analyses were performed with the program SAS version 9.5 (Cary, NC).

Results

A total of 140 potential subjects were identified. Twenty-five declined to participate, and two were unable to complete the outcome questionnaire and were excluded. The 113 patients who were included in this study had a mean age of 28.2 years (SD 8.1) and 63% (*n* = 71) were male.

The median BMI of our patient collective was 24.4 (IQR 22.3-26.1). [Table 1](#) illustrates the demographic data, as well as the intraoperative findings and respective surgical treatment.

Table 1. Baseline Description of Patients

Patient Characteristics	Value (Total <i>n</i> = 113)
Age	
Mean (SD)	28.1 (8.1)
Sex	
Female	42 (37%)
Male	71 (63%)
BMI	
Median (SD)	24.8 (3.5)
Preinjury Marx Activity Score	
Median (IQR)	12 (8-16)
Medial meniscus tear	
Yes	47 (42%)
No	66 (58%)
Lateral meniscus tear	
Yes	42 (37%)
No	71 (63%)
Chondral lesion	
Yes	50 (44%)
No	63 (56%)
High-grade chondral lesion	
Yes	9 (8%)
No	104 (92%)
Meniscus repair at time of surgery	
Yes	27 (24%)
No	86 (76%)
Meniscectomy at time of surgery	
Yes	44 (39%)
No	69 (61%)

BMI, body mass index; IQR, interquartile ratio.

Baseline patient KOOS scores, as well as 1-year follow-up are presented in [Table 2](#). At the one-year follow-up, all KOOS scores improved, with the exception of KOOS Symptoms, significantly in the cohort (*P* < .001).

Patient outcomes for 1-year single-legged hop test and ACL-RSI scores are presented in [Table 3](#).

Multivariable Regression

The multivariable linear regression model identifying factors associated with ACL-RSI score demonstrated a positive association of the KOOS Pain Score with ACL-RSI (Beta Estimate 1.13 [95% CI .63-1.62, *P* < .001] ([Table 4](#)). No other factors were found to be significantly associated with ACL-RSI score.

Univariate screening of associations between identified covariates and single-legged hop resulted in the inclusion of five covariates within our multivariable model: age, BMI, chondral lesions, KOOS Pain score, and ACL-RSI score ([Table 5](#)). A multivariable logistic regression model identifying factors associated with single-legged hop test results demonstrated a 1.06 times increased odds of passing the hop test with each point increase in the KOOS Pain score (less pain) (OR 1.06 [95% CI 1.002-1.12] *P* = .042) ([Table 5](#)). No other included covariates were found to have a statistically significant influence on the odds of passing the single-legged hop test.

Table 2. KOOS Domain Scores at Baseline and 1 Year

KOOS Domain	Baseline Score Mean (SD)	1-Year Score Mean (SD)	P Value
KOOS symptoms	56.7 (12.2)	57.0 (9.8)	.89
KOOS pain	75.3 (14.3)	89.8 (10.0)	<.001
KOOS function	83.9 (14.1)	94.9 (7.1)	<.001
KOOS sport/participation	50.0 (21.6)	77.8 (15.2)	<.001
KOOS QOL	31.6 (17.4)	66.0 (18.6)	<.001

KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, quality of life.

Discussion

Objective physical and psychological evaluations are an important part of determining readiness to return to sport in athletes following ACLR. However, there remains a lack of understanding of factors that predict successful outcome and return to sport after ACLR.⁴ The main finding of this present study is the fact that the KOOS pain score is significantly associated with patient performance on both physical and psychological return to sport evaluations. Several previous studies have examined predictors of outcome following ACLR, demonstrating that younger age, male sex, lower BMI, elite sporting level, and higher baseline knee function scores were associated with improved postoperative outcomes,^{20,21} while meniscal tears and cartilage lesions were associated with worse outcomes.²²⁻²⁴ This study failed to demonstrate a significant association between these factors and either physical or psychological readiness to return to sport. It is in keeping with a previous study by Heijne et al., which demonstrated that baseline patient factors explain only 37-44% of outcome variance one-year after ACLR.²⁸ These authors concluded with highlighting the important role psychological factors may play in explaining the remaining variance of ACLR outcomes. Previous studies looking at the role of psychological factors relating to ACLR outcomes have shown that fear of reinjury, lack of confidence in the knee, kinesophobia, self-efficacy, and self-motivation play an important part in patient readiness to return to sport.¹⁰⁻¹³ On the basis of these findings, Webster et al. developed a 12-item score that combined some of these factors in order to identify self-reported readiness to return to sports in athletes after ACLR.¹⁶ The ACL-RSI has proven to discriminate between athletes after ACLR who

Table 3. Summary of Outcome Measures at 1 year post-ACLR

Outcome Measures at 12 months	Value
Single-legged Hop Test, <i>n</i> (%)	
Pass ($\geq 90\%$)	77 (68%)
Fail ($< 90\%$)	36 (32%)
ACL-RSI	
Mean (SD)	55.7 (23.9)

ACLR, anterior cruciate ligament reconstruction.

do return to sport and athletes who do not, and the ACL-RSI score at 6 months seems to predict whether or not athletes can return to competition by 12 months.^{16,29} It was also shown that lower ACL-RSI scores among younger patients are associated with higher risks of a second ACL injury.³⁰ In the present study, a mean ACL-RSI score of 55.7 at 1 year post-ACLR was found, which is similar to previous studies with ACL-RSI scores varying from 46.3 to 76.8.^{8,31,32}

