Journal of Athletic Training 2023;58(11/12):998–1003
doi: 10.4085/1062-6050-0229.22

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Psychological Readiness, Injury-Related Fear, and Persistent Knee Symptoms After Anterior Cruciate Ligament Reconstruction

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Context: Poor psychological responses after anterior cruciate ligament reconstruction (ACLR) have been associated with a failure to return to sport and increased secondary injury risk. However, we do not know whether poor psychological responses after ACLR influence patient-reported knee function and knee symptoms.

Objective: To examine the association between psychological factors (ie, psychological readiness and injury-related fear) and the presence of persistent knee symptoms in individuals 6 to 12 months after ACLR.

Design: Cross-sectional study.

Setting: Research laboratory.

Patients or Other Participants: In total, 101 participants, aged 13 to 25 years old, between 6 and 12 months after primary unilateral ACLR were enrolled in the study.

Main Outcome Measure(s): Persistent knee symptoms were identified using an established criterion based on the subscales of the Knee injury and Osteoarthritis Outcome Score. Participants also completed the Anterior Cruciate Ligament-Return to Sport after Injury (ACL-RSI) and the Tampa Scale of Kinesiophobia-11 (TSK-11) to assess psychological readiness and injury-related fear, respectively. Higher ACL-RSI scores indicate higher psychological readiness, and higher TSK-11 scores indicate higher injury-related fear.

Results: Twenty-nine participants (29%) met the criteria for persistent knee symptoms. For every 1 SD lower in the ACL-RSI score, participants had 2.1 times greater odds of persistent knee symptoms after ACLR (95% CI = 1.3, 3.6). For every 1 SD higher in the TSK-11 score, participants had 1.9 times greater odds of persistent knee symptoms after ACLR (95% CI = 1.1, 3.3). Both the ACL-RSI and TSK-11 were considered *good* at classifying persistent knee symptoms, as the areas under the curve were 0.78 and 0.73, respectively.

Conclusions: Individuals with a lower level of psychological readiness and more injury-related fear after ACLR had greater odds of persistent knee symptoms. Overall, these results highlight the potential clinical benefit of a comprehensive, biopsychosocial approach to managing health and wellness for individuals after ACLR.

Key Words: psychology, rehabilitation

Key Points

- Between 6 and 12 months after anterior cruciate ligament reconstruction, 29% of individuals met the criteria for persistent knee symptoms.
- In the same time frame, participants with poor psychological readiness and elevated injury-related fear had greater odds of persistent knee symptoms.

Approximately 1 in 3 patients indicated that their anterior cruciate ligament reconstruction (ACLR) was a failure within 1 year of surgery.[1] In addition to a lack of satisfaction with the state of their knee,[2] only 65% of patients will return to preinjury levels of sports participation,[1] 29.5% of patients will sustain a secondary ACL injury,[3] and only about two-thirds of patients at 1 to 2 years after ACLR will perceive their knee symptoms as acceptable.[4] Currently, we understand that patients who undergo ACLR experience a psychological response to their injury and surgery that can be complex and individualized.[1] Poor psychological responses to ACL injury or ACLR play a role in determining whether patients return to their preinjury levels of sport participation[1] or experience a secondary ACL injury.[5] Therefore, the psychological response to injury and surgery may be an ideal target for assessment and intervention to reduce the secondary ACL injury risk.

A poor psychological response to returning to sport after injury can include an array of psychological factors, such as increased levels of injury-related fear and decreased levels of confidence.[6] Recently, assessments of psychological response to injury and surgery have become highly encouraged through the implementation of psychologically informed practice.[7] Patient-reported outcome measures, such as the ACL Return

to Sport after Injury Scale (ACL-RSI)[8] and the Tampa Scale of Kinesophobia-11 (TSK-11),[9] have been used to examine overall psychological readiness for return to sport (ie, emotions, confidence, and risk appraisal) and injury-related fear in patients after ACLR, respectively. Although quantifying psychological responses to injury is increasingly common in identifying whether a patient may be ready to return to sport, examining these factors may also provide insight into the risk for persistent knee symptoms after ACLR that can later develop into knee osteoarthritis (OA).[5] In patients with knee OA, poor psychological responses have been associated with increased knee pain, worse knee symptoms, and decreased knee-related quality of life.[10–12]

