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Does Chronicity of Anterior Cruciate Ligament Rupture Influence Patient Reported Outcomes Prior to Surgery?

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Abstract

Background—Time between injury and ACL reconstruction (ACLR) may influence baseline knee-related and general-health related patient-reported outcome measures (PROMs). Despite the common use of PROMs as main outcomes in clinical studies, this has never been evaluated.

Hypothesis/Purpose—To determine whether time from injury to ACLR influences: (1) baseline PROMs; (2) pattern and prevalence of concurrent articular cartilage and meniscal injury.

Study design—Cross-sectional (level III).

Methods—1,192 patients from the MOON consortium who underwent primary ACLR were eligible. ‘Acute’ ACLR was defined as <3 months (n=853; 72%), and ‘chronic’ as >6 months (n=339; 28%) from injury. Patient demographic, surgical characteristics (articular cartilage injury, medial [MM] and lateral [LM] meniscal tears), and baseline PROMs (Marx activity scale, IKDC, KOOS, SF-36) were collected. To determine whether time from injury to ACLR influences: (1) baseline PROMs; (2) pattern and prevalence of concurrent articular cartilage and meniscal injury. Analysis of covariance models were used to adjust for confounders on baseline outcome scores (age, sex, body mass index [BMI], smoking status, competition level, education).

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Results—The median age was 23 years (IQR 17–35), n=530 (45%) were female, and median BMI was 25.0 kg/m² (IQR 22.3–27.9); however, the chronic group was older, had higher BMI and fewer collegiate athletes. A significantly greater number of partial LM tears were seen acutely (14% vs. 6%; p<0.001), but more meniscal tears overall (74% vs 63%; p=0.001), complete MM tears (49% vs. 23%; p<0.001), and articular cartilage injury (54% vs. 33%; p<0.001) chronically. After controlling for confounders, chronic ACLR patients reported significantly lower baseline Marx (7.8 vs. 12.1, p<0.001), but higher baseline IKDC, physical function SF-36, and all KOOS subscales except quality of life (QoL). However, only the sports and recreation subscale exceeded the minimum clinically importance difference of 8 points (62.3 vs. 48.3; p<0.001).

Conclusion—After controlling for age, sex, competition level, smoking and BMI, chronic ACLR patients participated in less pivoting and cutting sports, but reported better pain/function. Whether decreased activity is deliberate after ACL injury, or these are simply less active patients who may be treated successfully without surgery warrants further investigation. Non-randomized studies that utilize PROMs should consider time from injury in design and data interpretation.

Keywords

Anterior cruciate ligament; Patient reported outcomes; KOOS; Marx Activity Scale; Delayed ACL reconstruction

INTRODUCTION

The anterior cruciate ligament (ACL) is one of the most commonly injured knee ligaments, and as many as 200,000 ACL reconstructions (ACLR) are performed annually in the United States.^{16, 22, 35} Despite being a common procedure, patients may present for surgical care at different times from injury and with different constellations of associated meniscal and articular cartilage pathology. Fortunately, the advent of health-related quality of life (HRQoL) measures has provided a valuable tool to quantifiably measure patient activity, symptoms, and function at presentation.^{23, 38}

To our knowledge, no prospective cohort studies and only one registry¹⁷ have considered the potential differences of HRQoL at baseline between patients who are enrolled and undergo surgery soon after their injury, and those who undergo surgery at a later time. The classification of time from injury to ACLR, usually termed ‘acute’ and ‘chronic,’ lacks a consensus definition in the orthopaedic community, although there is some agreement that ‘chronic’ ACLR is based on a minimum 6 months after injury.¹² Both surgeon and patient preference may influence surgical timing. For example, proponents of early surgical intervention following an acute ACL injury suggest that early intervention may minimize the risk of further meniscal or cartilage injuries which are often associated with degenerative joint conditions.²⁹ Conversely, performing surgery too close to injury when knee motion has not been properly restored increases the risk of complications such as arthrofibrosis³⁴ and wound complications.^{28, 33} Additional high-quality evidence suggests that in some patients, post-injury functional rehabilitation only and no surgery can also produce successful outcomes.^{13,18}

While ACL-deficient patients are known to score worse on Patient Reported Outcome Measures (PROMs) than the general population,¹² this can be improved with ACLR.^{1, 7, 8} However, to our knowledge no study has investigated how time from injury affects baseline PROMs within an ACL-deficient population. The objective of this study was to compare baseline HRQoL measures and prevalence/patterns of meniscal and articular cartilage pathology between patients that had acute and chronic ACLR, in order to provide clinicians with benchmark PROMs in two different ACL-injured patient populations. We hypothesize that these two populations will demonstrate differences in their responses to various knee-specific outcome measures.

MATERIALS AND METHODS

The study was approved by the coordinating center's Institutional Review Board (IRB). Following IRB approval, a cross-sectional review of data from a prospective multicenter cohort study, MOON, was conducted to evaluate patients' knee-related and general-HRQoL measures before undergoing primary unilateral ACLR.

