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The Relationship of Athlete Factors and Patient Reported Outcomes on Return To Play 1-Year Post-Anterior Cruciate Ligament Reconstruction

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Abstract

Introduction: Anterior cruciate ligament (ACL) tears are the most frequently reported knee injury in athletes. For those who wish to return to play (RTP), ACL reconstruction (ACLR) is recommended to restore knee function and stability. Knowledge of important predictors of RTP post-ACLR can aid surgeons and allied health professionals to effectively manage athletes' rehabilitation expectations. The purpose of this study was to determine which athlete factors and patient reported outcomes predict RTP at 1-year post-ACLR.

Methods: This prospective cohort study recruited 336 participants who underwent ACLR at SSC in Dublin. Data collected included; baseline demographics, details of sport participation, injury mechanism, intent to RTP and patient-reported outcome measure (PROM) questionnaires at baseline (Marx, ACL-RSI) and at 1-year post-ACLR (Marx, ACL-RSI, Cincinnati, IKDC). Participants were categorised based on successful RTP 1-year post-ACLR. Univariate and multivariate logistic regression analysis were used to evaluate the association between RTP and athlete factors and PROMs.

Results: Two hundred twenty (65.45%) participants RTP at 1-year post-ACLR. Participants were more likely to RTP if they were younger (OR:0.972, 95%CI:0.952-0.995), intended to return to a higher level of sport (OR:2.125, 95%CI:1.169-3.861), had higher baseline Marx scores (OR: 1.066, 95%CI:1.022-1.111), and higher Marx (OR:1.291, 95%CI:1.214-1.373) and IKDC scores at 1-year post-operative (OR:1.065, 95%CI:1.041-1.088). Higher Marx scores at 1-year post-operative (OR:1.291, 95%CI:1.214-1.373) were the only significant predictors of RTP. The model yielded an area under the curve of 0.81, demonstrating excellent discriminative ability.

Discussion: Patients were more likely to RTP if they had better functional activity outcomes at 1-year post-ACLR, suggesting that PROMs can be used to assess how likely an athlete is to RTP.

Conclusion: Further research should focus on identifying which PROMs are modifiable and can be improved during post-ACLR rehabilitation to further encourage RTP.

Keywords: anterior cruciate ligament reconstruction; return to play; patient reported outcome measures; athletes

Introduction

Knee injuries are the most common cause of sports-related injuries [1], with anterior cruciate ligament (ACL) tears being the most frequently reported knee injury in athletes [2]. There are 30 cases of ACL tears per every 100 000 people in Ireland annually [3]. ACL reconstructions (ACLR) are performed in order to restore knee stability, prevent further injury, and improve overall knee joint function [4]. Non-surgical interventions, including extensive rehabilitation and strengthening, can also be considered as an alternative for ACL tear management; however, such methods are particularly unsuccessful in young, athletic individuals [5]. Opting-out of ACLR often results in persistent knee instability and further chondral and/or meniscal damage [5]. For these reasons, surgical

intervention is advised for all patients who wish to return to sport participation [2].

Not all athletes, however, return to play (RTP) following ACLR despite being cleared for sport participation. Of those that do RTP, not all return to their pre-injury level of play. In a systematic review and meta-analysis by Ardern et al., of the 90% of individuals that achieved normal knee function post-operatively, 82% returned to play, 63% returning to pre-injury level of play, and 44% returning to competitive sport [6]. Several ACLR rehabilitation protocols exist that outline clinical criteria that should be met before an athlete returns to sport. These criteria include range of motion (ROM), strength and power comparable to the contralateral, non-operated knee, absence of joint pain or swelling, and the ability to perform sport-

specific tasks. Most protocols allow athletes to RTP by 8-12 months post-operatively [4]. Despite these protocols and guidelines, published research has shown that there are differences between athletes' RTP expectations and outcomes [5].