The main finding of this study is that postoperative knee pain, measured by the KOOS Pain subscale, is significantly associated with both psychological (ACL-RSI) and physical (single-legged hop test) readiness to return to sport. Across multiple surgical and medical subspecialties, pain has been identified as a linking factor between physical symptoms, psychological wellness, and recovery.^{33,34} Interestingly, ongoing knee pain seems to be one of the most common factors identified in those patients who are unable to return to sport at preinjury level.^{12,35} Some have postulated that persistent pain following surgery and the associated fear of provoking pain prevents patients from further increasing their activity levels, thus limiting ability to return to sport.^{12,35} On the basis of these findings and others, it may be appropriate to manage patients' expectations regarding knee symptoms and to provide patients with specific strategies for symptom management in order to improve readiness to return to sport after surgery. Furthermore, psychological factors of

Table 4. Multivariable Linear Regression Models to Check the Variables Associated With Psychological Readiness to Return to Sport

Variables	β Estimate (95% CI)	P Value
Age	.27 (-.28-0.82)	.33
Sex (Ref: Female)	-5.56 (-15.15-4.03)	.25
BMI	.43 (-.86-1.73)	.51
Baseline marks activity score	.05 (-.75-0.85)	.91
Meniscal tear	-3.75 (-12.23-4.73)	.38
High grade chondral lesion	5.20 (-10.201-20.42)	.50
KOOS pain score (12 mo)	1.13 (.63-1.62)	<.001
KOOS symptom Score (12 mo)	.19 (-0.28-0.66)	.43
Single-legged hop test pass (12 mo)	4.49 (-3.33-14.52)	.22

Bolded value indicates significant difference.

BMI, body mass index; KOOS, Knee Injury and Osteoarthritis Outcome Score.

Table 5. Multivariable Logistic Regression Results for Association with Physical Readiness to Return to Sport (Single-Legged Hop Test)

Variables	Univariate P Value	Inclusion in Multivariable Model	Multivariable OR (95% Confidence Interval)	P Value
Age	.16	Yes	.98 (.92-1.03)	.42
BMI	.21	Yes	.89 (.79-1.02)	.09
High grade chondral lesion	.13	Yes	1.50 (.26-8.72)	.65
KOOS Pain score (12 mo)	.003	Yes	1.06 (1.002-1.12)	.042
ACL-RSI Score (12 mo)	.01	Yes	1.01 (.99-1.04)	.24
Sex (Ref: Female)	.94	No		
Baseline Marks Activity Score	.33	No		
Meniscal tear	.58	No		
KOOS for symptoms (12 mo)	.44	No		

Bold values indicate significant difference.

ACL-RSI, Anterior Cruciate Ligament Return to Sport Index; BMI, body mass index; KOOS, Knee Injury and Osteoarthritis Outcome Score.

knee function are modifiable factors, which can be addressed with increased surveillance and cognitive therapy during rehabilitation.

Improving or avoiding persistent postoperative knee pain presents a complex problem for ACLR surgeons, since pain may be the consequence of multiple factors, including concomitant cartilage or meniscus injuries, suboptimal rehabilitation, lack of healing of meniscal repair procedures, arthrofibrosis, fat pad scarring, donor site morbidity, or individual differences in pain perception.³⁶⁻³⁸ Understanding and evaluating postoperative knee pain is of particular prudence when deciding to use a BTB graft, given that studies have demonstrated an increased incidence of anterior knee pain postoperatively compared with graft alternatives.³⁹ Previous studies have placed the incidence of anterior knee pain in these patients as high as 60%,⁴⁰ with one study demonstrating continuance to 6 months postoperatively in at least 34% of patients.⁴¹ In accordance with this, several interventions have demonstrated improvement in postoperative pain for BTB patients, including platelet-rich plasma application to the donor site,⁴² double incision mini-invasive approaches for graft harvest,⁴³ peritendon closure and filling of bony defects,⁴⁴ and early knee extension rehabilitation.⁴⁵ Furthermore, we believe identifying and treating concomitant knee injuries and additional pain generators after an ACL injury can have a significant impact on the postoperative clinical and functional outcome after ACLR. Whether these interventions have any impact on return to sport readiness through their reduction in postoperative pain remains to be seen and is an area for future investigation.

Limitations

This study has several limitations. Compared to previous studies evaluating factors associated with ACLR outcomes and return to sport using population-level databases,⁴⁶ our small sample size of 113 patients is relatively small. However, prospectively collected

patient data were used in consecutively treated ACLR with a complete dataset. In the present study, the mean follow-up was 1 year, whereas other studies have evaluated return to sport after ACLR with follow-ups greater than 1 year.⁴⁷ However, we believed that given the standard of care to return to sport within 1 year following ACLR, we were able to capture true patient success of readiness to return to sport with this follow-up time frame. However, we acknowledge that a small subset of our patients could have further improved if the follow-up period had been extended to 2 years. A further limitation is that we did not specify the source of postoperative pain in our study. Therefore, we cannot assume that all postoperative pain was anterior knee pain caused by the BTB graft. The possibility that other potential predictive factors were not included in this analysis despite our efforts to identify and use an exhaustive list of clinically relevant variables in our statistical models is also a limitation of this present work. Finally, we did not record the preoperative and postoperative level of sports participation, as well as the actual number of patients that returned to sports after ACLR in this study.

Conclusion

Patients with higher reported pain levels at 1 year following ACLR have lower psychological and physical readiness to return to sport.

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