Eighteen surgeons at seven sites enrolled patients and performed the surgical procedures. Patients were classified as 'acute' or 'chronic' based on the recorded date of injury to ACLR. Acute was defined as <91 days (or approximately 3 months), and chronic as >180 days (or approximately 6 months).¹² The chosen definition for 'acute' included a range of time reflecting what some might label as 'subacute' (i.e., 6–12 weeks); however, we felt this was still a reasonable time-frame to include intentional early reconstruction based on time to diagnosis, referral and pre-surgical rehabilitation. A total of 1,396 primary ACL reconstructions performed between 2002 and 2004 were eligible. The time of diagnosis or decision to treat the ACL tear surgically was not recorded. Pre-surgery bracing, activity modification and rehabilitation were left at the discretion of the treating surgeon.

Patients were asked to complete a baseline questionnaire self-reporting personal demographic information, injury characteristics, sports participation history, previous knee surgery (either knee), and general health status. Patient reported outcome measures included the Marx Activity Rating Scale,²⁵ Knee Injury and Osteoarthritis Outcome Score (KOOS),³¹ IKDC Subjective Knee Form,¹⁹ and the Short Form 36 Health Survey (SF-36).²⁷ Surgeons were asked to complete a questionnaire that documented additional intra-articular injuries to the meniscus and articular cartilage at the time of ACL surgery. Meniscal injuries were classified by side (medial, lateral) and as partial or complete tears. Chondral injury was graded according to the modified Outerbridge classification,⁴ and located in the medial or lateral tibial plateau, undersurface patella, medial or lateral femoral condyle, or trochlear groove. A high degree of inter-rater reliability for grading of meniscal pathology and articular cartilage in this cohort had been previously established.^{10, 24} For purposes of this study, articular cartilage injury was reclassified as a dichotomous variable (normal/grade 1 vs. grade 2/3/4).

The Marx Activity Rating Scale is a four-question survey that evaluates patients' frequency and intensity of participation in a sporting activity from the past year at their healthiest state.²⁵ Running, cutting, decelerating and pivoting each account for a score of between 0 and 4

points (max total 16). The IKDC Subjective Knee Form is an 18-question survey that assesses knee-specific conditions from the past one month, including ligament, meniscus, articular cartilage, osteoarthritis, and patellofemoral pain on a 0 (worst) to 100 (best) point scale.¹⁹ The KOOS is a 42-item survey that measures five domains: frequency and severity of pain during functional activities (“KOOS_{Pain}”); symptoms including stiffness, swelling, grinding/clicking, catching and restricted motion (“KOOS_{symptoms}”); difficulty experienced during activities of daily living (“KOOS_{ADL}”); difficulty experienced with sport and recreational activities (“KOOS_{sports&rec}”); and knee-related quality of life (“KOOS_{QoL}”).³¹ Each dimension is transformed to a 0 to 100 scale, with 100 representing an asymptomatic state. The response is supposed to reflect the past one week. The SF-36 is a general survey of 36 questions that measures perceived health in eight domains with a summarized physical (PCS) and mental (MCS) component summary score.²⁷

Statistical Analysis

Descriptive analysis of the study population was performed for continuous (median and interquartile range) and discrete (frequency/percentage) variables. To evaluate the association of patient and clinical characteristics between the acute and chronic study groups, independent samples t-tests (continuous) and chi-square tests (discrete variables) were used. Normality of continuous data was evaluated and confirmed using Shapiro-Wilks test.

Analysis of covariance models (ANCOVA) were generated to adjust for any potential confounding patient factors (e.g., age, sex, education level) on the relationship between chronicity and baseline PROMs. All independent variables were considered as eligible candidates to be evaluated in the ANCOVA models, including all patient demographic and intra-operative meniscal and articular cartilage data. All analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, NY) with statistical significance set at $p = 0.05$.

Post-hoc analysis

After noting a difference in the prevalence of chondral and meniscal pathology with length of time from injury to surgery, we analyzed the cohort to determine all independently associated factors that changed the odds of meniscal tear or chondrosis at surgery. This was performed utilizing a multivariate logistic regression model. All baseline demographics, including time from injury were considered covariates. As above, analysis performed in SPSS with statistical significance set at $p = 0.05$. Odds Ratio (OR) and 95% confidence intervals are presented.

RESULTS

From 2002 to 2004, 1,396 MOON consortium patients were eligible. Among them, 853 (61%) had ACLR <~3 months, and 339 (24%) at >~6 months after their initial injury. The remaining 204 (15%) patients underwent surgery between three and six months or were not classified due to a lack of information on date of injury and were excluded, yielding a final study $n=1,192$ patients. The median age was 23 years (17–35), and $n=530$ (45%) were female. Body mass index (BMI) of the cohort was 25.0 kg/m^2 (range 16.5 to 50.1), with

nearly half (49.5%) classified as overweight or obese by BMI ≥ 25 kg/m². Table 1 reports complete data.

While there was no difference between the proportions of patients with complete lateral meniscus (LM) tears, there was a significantly higher rate of patients with partial tears in the acute group (14%) compared to those in the chronic group (6.5%, $p<0.001$). Conversely, for medial meniscus (MM) tears, there was no difference in the percentage of partial tears, but a significantly higher rate of complete meniscal tears in the chronic group (49%) versus the acute group (23%, $p<0.001$). Chronic patients also had a significantly higher prevalence of articular cartilage injury versus acute ACL patients (54% vs. 33%, $p<0.001$).