Knowledge of important predictors of RTP post-ACLR can aid surgeons and allied health professionals to effectively manage athletes' rehabilitation expectations. To our knowledge, no prospective cohort study has evaluated the association between subjective physical and psychological patient reported outcome measures (PROM) and RTP. No previous studies have correlated athletes' intent to RTP with actual RTP outcomes. The purpose of this study was to determine the proportion of athletes that RTP 1-year post-ACLR and which athlete factors and PROMs predict RTP at 1-year post-ACLR.

Methods

Design and participants

This is a prospective cohort study. Eligible participants were recruited at their pre-operative appointment and underwent ACLR at the Sports Surgery Clinic (SSC) in Santry, Dublin between 2013 and 2018. Participants between the ages of 13 and 45 years old were included in this study if they underwent primary ACLR, including those with previous contralateral knee injury. Participants of all levels of sport participation were included. Participants were excluded if they underwent revision ACLR and/or had concomitant ligament tears requiring surgical repair. The surgery was performed by one of two orthopedic surgeons specialized in knee surgery, using either bone-patellar tendon-bone or hamstring autografts.

Data collection

All participants were required to provide informed consent at their pre-operative appointment. Extensive baseline data were collected from each participant via the SCC pre-operative performance questionnaire, including patient demographics, details of sport participation, injury mechanism, and intent to return to sport. Participants completed the Marx Activity Rating Scale (Marx) and ACL-Return to Sport After Injury Scale (ACL-RSI) questionnaires pre-operatively and at 1-year post-operative. Furthermore, at 1-year post-operative, participants also completed the Cincinnati Knee Rating Scale and International Knee Documentation Committee Subjective Knee Form (IKDC) questionnaires. Return to sport, the primary outcome measure for this study, was evaluated through the SSC return to performance questionnaire. This included questions about what level of sport participants returned to, reasons for not returning to sport, as well as questions about knee re-injury and symptoms.

Patient-reported outcome measures

The Marx Activity Rating Scale is a validated questionnaire that assesses knee function by evaluating an athlete's ability to run, cut, pivot, and decelerate. Each item is scored from one to four, with higher scores indicating that the individual is able to perform each activity more frequently [7].

The IKDC is a validated and reliable questionnaire used to assess symptoms, function and sports activity in individuals with a variety of knee conditions, including ligament and meniscal injuries. The questionnaire contains 18 questions. Each answer is either assigned zero to four or zero to ten points. The overall score is then converted to a score from zero to 100, with higher scores indicating a higher level of knee function and sports activity, and fewer knee-related symptoms [8,9].

The ACL-RSI is a validated questionnaire used to assess an athlete's psychological readiness to RTP after ACL injury and reconstruction. The questionnaire contains 12 questions relating to an individual's emotions, confidence in performance, and risk appraisal. Each question is scored from zero to 100 in 10-point increments. Total scores are converted to a score over 100, with higher scores indicating more positive psychological responses to RTP [10,11].

The Cincinnati Knee Rating Scale is a validated questionnaire that assesses knee function following injury. It consists of multiple scales that evaluate occupational and athletic activities, symptoms, and functional limitations with regards to sports and activities of daily living. Subscores are accumulated and converted to a score over 100, with higher scores indicating higher knee function [12].

Data analysis

Data was compiled using Microsoft Excel and was analysed using SAS version 9.4. Descriptive statistics were conducted for all relevant variables in the dataset. Continuous variables were presented as means with standard deviations and ranges. Categorical variables were described with frequencies and percentages.

Univariate logistic regression analyses were used to assess the relationship between RTP and various patient factors and PROMs. Predictors that yielded a p-value < 0.3 in univariate analysis were further examined in multivariate analysis. Results are expressed as odds ratios with 95% confidence intervals. Significance was set at a p-value <0.0.5.

Collinearity of all variables was assessed by calculating tolerance. Manual backward stepwise regression was used to determine the best combination of predictors. In the event of collinear variables, separate models were run to determine which yielded a model with the best fit. The predictive performance of the model was evaluated by computing the area under the receiver operating characteristic (ROC) curve. A ROC curve plots the true positive rate against the false positive rate. An area under the curve (AUC) of one reflects a test with 100% specificity and 100% sensitivity, whereas an area of 0.5 indicates no discriminative value.