Knee OA is defined by structural changes at a joint (ie, *disease*) and symptoms characterized by patient-reported outcome measures (ie, *illness*).[13] We will use *knee OA illness* to reflect the patients' perceptions of their knee health via patient-reported outcome measures. Approximately 50% of patients have radiographic signs of knee OA disease within 2 decades of ACLR, and 1 in 3 patients will display magnetic resonance evidence of knee OA within 1 year of surgery.[14,15] Patient-reported classification criteria were recently introduced to define early knee OA illness using the Knee injury and Osteoarthritis Outcome Score (KOOS). Using these classification criteria, 21% of patients were considered to have early knee OA illness at 5 years after ACLR.[16] However, we do not know whether maladaptive psychological responses are associated with persistent knee symptoms in patients after ACLR that may later turn into early knee OA illness.[16]

In other populations with pathologic conditions (eg, low back pain), psychological responses to injury influence functional capacity and the experience of pain.[17] Yet how psychological responses influence patient-reported function and symptoms among individuals with ACLR is unclear. Understanding these is important as patient-reported knee function and symptoms are likely influenced by psychological responses to injury. Exploring the association between psychological responses and persistent knee symptoms during the first year after ACLR could lead to identification of intervention strategies that mitigate the future development of early knee OA illness. Therefore, the purpose of our study was to examine the association between psychological factors (ie, psychological readiness and injury-related fear) and persistent knee symptoms in individuals 6 to 12 months after ACLR. We hypothesized that individuals reporting worse psychological readiness and greater injury-related fear would also demonstrate persistent knee symptoms 6 to 12 months after ACLR.

METHODS

A cross-sectional study design was used to determine whether psychological readiness and injury-related fear were associated with persistent knee symptoms in individuals after ACLR. Individuals who were between 6 and 12 months after ACLR completed a series of patient-reported outcome measures via an online survey portal (Qualtrics LLC). The independent variables were psychological readiness (ie, ACL-RSI score) and injury-related fear (ie, TSK-11 score). The dependent variable was persistent knee symptoms after ACLR, operationally defined using established criteria based on the subscales of the KOOS.[18] Informed consent was obtained from adult participants, and parental consent and assent was obtained from minors before participation. This study was approved by the Michigan State University Institutional Review Board.

Participants

In total, 101 participants were recruited from a local sports medicine clinic from October 2017 to March 2020. Participants were included in the study if they were between 13 and 25 years old and had undergone primary, unilateral ACLR 6 to 12 months before completion of the patient-reported outcome measures. Recruits were excluded if they had a history of knee surgery before their ACLR, a multiligament reconstruction involving the posterior cruciate ligament, or a surgical procedure to treat an articular cartilage lesion at the time of their ACLR.

Study Procedures

After we obtained informed consent, participants completed an intake questionnaire that addressed demographics (eg, sex and age) and basic surgical characteristics (eg, date of injury and date of surgery). After completing the demographics questionnaire, participants completed the ACL-RSI, TSK-11, and KOOS.

Outcome Measures

The ACL-RSI. The ACL-RSI is a 12-item questionnaire that assesses a patient's psychological readiness to return to sport. Three domains are evaluated: emotions (5 items), confidence (5 items), and risk appraisal (2 items). The ACL-RSI is scored on a scale of 0 to 100, with 0 representing *low psychological readiness* and 100 representing *high psychological readiness*. The ACL-RSI has demonstrated high validity and internal consistency (Cronbach $\alpha = .96$).[8]

The TSK-11. The TSK-11 is a valid and reliable 11-item questionnaire that assesses *kinesiophobia* (ie, the fear of movement or reinjury).[9] The TSK-11 was created to assess kinesiophobia in patients with chronic low back pain but has since been used in and validated for patients with ACLR.[19] The TSK-11 is scored on a scale of 11 to 44, with higher scores representing higher levels of kinesiophobia. The TSK-11 exhibited excellent internal consistency (Cronbach $\alpha = .79$) and good reliability (intraclass correlation coefficient = 0.81).[9]