Differences in PROMs were also observed between the acute and chronic ACL patients (Table 2). Chronic patients had significantly lower Marx scores compared to the acute population (7.4 vs. 12.7, $p<0.001$), but higher IKDC subjective scores at baseline compared to the acute ACLR group (56.2 vs. 50.5, $p<0.001$). Statistical significance for higher reported KOOS scores among chronic ACLR patients was achieved in all subscales except KOOS_{QoL} (36.7 vs. 38, $p=0.312$; Table 2). While there was no statistical difference found in the SF-36 MCS between chronic (51.8) and acute (51.6) ACL patients ($p=0.847$), chronic patients did have a significantly higher SF-36 PCS score compared to acute patients (44.0 vs. 40.1, $p<0.001$).

Confounding variables on baseline PROMs were assessed using ANCOVA models (see Appendix). Increased age, BMI, female sex, and having been or being a smoker consistently predicted worse knee-specific PROM. In contrast, LM or MM injuries did not demonstrate an interaction effect. Only concomitant chondral injury was associated with lower baseline Marx scores.

The models testing the relationship between chronicity and baseline PROMs were adjusted for confounding (full listing in Appendix) baseline factors (Table 3). The IKDC, KOOS, Marx and SF-36 differences are depicted graphically in Figure 1. Most differences in baseline PROMs increased after adjustment.

Post-hoc analysis revealed relatively consistent predictors of meniscal tear or articular cartilage wear at surgery. A delay >6 months increased the odds of meniscal tear 69% (OR 1.69 (1.26–2.28), $p<0.001$) and chondral damage 40% (OR 1.40 (1.02–1.92), $p=0.04$). Both were also more common in more competitive athletes (professional/college/high school vs. recreational or non-athletes). The odds of meniscal tear was greater in males, and chondral wear in older persons and those with higher BMI (Table 4). When broken down by lateral and medial meniscal tears, patients who delayed surgery >6 months had over a two-fold risk of having a medial meniscal tear (OR 2.64, $p<0.001$), particularly a complete tear of the medial meniscus (OR: 2.85, $p<0.001$) when controlling for all other factors in the model (Table 5).

DISCUSSION

This is only the second study designed to identify factors that contribute to differences in PROMs at baseline for primary ACLR,⁹ and the only study to specifically examine the

influence of chronicity from injury. We noted IKDC, SF-36 physical function, KOOS_{Pain}, KOOS_{Sports&Rec}, and KOOS_{symptoms} scores that were statistically significantly higher in patients more than 6 months from injury. However, of these only the Marx activity scores were significantly lower. Of these, only the KOOS_{sports&rec} subscale difference was greater than the Minimal Detectable Change (MDC) of 5.8 points.^{6, 30, 32} Our findings suggest that future non-randomized studies examining outcomes of ACLR require the inclusion of time from injury as a covariate, or statistical adjustment of the baseline PROM based on time from injury.

The demographic of those patients reconstructed >6 months from injury differed from those patients reconstructed early in almost every category. Most notably, these patients were older, had a higher BMI, played a lower competitive level of sports (some of which was confounded by age – for example, collegiate or high school) and were more often male. These findings have not been previously reported in the ACL literature. In practice, patients reconstructed late likely represent two sub-populations – older, less active individuals who may have attempted a longer duration of nonoperative treatment of their ACL injury, and a mixed group of high- and lower-activity level individuals who lacked access to care or purposefully delayed surgery for other reasons. Level-I evidence supports delayed reconstruction as a plausible treatment pathway¹³, although which patients benefit most from early surgery versus. optional delayed reconstruction remains to be determined.^{13, 18}

Preoperative PROMs were also distributed differently according to various demographic factors, including lower scores among patients who were older, female, had a higher BMI or were current smokers. This was the rationale for performing an adjusted analysis, which demonstrated persistence and even strengthened most baseline differences between acutely and chronically reconstructed patients. Thus, although chronically reconstructed patients were less active by Marx score, they scored significantly better for sports/function (i.e., higher KOOS) in the sports for which they still participated, irrespective of age or sex. The Marx score is weighted higher towards ACL-dependent sports (i.e., involving cutting or pivoting), suggesting that this group has either adapted activity to the ACL deficient state, or were less involved with cutting and pivoting sports prior to injury.

Patient or surgeon preference may also trigger delayed surgical treatment. Patients with lower activity and competition levels may be less keen to pursue operative management or may be more likely to be offered nonoperative management at the initial injury. Surgeon recommendation, for example for/against ACL reconstruction for patients at different level of competition, who play certain sports, and by patient age or sex, may also influence treatment.