Results

Subjects

A total of 336 participants were included in the study. The cohort consisted of 180 men (53.57%) and 156 women (46.43%), with a mean age of 26.38 ±10.13 years (range 13 to 56 years old). Field sports were the most common sports played during injury, including Gaelic football (32.74%), soccer (16.67%), hurling/camogie (12.5%), and rugby (10.71%). The most common mechanism of injury was turning (31.85%).

Two-hundred forty-two participants (72.02%) intended to return to the same level of sport post-ACLR, while 78 participants (23.21%) intended to return to a higher level of sport. In contrast, 7 participants (2.08%) intended to return to a lower level of sport, 5 (1.49%) intended to return to a different sport, and 4 (1.19%) did not intend to return to sport at all. Table 1 summarizes the demographic information of participants and provides complete details on injury side, injury mechanism, sport when injured, and contact during injury.

Return to play

Two hundred twenty (65.48%) participants returned to play 1-year post-ACLR. One hundred thirty (38.69%) returned to the same level of sport as before the injury, 68 (20.24%) returned to a lower level, and 22 (6.55%) returned to a higher level. Of those that did not RTP, 75 (64.66%) said it was due to the operated knee. Specifically, 21 (28.00%) did not RTP due to low confidence in performance, 14 (18.67%) due to pain in the operated knee, 13 (17.33%) due to fear of reinjury, and 27 (36.00%) due to other reasons. Table 2 summarizes RTP outcomes 1-year post-ACLR.

Table 1. Study population demographics

Variable	Total (n=336)
Age	26.38 ±10.13 (13-56)
Gender	
Male	180 (53.57%)
Female	156 (46.43%)
Smoking status	
Non-smoker	317 (94.35%)
Smoker	19 (5.65%)
Injured side	
Dominant leg	203 (60.42%)
Nondominant leg	133 (39.58%)
Sport when injured	
Gaelic football	110 (32.74%)
Soccer	56 (16.67%)
Hurling/camogie	42 (12.50%)
Rugby	36 (10.71%)
Skiing	29 (8.63%)
Basketball	8 (2.38%)

Table 1. (Continued) Study population demographics

Variable	Total (n=336)
Snow sports	7 (2.08%)
Racket sports	2 (0.60%)
Athletics	1 (0.30%)
RTA	1 (0.30%)
Other	44 (13.10%)
Mechanism of injury	
Turning	107 (31.85%)
Being tackled	56 (16.67%)
Landing	54 (16.07%)
Side stepping/evading	42 (12.50%)
Tackling	25 (7.44%)
Jumping	11 (3.27%)
Other	41 (12.2%)
Contact during injury	
Non-contact (no other player involved)	218 (64.88%)
Direct contact to knee	63 (18.75%)
Indirect contact (other body part)	55 (16.37%)
Target activity level at RTP	
Same level	242 (72.02%)
Higher level	78 (23.21%)
Lower level	7 (2.08%)
Other sport	5 (1.49%)
No sport	4 (1.19%)

Table 2. RTP outcomes 1-year post-ACLR

Variable	Total (n=336)
Return to sport	
Yes	220 (65.48%)
No	116 (34.52%)
Level of sport at RTP	(n=220)
Same as pre-injury	130 (59.09%)
Lower level than pre-injury	68 (30.91%)
Higher level than pre-injury	22 (10.00%)
Reason for not RTP	(n=116)
Operated knee	75 (64.66%)
Other	41 (35.34%)
Reason for not RTP if due to operated knee	(n=75)
Confidence in performance	21 (28.00%)
Pain	14 (18.67%)
Fear of re-injury	13 (17.33%)
Other	27 (36.00%)

Patient reported outcome measures

Prior to ACLR, the mean Marx score was 10.47 ± 5.34 and the mean ACL-RSI score was 48.09 ± 57.92. One-year post ACLR, the mean Marx score was 9.93 ± 4.72, the mean ACL-RSI score was 84.86 ± 114.88, the mean IKDC score was 82.94 ± 11.19, and the mean Cincinnati score was 106.65 ± 120.87.