Overall, patients who underwent ACLR at a time further away from their injury in this cohort were significantly more likely to have meniscal (73.5% vs. 63.2%) and chondral pathology (54.0% vs. 32.8%) at surgery, although both groups had a clinically significant prevalence of concurrent pathology. While others have shown that LM tears are more common in the acute scenario, we demonstrated the pattern of this injury – namely that partial LM tears predominate closer to injury (14%), but are less common over time (6%).⁵ It is plausible that a significant number of these partial LM tears heal, even in the ACL

deficient knee. Previous MOON consortium findings have supported that at 2 and 6 years after ACLR untreated partial LM tears confer no effect PROMs.⁷ The reliability of these findings is supported by the high inter-surgeon reliability for meniscal and articular cartilage injury classification among MOON consortium surgeons.^{10, 24}

The differences we noted in complete MM tears (49% of chronic vs. 22.5% acute) drove much of the difference overall – a 70% increased odds of meniscal tear based on chronicity >6 months. A higher prevalence of MM tears with greater time from ACL injury has been demonstrated previously.^{5, 17, 21} Even in the KANON study,¹³ among patients who did not undergo ACLR approximately 1/3 still underwent meniscectomy. This pattern may relate to the known function of the posterior horn of the medial meniscus as a dynamic secondary stabilizer to anterior knee translation in the ACL-deficient knee.^{2, 3} Furthermore, our results have demonstrated that the meniscal tears seen in the chronic group were more likely to be complete; these types of tears may be associated with poorer outcomes or more expensive treatment such as meniscal repair.⁷ Better protection of critical knee structures during rehabilitation or in those awaiting surgery seems warranted.

A higher prevalence of chondral injury with chronicity has also been reported in prior single surgeon series, although with variable definitions of ‘chronic’ from >6 weeks¹⁴ to >2 years,³⁷ and in one ACLR registry.¹⁷ We also found that patients who were older, played at a collegiate level, or had a lower Marx score at baseline had increased odds of chondral damage.

The highest comparable published quality of evidence for the interaction between timing of ACLR and associated pathology comes from the Norwegian registry of 3,475 patients.¹⁷ In this cohort, 26% had articular cartilage lesions, 47% meniscal tears and 15% had both – similar results to our own. They demonstrated that adults <40 years of age had a 3% increased odds of articular cartilage injury for each month from injury to surgery, and 0.4% increase for meniscal tears. These authors’ evaluation of their data by month from injury is a potentially clinically useful tool, however, it assumes the relationship between time and associated injury is linear.

Limitations

The primary limitation of this study is a lack of understanding why some MOON patients delayed surgery. Others have explored this issue previously.³⁶ Defining those who intentionally and non-intentionally delay reconstruction will help further inform treatment and prognostic recommendations. There are some people for whom delay is potentially safe from the perspective of limiting further meniscal and articular cartilage injury, and others for whom it is likely not. Presumably, those who delay surgery may not further damage their knee if they can control instability through activity modification, bracing, or functional rehabilitation, but this has not been proven.^{11, 15, 20} While MOON consortium patients were all directed to undergo the same standardized post-operative rehabilitation, pre-surgery rehabilitation and treatment (including recommendations and compliance for activity modification and bracing), as well as compliance were not recorded.

A second limitation is the lack of a standardized chronicity classification for ACLR, limiting some of the interpretation of these results compared to published literature. We chose a classification in-line with the majority,¹² however, we modified the ‘acute’ definition from a ceiling of 6 weeks to ~12 weeks (or 3 months) for clinical plausibility. This likely captured what some might consider a ‘subacute’ population. By author consensus, however, it was felt that patients undergoing purposeful acute reconstruction (the goal for defining this ‘acute’ cohort) may require up to 3 months from injury through diagnosis, referral and preoperative rehabilitation to come to surgery. In contrast, we hypothesized that those reconstructed >6 months were most likely to have purposefully delayed seeking surgical treatment, or be initially treated with a purely nonoperative plan.

A final limitation lies in the relationship between the time-frames examined and the PROMs utilized in this study, specifically the Marx score. The Marx score asks a patient to reflect on activity in their ‘healthiest state’ in the last ‘one year.’ We assumed most patients who come to a surgeon for ACLR would deem this to mean their pre-injury status (i.e., ‘healthiest state’), however, individual interpretation and the time-frame from injury (if >1 year) may have influenced this response. Patients who modified activity (e.g., via ‘coping’ or based on medical advice) pre-surgery may account for the lower Marx score by chronicity but we cannot be certain. In contrast, the KOOS and SF-36 refer to one month and one week prior and therefore represent the pre-surgical state.

Conclusion & Future studies

After controlling for age, sex, competition level, smoking and BMI, patients reconstructed greater than 6 months after injury participated in less pivoting and cutting sports, but reported better pain/function scores than those reconstructed within 3 months. Whether decreased activity is deliberate after ACL injury, or these are simply less active patients, many of whom may be treated successfully without surgery, warrants further investigation. These findings have considerable implications for the interpretation of PROMS from previously published and future non-randomized studies (e.g., cohorts, registries, case series) that did not consider time from injury in design and data interpretation.

Future work should be aimed at separating remotely reconstructed patients based on nonoperative treatment strategies and patient modifications. As outcomes become available in this cohort, a second significant future endeavor will be to compare intermediate and long-term outcomes (revision, re-operation and PROMs) based on chronicity. Cost-benefit analysis of early surgery versus late surgery from the perspective of PROMs and potential risks of increased post-traumatic osteoarthritis are also important questions.²⁶

APPENDIX

Table 1

Results of multivariable ANCOVA models

Parameter	B	SE	95% CI		P-value
			Lower Bound	Upper Bound	
Marx					
Intercept	20.884	0.859	19.199	22.569	0.000
Patient age	−0.141	0.016	−0.172	−0.109	0.000
Male sex	1.306	0.258	0.799	1.812	0.000
BMI	−0.153	0.030	−0.212	−0.093	0.000
School years completed	−0.096	0.047	−0.188	−0.004	0.040
Current/previous smoker	−1.133	0.334	−1.788	−0.479	0.001
Partial lateral meniscal tear	−0.150	0.458	−1.049	0.750	0.744
Complete Lateral meniscal tear	0.254	0.322	−0.379	0.886	0.431
Partial medial meniscal tear	0.497	0.648	−0.775	1.769	0.443
Complete medial meniscal tear	−0.302	0.357	−1.002	0.398	0.397
Any chondral pathology	−0.186	0.328	−0.829	0.457	0.571
Chronic ACL	−2.825	0.513	−3.831	−1.818	0.000
Chronic ACL * partial lateral meniscus tear	−0.622	1.204	−2.985	1.741	0.606
Chronic ACL * complete lateral meniscus tear	−0.524	0.599	−1.699	0.650	0.381
Chronic ACL * partial medial meniscus tear	−0.460	1.518	−3.439	2.520	0.762
Chronic ACL * complete medial meniscus tear	−0.174	0.611	−1.372	1.025	0.776
Chronic ACL * Any chondral pathology	−1.276	0.573	−2.400	−0.153	0.026
IKDC					
Intercept	63.819	3.286	57.371	70.266	0.000
Patient age	−0.309	0.062	−0.432	−0.187	0.000
Male sex	3.980	0.989	2.040	5.920	0.000
BMI	−0.566	0.117	−0.795	−0.337	0.000
School years completed	0.546	0.178	0.196	0.896	0.002
Current/previous smoker	−4.588	1.284	−7.108	−2.069	0.000
Partial lateral meniscal tear	−1.813	1.763	−5.273	1.648	0.304
Complete Lateral meniscal tear	−1.293	1.236	−3.718	1.133	0.296
Partial medial meniscal tear	2.496	2.491	−2.392	7.384	0.317
Complete medial meniscal tear	−1.312	1.364	−3.987	1.364	0.336
Any chondral pathology	1.349	1.259	−1.122	3.820	0.284
Chronic ACL	10.296	1.955	6.460	14.133	0.000
Chronic ACL * partial lateral meniscus tear	−1.425	4.600	−10.451	7.600	0.757
Chronic ACL * complete lateral meniscus tear	2.045	2.275	−2.419	6.508	0.369
Chronic ACL * partial medial meniscus tear	2.438	5.831	−9.003	13.879	0.676
Chronic ACL * complete medial meniscus tear	−1.818	2.325	−6.381	2.744	0.434
Chronic ACL * Any chondral pathology	−2.569	2.185	−6.855	1.718	0.240
KOOS qol					
Intercept	50.685	4.175	42.493	58.877	0.000

Parameter	B	SE	95% CI		P-value
			Lower Bound	Upper Bound	
Patient age	-0.256	0.079	-0.410	-0.102	0.001
Male sex	2.462	1.254	0.002	4.922	0.050
BMI	-0.286	0.148	-0.577	0.004	0.054
School years completed	0.046	0.226	-0.398	0.490	0.840
Current/previous smoker	-6.998	1.620	-10.175	-3.820	0.000
Partial lateral meniscal tear	2.499	2.230	-1.876	6.875	0.263
Complete Lateral meniscal tear	-0.880	1.568	-3.957	2.197	0.575
Partial medial meniscal tear	0.272	3.154	-5.916	6.460	0.931
Complete medial meniscal tear	-3.010	1.731	-6.408	0.387	0.082
Any chondral pathology	1.288	1.594	-1.839	4.415	0.419
Chronic ACL	3.415	2.488	-1.467	8.296	0.170
Chronic ACL * partial lateral meniscus tear	2.590	5.859	-8.905	14.086	0.658
Chronic ACL * complete lateral meniscus tear	1.027	2.883	-4.630	6.683	0.722
Chronic ACL * partial medial meniscus tear	-4.981	7.380	-19.461	9.499	0.500
Chronic ACL * complete medial meniscus tear	-0.384	2.946	-6.165	5.396	0.896
Chronic ACL * Any chondral pathology	-1.838	2.770	-7.274	3.597	0.507
KOOS sports					
Intercept	79.110	6.056	67.229	90.992	0.000
Patient age	-0.166	0.114	-0.389	0.058	0.146
Male sex	1.636	1.819	-1.934	5.206	0.369
BMI	-1.028	0.215	-1.450	-0.606	0.000
School years completed	0.075	0.327	-0.568	0.717	0.820
Current/previous smoker	-4.251	2.349	-8.861	0.359	0.071
Partial lateral meniscal tear	-4.014	3.261	-10.412	2.384	0.219
Complete Lateral meniscal tear	-2.051	2.275	-6.515	2.412	0.367
Partial medial meniscal tear	4.738	4.602	-4.293	13.768	0.304
Complete medial meniscal tear	-1.055	2.503	-5.965	3.856	0.674
Any chondral pathology	2.256	2.306	-2.268	6.780	0.328
Chronic ACL	10.006	3.613	2.917	17.094	0.006
Chronic ACL * partial lateral meniscus tear	9.626	8.477	-7.007	26.258	0.256
Chronic ACL * complete lateral meniscus tear	5.924	4.187	-2.291	14.138	0.157
Chronic ACL * partial medial meniscus tear	-5.050	10.682	-26.009	15.909	0.636
Chronic ACL * complete medial meniscus tear	-0.576	4.274	-8.963	7.811	0.893
Chronic ACL * Any chondral pathology	-1.855	4.014	-9.731	6.020	0.644
KOOS adi					
Intercept	99.401	3.406	92.719	106.084	0.000
Patient age	-0.257	0.064	-0.383	-0.131	0.000
Male sex	1.300	1.023	-0.708	3.308	0.204
BMI	-0.709	0.121	-0.946	-0.471	0.000
School years completed	0.467	0.185	0.105	0.830	0.012
Current/previous smoker	-4.456	1.325	-7.056	-1.855	0.001