Table 3. PROMs pre-ACLR and 1-year post-ACLR

Variable	Mean score pre-ACLR (n=336)	Mean score 1-year post-ACLR (n=336)
Marx score	10.47 ± 5.34	9.93 ± 4.72
ACL RSI score	48.09 ± 57.92	84.86 ± 114.88
IKDC score	N/A	82.94 ± 11.19
Cincinnati score	N/A	106.65 ± 120.87

Univariate analysis

Based on univariate analysis, patients were more likely to RTP 1-year post-ACLR if they (i) were younger (odd ratio [OR]: 0.972, 95% confidence interval [CI]: 0.952-0.995); (ii) intended to return to a higher level of sport (OR: 2.125, 95%CI: 1.169-3.861); (iii) had higher baseline Marx scores (OR: 1.066, 95%CI: 1.022-1.111); (iv) had higher 1-year post-operative Marx scores (OR: 1.291, 95%CI: 1.214-1.373); and (v) had higher 1-year post-operative IKDC scores (OR: 1.065, 95%CI: 1.041-1.088).

Table 4. Univariate analysis evaluating important predictors of RTP at 1-year post-ACLR

Variable	Odds Ratio	95% CI	P value
Age	*0.973*	*(0.952-0.995)*	***0.0164***
Injury side, ref. = nondominant	0.719	(0.451-1.147)	0.1658
Smoker, ref. = non-smoker	0.566	(0.223-1.435)	0.2306
Gender, ref. = male	1.103	(0.702-1.733)	0.6692
Injury with contact, ref. = noncontact			
Contact direct to knee	0.912	(0.509-1.636)	0.7576
Contact other than to knee	1.078	(0.575-2.022)	0.8147
Target activity level at RTP, ref. = same level	*2.125*	*(1.169-3.861)*	***0.0134***
Marx score pre-ACLR	*1.066*	*(1.022-1.111)*	***0.0029***
ACL RSI score pre-ACLR	1.008	(0.999-1.018)	0.0653
Marx score 1-year post-ACLR	*1.291*	*(1.214-1.373)*	***<0.0001***
ACL RSI score 1-year post-ACLR	1.003	(0.998-1.009)	0.2078
Cincinnati 1-year post-ACLR	1.001	(0.999-1.003)	0.4467
IKDC score 1-year post-ACLR	*1.065*	*(1.041-1.088)*	***<0.0001***

*note p-values <0.05 are in bold

Multivariate analysis

Assessment of tolerance indicated that Marx and IKDC scores at 1-year post-operative were highly collinear. Following multivariate analysis, the Marx score at 1-year post-operative (OR: 1.291, 95%CI: 1.214-1.373) was the only significant predictor of RTP. Specifically, the odds of RTP were 1.291 times higher for every 1-point increase in the Marx score at 1-year post-ACLR. The model yielded an area under the curve of 0.81, demonstrating excellent discriminative ability.

Table 5. Multivariate analysis evaluating important predictors of RTP at 1-year post-ACLR

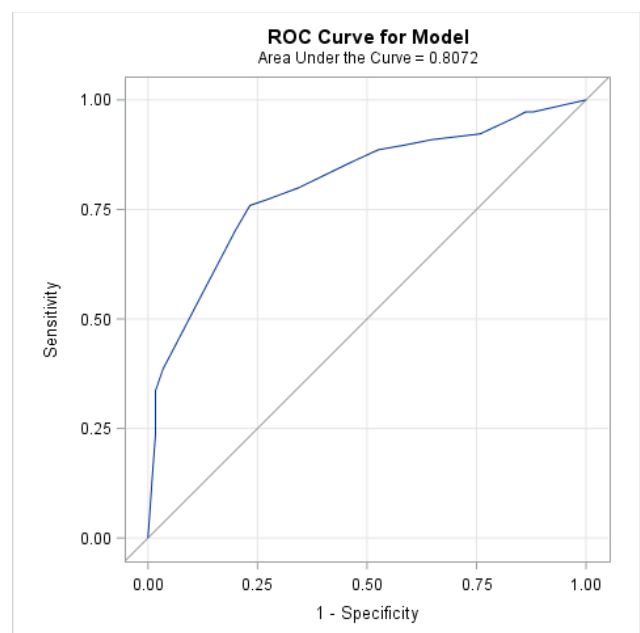| Variable	Odds Ratio	95% CI	P value
Marx score 1-year post-ACLR	1.291	(1.214-1.373)	<0.0001