Parameter	B	SE	95% CI		P-value
			Lower Bound	Upper Bound	
Partial lateral meniscal tear	-3.307	1.820	-6.877	0.264	0.070
Complete Lateral meniscal tear	0.025	1.280	-2.487	2.536	0.985
Partial medial meniscal tear	5.718	2.585	0.646	10.789	0.027
Complete medial meniscal tear	-0.019	1.416	-2.797	2.760	0.989
Any chondral pathology	1.355	1.301	-1.198	3.908	0.298
Chronic ACL	6.345	2.030	2.363	10.328	0.002
Chronic ACL * partial lateral meniscus tear	1.883	4.781	-7.498	11.264	0.694
Chronic ACL * complete lateral meniscus tear	-0.088	2.353	-4.704	4.528	0.970
Chronic ACL * partial medial meniscus tear	-5.107	6.027	-16.933	6.718	0.397
Chronic ACL * complete medial meniscus tear	-1.395	2.406	-6.116	3.327	0.562
Chronic ACL * Any chondral pathology	-1.972	2.261	-6.408	2.465	0.383
KOOS symptoms					
Intercept	80.041	3.670	72.840	87.242	0.000
Patient age	-0.202	0.069	-0.338	-0.067	0.003
Male sex	3.736	1.102	1.573	5.899	0.001
BMI	-0.464	0.130	-0.720	-0.209	0.000
School years completed	0.330	0.199	-0.060	0.720	0.097
Current/previous smoker	-3.979	1.427	-6.779	-1.179	0.005
Partial lateral meniscal tear	-2.011	1.967	-5.871	1.848	0.307
Complete Lateral meniscal tear	-2.147	1.377	-4.850	0.556	0.119
Partial medial meniscal tear	2.653	2.777	-2.796	8.103	0.340
Complete medial meniscal tear	-3.740	1.522	-6.725	-0.754	0.014
Any chondral pathology	-0.537	1.401	-3.285	2.211	0.701
Chronic ACL	8.192	2.186	3.904	12.480	0.000
Chronic ACL * partial lateral meniscus tear	1.294	5.151	-8.814	11.401	0.802
Chronic ACL * complete lateral meniscus tear	0.824	2.533	-4.146	5.794	0.745
Chronic ACL * partial medial meniscus tear	-4.225	6.488	-16.954	8.504	0.515
Chronic ACL * complete medial meniscus tear	-0.713	2.589	-5.792	4.367	0.783
Chronic ACL * Any chondral pathology	-1.484	2.435	-6.260	3.293	0.542
SF-36 PCS					
Intercept	43.667	2.040	39.664	47.671	0.000
Patient age	-0.150	0.038	-0.224	-0.075	0.000
Male sex	1.412	0.606	0.223	2.602	0.020
BMI	-0.287	0.072	-0.429	-0.145	0.000
School years completed	0.492	0.110	0.277	0.708	0.000
Current/previous smoker	-2.152	0.784	-3.689	-0.614	0.006
Partial lateral meniscal tear	-0.266	1.081	-2.387	1.854	0.805
Complete Lateral meniscal tear	-1.097	0.759	-2.586	0.391	0.148
Partial medial meniscal tear	1.490	1.526	-1.504	4.485	0.329
Complete medial meniscal tear	-0.703	0.837	-2.345	0.938	0.401
Any chondral pathology	1.835	0.771	0.322	3.349	0.018

Parameter	B	SE	95% CI		P-value
			Lower Bound	Upper Bound	
Chronic ACL	6.871	1.214	4.488	9.254	0.000
Chronic ACL * partial lateral meniscus tear	-2.257	2.833	-7.814	3.301	0.426
Chronic ACL * complete lateral meniscus tear	1.250	1.397	-1.492	3.991	0.371
Chronic ACL * partial medial meniscus tear	0.583	3.565	-6.413	7.579	0.870
Chronic ACL * complete medial meniscus tear	-0.875	1.430	-3.681	1.932	0.541
Chronic ACL * Any chondral pathology	-2.851	1.344	-5.489	-0.214	0.034
SF-36 MCS					
Intercept	54.863	2.513	49.932	59.794	0.000
Patient age	0.011	0.047	-0.081	0.103	0.819
Male sex	0.282	0.747	-1.183	1.748	0.705
BMI	-0.086	0.089	-0.261	0.088	0.332
School years completed	-0.059	0.135	-0.325	0.206	0.661
Current/previous smoker	-4.781	0.965	-6.675	-2.888	0.000
Partial lateral meniscal tear	0.887	1.332	-1.726	3.499	0.506
Complete Lateral meniscal tear	0.766	0.934	-1.067	2.600	0.412
Partial medial meniscal tear	-2.097	1.880	-5.785	1.591	0.265
Complete medial meniscal tear	-1.048	1.030	-3.070	0.974	0.309
Any chondral pathology	0.287	0.950	-1.578	2.151	0.763
Chronic ACL	-0.190	1.496	-3.125	2.745	0.899
Chronic ACL * partial lateral meniscus tear	2.287	3.489	-4.559	9.133	0.512
Chronic ACL * complete lateral meniscus tear	0.328	1.721	-3.050	3.705	0.849
Chronic ACL * partial medial meniscus tear	-1.919	4.392	-10.536	6.698	0.662
Chronic ACL * complete medial meniscus tear	1.089	1.762	-2.368	4.546	0.537
Chronic ACL * Any chondral pathology	1.083	1.656	-2.166	4.331	0.513

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What is known about the subject?

The pattern of concurrent injury based on proximity to injury – that partial LM tears are more common during early ACLR, and complete MM in late ACLR – has been demonstrated in previous small case series and one registry.^{5, 17, 21} In the Norwegian Registry,¹⁷ chronicity was associated with increased odds for articular cartilage pathology at surgery, and medial meniscal tears. The influence of time from injury to surgery on baseline PROMs, however, has never been reported.

What this study adds to the existing knowledge?

Our study is derived from a prospectively collected dataset which utilizes inter-surgeon validated articular cartilage and meniscal injury classifications. Thus, we have confirmed, with the highest level of evidence in the literature, previous published patterns of concurrent injury at ACLR based on chronicity. More importantly, however, this study is the first to examine whether differences in baseline PROMs are influenced by chronicity. This is valuable information given that the vast majority of current and previously published clinical studies include a mix of patients in terms of timing of surgery. These and future studies should control for time from injury in their analysis when reporting on PROM in order to avoid confounding. This is especially true for non-randomized and registry-based studies.

Finally, we have identified a sub-population of ACLR patients that would benefit from further study and identification. Even after controlling for known confounders, patients reconstructed remote from injury were significantly more likely to report lower Marx activity scores and better pain/function scores.

Figure 1.
Figure 1A–D: Adjusted differences between Acute and Chronic ACL study groups in (A) Marx Activity Rating Scale, (B) IKDC Subjective Form, (C) KOOS subscales, and (D) SF-36 Physical and Mental Component Summary scores. Error bars indicate 95% confidence intervals.

Table 1
Baseline and comparison of patient and surgical characteristics between Acute and Chronic ACL patients.

	Total N	Overall Median (IQR) or N (%)	Acute ACL Median (IQR) or N (%)	Chronic ACL Median (IQR) or N (%)	P-value
Patient age	1192	23.0 (17.0–35.0)	20.0 (17.0–31.0)	30.0 (23.0–40.0)	<0.001
Female sex	1192	530 (44.5%)	407 (47.7%)	123 (36.3%)	<0.001
BMI	1169	25.0 (22.3–27.9)	24.2 (22.0–27.0)	26.5 (23.4–29.5)	<0.001
Normal	1169	590 (50.5%)	474 (56.5%)	116 (35.2%)	<0.001
Overweight	1169	409 (35.0%)	263 (31.3%)	146 (44.2%)	
Obese	1169	170 (14.5%)	102 (12.2%)	68 (20.6%)	
School years completed	1164	14.0 (11.0–16.0)	13.0 (11.0–16.0)	15.0 (12.0–17.0)	<0.001
Smoke status					
Never	1182	951 (80.5%)	717 (84.9%)	234 (69.4%)	<0.001
Quit/Current	1182	231 (19.5%)	128 (15.1%)	103 (30.6%)	
Competition level					
None/Recreational	1186	548 (46.2%)	315 (37.0%)	233 (69.8%)	<0.001
High School	1186	339 (28.6%)	296 (34.7%)	43 (12.9%)	
College	1186	117 (9.9%)	103 (12.1%)	14 (4.2%)	
Amateur	1186	159 (13.4%)	121 (14.2%)	38 (11.4%)	
Professional	1186	23 (1.9%)	17 (2.0%)	6 (1.8%)	
Previous contralateral surgery	1192	107 (9.0%)	77 (9.0%)	30 (8.8%)	0.923
Lateral meniscal tear					
No tear	1192	651 (54.6%)	447 (52.4%)	204 (60.2%)	0.001
Partial	1192	143 (12.0%)	121 (14.2%)	22 (6.5%)	
Complete	1192	398 (33.4%)	285 (33.4%)	113 (33.3%)	
Medial meniscal tear					
No tear	1192	733 (61.5%)	587 (68.8%)	146 (43.1%)	<0.001
Partial	1192	101 (8.5%)	74 (8.7%)	27 (8.0%)	
Complete	1192	358 (30.0%)	192 (22.5%)	166 (49.0%)	
Any meniscal pathology	1192	788 (66.1%)	539 (63.2%)	249 (73.5%)	0.001
Any chondral pathology	1192	463 (38.8%)	280 (32.8%)	183 (54.0%)	<0.001

Table 2

Unadjusted differences in PROMs between Acute and Chronic ACL study groups.