Figure 1. Receiver operating characteristic curve for 1-year post-operative Marx score

Discussion

The objectives of this study were to (i) determine the proportion of athletes that RTP 1-year post-ACLR and (ii) assess which athlete factors and PROMs predict RTP. Based on our results, 220 participants (65.45%) RTP 1-year post-ACLR. Participants were more likely to RTP if they were younger, intended to return to a higher level of sport, had higher baseline Marx scores, and had higher Marx and IKDC scores at 1-year post-operative. Following multivariate analysis, a higher Marx score at 1-year post-operative was the only significant predictor of RTP.

Thirty five percent of athletes did not RTP following their ACLR. In contrast, prior to surgery, only 1% of participants did not intend on returning to sport, demonstrating a discrepancy between athlete expectations and outcomes following ACLR. To our knowledge, our study was the first to assess whether pre-operative intent to RTP predicts RTP. In univariate analysis, athletes that intended to return to a higher level of sport were more likely to RTP; however, this predictor was not significant in multivariate analysis. Further studies are required to clarify why a discrepancy exists between intended and actual RTP outcomes. In our study, 59% of athletes returned to the same level of sport performance as before their ACLR. These results are within the range of previously published data. In a study by Ardern et al., only 33% returned to the same level of competitive sport 12 months post-surgery [13]. In contrast, a systematic review and meta-analysis of 48 studies, reported that 66% of athletes RTP at the same level of sport [6]. Discrepancy in the literature may in part be attributed to the fact that the latter study looked at RTP within 24 months of surgery, as opposed to within 12 months post-ACLR. This suggests that a larger number of athletes may be found to return to the same level of sport if followed-up for a longer period of time, which may have been the case in our study had participants been assessed beyond the 1-year post-operative mark.

In univariate analysis, our study found younger age to be an important predictor of RTP. Specifically, for every one year increase in age, participants were 3% less likely to RTP. This finding has been reported previously, including in a study from the Multicenter Orthopedic Outcomes Network (MOON) group that found younger, male soccer players to be more likely to RTP post-ACLR [14]. Potential explanations for this finding include that women are more likely to attribute not returning to sport post-ACLR to reasons external to their ACL injury [14], such as personal and professional commitments. Such factors may pose less of an obstacle if returning to sport at a younger age.

Gender was not a significant predictor of RTP in our study. Previous studies have indicated that female soccer players [15] and female athletes participating in other competitive sports [16] were less likely to RTP when compared to their male counterparts following ACLR. Based on a third study, however, women were more likely to endure graft re-tear or contralateral ACL injury within 12 months of returning to play following primary ACLR [17]. Given this finding, it is possible that gender may have been a significant predictor of RTP if subjects with previous ipsilateral ACLRs were included in our cohort.

Superior knee function and reduced knee symptoms were identified as positive predictors of RTP, as demonstrated by higher Marx and IKDC scores. These results were expected as previous studies have demonstrated that athletes with lower IKDC scores fail to meet RTP criteria [18], while those that RTP at 1-year post-operative have higher IKDC scores [19]. Higher IKDC scores at long term post-ACLR follow-up have also been identified in athletes who RTP when compared to controls that do not RTP [20,21]. In our univariate analysis, both baseline and 1-year post-operative Marx scores were predictive of RTP. Furthermore, post-operative Marx score was the only significant predictor following multivariate analysis, indicating that it may be the most important factor when considering RTP. A previous study conducted in American football players also reported higher 2-year post-operative Marx scores in athletes that returned to play [21]. However, to our knowledge, our study is the first to determine a statistically significant association between 1-year post-operative PROMs and RTP. This finding suggests that subjective outcome measures can be used to manage athletes' expectations surrounding RTP. Furthermore, since PROMs are correlated with specific functional measures, such as hop tests [22], they can be used to indirectly guide which physical parameters should be targeted in rehabilitation protocols post-ACLR. For example, the Marx score specifically looks at an athlete's ability to run, cut, decelerate, and pivot. Addressing weaknesses in an athlete's ability to perform these activities earlier on in their rehabilitation course may improve future RTP outcomes.

While post-ACLR return to sport criteria can be protocol-dependent, many use objective knee function assessments to assess athletes' preparedness to return to sport. Objective measures include isokinetic quadricep and hamstring strength and endurance tests, active and passive range of motion tests, leg circumference measurements compared to the contralateral leg, and hop tests [23]. While the IKDC score has been used for subjective symptomatic and functional knee assessment before returning to play [23], the Marx score is not routinely used as a component of rehabilitation protocols. Given that the Marx scale is an accessible, short and simple questionnaire, incorporating it as a tool to help guide RTP outcomes and expectations may be a feasible and convenient option. Allied health professionals, in particular physiotherapists and surgeons, could use the questionnaire as a method to not only assess an athlete's post-ACLR functional progress, but to also help counsel athletes on how likely they are to RTP.

Of the participants that did not RTP, many identified fear of re-injury, pain, and confidence in performance as reasons for not returning to play. Despite these findings,

there was no significant association between psychological PROMs and RTP. Previous studies have identified fear of re-injury to be greater in athletes that do not RTP [24,25]. Furthermore, athletes that do RTP have superior psychological responses post-ACLR as measured by higher ACL-RSI scores [26,27]. Based on the findings in the literature, there likely is a psychological component that impacts an individual's ability and decision to RTP post-ACLR.

Strengths and Weaknesses
This study is the first to explore the association between an athlete's pre-operative intent on returning to play and RTP outcomes. Furthermore, it is the first study to identify 1-year post-operative Marx scores as a predictor of RTP. All our participants underwent the same, standardized surgical procedures and were evaluated using four validated and reliable questionnaires. The results of this study can be generalized to a diverse group of athletes based on gender, age, and participation in a wide range of sports.

Our study, however, is not without limitations. First, all participants were recruited from only one institution, the Sports Surgery Clinic in Dublin. Second, rehabilitation compliance was not accounted for in our study which could impact subjective outcome measures. Third, despite our heterogeneous sample, athletes with concomitant ipsilateral knee injuries were excluded, limiting the applicability of our findings. Finally, while the majority of questionnaires used in this study are validated, the SSC pre-operative performance and return to performance questionnaires are non-validated questionnaires that were used to assess intent to RTP and RTP outcomes.

Conclusion
Athletes were more likely to RTP if they had better functional activity outcomes at 1-year post-ACLR, suggesting that PROMs can be used to assess how likely an athlete is to RTP. Our findings suggest that use of the Marx score post-operatively can help surgeons, physiotherapists, and other allied health professionals tailor athletes' expectations surrounding RTP outcomes. Future studies should look at which PROMs are modifiable and can be targeted in post-ACLR rehabilitation protocols.

List of Abbreviations Used
ACL: Anterior cruciate ligament
ACLR: anterior cruciate ligament reconstruction
ACL-RSI: ACL-Return to Sport After Injury Scale
IKDC: International Knee Documentation Committee Subjective Knee Form
Marx: Marx Activity Rating Scale
PROM: patient-reported outcome measures
ROC: receiver operating characteristic
RTP: return to play
SSC: Sports Surgery Clinic

Conflicts of Interest
The authors declare that that they have no conflict of interest.

Ethics Approval and/or Participant Consent
Ethical approval for the study was received from the Clinical Research Ethics Committee of the Cork Teaching Hospitals in December 2018. All participants provided informed consent prior to participation.

Authors' Contributions
LB: drafted the primary manuscript, contributed to study design and planning, and contributed to analysis and interpretation of data.
EK: contributed to study design and planning, contributed to collection of data, and gave final approval of the version to be published.
LT: contributed to data analysis and interpretation, revised the manuscript.
EF: contributed to study design and planning, role of research supervisor, and gave final approval of the version to be published.

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