	Acute ACL		Chronic ACL		P-value
	N	Mean (SE)	N	Mean (SE)	
Marx Activity Rating Scale	851	12.74 (0.16)	331	7.44 (0.26)	<0.001
IKDC Subjective Form	842	50.50 (0.57)	331	56.19 (0.90)	<0.001
KOOS Quality of Life	852	38.05 (0.71)	338	36.70 (1.13)	0.312
KOOS Pain	851	73.11 (0.59)	333	75.68 (0.94)	0.020
KOOS Function: Sports and Recreational	843	50.23 (1.01)	335	57.53 (1.61)	<0.001
KOOS Function: Daily Living	851	82.07 (0.58)	338	83.31 (0.92)	0.255
KOOS Symptoms	852	67.39 (0.62)	338	71.03 (0.99)	0.002
SF-36 Physical Functioning	852	58.91 (0.84)	337	66.15 (1.34)	<0.001
SF-36 Physical Role Functioning	849	32.45 (1.39)	337	55.69 (2.21)	<0.001
SF-36 Bodily Pain	853	57.03 (0.74)	338	62.94 (1.18)	<0.001
SF-36 General Health Perceptions	853	86.49 (0.48)	338	80.85 (0.76)	<0.001
SF-36 Vitality	852	63.22 (0.67)	337	62.09 (1.06)	0.368
SF-36 Social Role Functioning	853	72.92 (0.82)	338	79.11 (1.30)	<0.001
SF-36 Emotional Role Functioning	849	73.36 (1.31)	337	79.13 (2.08)	0.019
SF-36 Mental Health	852	74.97 (0.57)	337	76.60 (0.90)	0.128
SF-36 PCS	847	40.07 (0.34)	334	44.04 (0.54)	<0.001
SF-36 MCS	847	51.62 (0.41)	334	51.77 (0.66)	0.847

Table 3

Adjusted differences in PROMs between Acute and Chronic ACL study groups.

	Acute ACL			Chronic ACL			P-value
	N	Mean (SE)	N	Mean (SE)	N	P-value	
Marx Activity Rating Scale	818	12.10 (0.32)	315	7.75 (0.44)	315	<0.001	<0.001
IKDC Subjective Form	810	48.19 (1.22)	315	57.82 (1.72)	315	<0.001	<0.001
KOOS Quality of Life	818	35.06 (1.54)	320	36.68 (2.16)	320	0.528	0.528
KOOS Pain	818	70.51 (1.27)	317	75.31 (1.81)	317	0.025	0.025
KOOS Function: Sports and Recreational	809	48.26 (2.23)	317	62.30 (3.11)	317	<0.001	<0.001
KOOS Function: Daily Living	817	81.33 (1.26)	320	84.34 (1.76)	320	0.152	0.152
KOOS Symptoms	818	64.42 (1.35)	320	70.46 (1.89)	320	0.008	0.008
SF-36 Physical Functioning	818	56.72 (1.81)	318	67.32 (2.54)	318	<0.001	<0.001
SF-36 Physical Role Functioning	815	28.83 (3.06)	318	52.80 (4.28)	318	<0.001	<0.001
SF-36 Bodily Pain	819	55.58 (1.63)	319	63.08 (2.28)	319	0.006	0.006
SF-36 General Health Perceptions	819	82.53 (1.04)	319	80.80 (1.45)	319	0.315	0.315
SF-36 Vitality	819	58.17 (1.45)	319	61.49 (2.03)	319	0.171	0.171
SF-36 Social Role Functioning	819	72.49 (1.81)	319	78.02 (2.53)	319	0.067	0.067
SF-36 Emotional Role Functioning	816	65.80 (2.88)	318	75.59 (4.03)	318	0.041	0.041
SF-36 Mental Health	819	72.51 (1.26)	319	75.19 (1.76)	319	0.202	0.202
SF-36 PCS	815	39.46 (0.74)	316	44.26 (1.04)	316	<0.001	<0.001
SF-36 MCS	815	49.28 (0.92)	316	50.52 (1.28)	316	0.416	0.416

Table 4
Significant predictors of chondral or articular cartilage damage at surgery from multivariate logistic regression.

	Meniscus tear		Chondral pathology	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Age	-----	NS	1.07 (1.05–1.09)	<0.001
Female sex	0.71 (0.55–0.92)	0.009	-----	NS
BMI (higher)	-----	NS	-----	NS
Competition level (vs. None/Recreational)				
Professional	3.59 (1.05–12.26)	0.040	-----	NS
College	-----	NS	2.2 (1.35–3.57)	0.001
Chronic ACLR	1.69 (1.26–2.28)	0.001	1.4 (1.02–1.92)	0.040
Marx at baseline (higher score)	-----	NS	0.96 (0.93–0.98)	0.004

OR, odds ratio; 95% CI, 95% confidence interval

NS, no significant (p>0.05)

Table 5

Adjusted odds ratios of delayed surgery for lateral and medial meniscal tear.

	Lateral Meniscus Tear			Medial Meniscus Tear		
	Overall	Partial	Complete	Overall	Partial	Complete
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Chronic ACLR	NS	0.39 (0.23–0.66) *	NS	2.64 (1.93–3.61) *	NS	2.85 (2.07–3.92) *

* P-value was p<0.001

All models were adjusted for age, sex, BMI, smoking status, competition level, and patient reported outcome scores