The KOOS. The KOOS is a 42-item questionnaire that assesses knee-related disability in individuals with knee conditions.[20] The KOOS has 5 subscales: symptoms (7 items), pain (9 items), activities of daily living (17 items), function in sport and recreation (5 items), and quality of life (4 items). Each subscale is scored separately on a scale of 0 to 100. A score of 0 represents *extreme knee problems*, and a score of 100 represents *no knee problems*. The KOOS displayed adequate content validity, internal consistency, test-rest reliability, construct validity, and responsiveness.[21]

Persistent Knee Symptoms Classification. Luyten et al[18] developed classification criteria for the identification of early knee OA illness that consisted of (1) knee pain, function, and symptoms using the KOOS score; (2) clinical examination for joint line tenderness or crepitus; and (3) a Kellgren and Lawrence (KL) grade of 0 or 1 based on knee radiographs. To identify individuals after ACLR with persistent

Table 1. Participant Demographics

Characteristic	Persistent Knee Symptoms: Present (n = 29)	Persistent Knee Symptoms: Absent (n = 72)	Total (N = 101)	*P* Value
Sex, No. (%)				.55
Females	18 (62)	40 (55)	58 (58)	
Males	11 (37)	32 (44)	43 (43)	
Age, y	19.4 (3.1)	18.2 (2.5)	18.5 (2.7)	.03
Body mass index, kg/m^2, mean ± SD	23.9 ± 3.5	24.9 ± 4.6	24.6 ± 4.8	.29
Graft type, No. (%)				.27
Bone-tendon-bone	5 (17)	16 (23)	21 (21)	
Hamstrings	21 (73)	53 (75)	74 (74)	
Allograft	3 (10)	2 (2)	5 (5)	
Time since surgery, mo, mean ± SD	7.9 ± 1.9	8.0 ± 1.7	8.0 ± 1.7	.77
Knee injury and Osteoarthritis Outcome score, mean ± SD				
Symptoms	73.2 (9.2)	91.7 (9.0)	86.4 (12.4)	<.0001
Pain	89.3 (8.4)	96.9 (3.6)	94.7 (6.3)	<.0001
Activities of Daily Living	93.8 (17.1)	99.3 (1.8)	97.7 (9.5)	.007
Function in Sport and Recreation	78.3 (16.5)	91.4 (10.3)	87.6 (13.6)	<.0001
Quality of Life	56.3 (14.7)	75.0 (19.4)	69.6 (20.0)	<.0001

knee symptoms, we used modified Luyten et al[18] criteria to categorize them into 2 groups (ie, persistent knee symptoms or no persistent knee symptoms) based on their KOOS scores. We did not include a clinical examination or KL grade and therefore were unable to categorize based on early knee OA illness status.[18] *Persistent knee symptoms* were defined as scoring ≤85.0 on 2 or more of the following KOOS subscales: symptoms, pain, activities of daily living, or quality of life.

Statistical Analysis

Demographics and surgical characteristics were compared between participants with persistent knee symptoms and those with no persistent knee symptoms using independent-samples *t* tests and χ^2 analyses when appropriate. Descriptive statistics were calculated for the independent variables (ie, ACL-RSI and TSK-11 scores) and the individual KOOS subscale scores. Separate logistic regression models were developed to determine if psychological readiness or injury-related fear was associated with persistent knee symptoms after ACLR. We adjusted the logistic regression models for age, sex, body mass index, time since surgery, and graft type. Unadjusted and adjusted odds ratios (ORs, aORs) and 95% CIs were computed for each model and reported as odds of having persistent knee symptoms for each 1 SD of worsening in the independent variable of interest. Because the 2 independent variables have opposite scales, the OR for the ACL-RSI analysis is interpreted as the odds of persistent knee symptoms per unit decrease in the overall group ACL-RSI SD. Alternatively, the OR for the TSK-11 analysis is interpreted per unit increase equivalent to the overall group TSK-11 SD. Unadjusted and adjusted area under the curve (AUC) was calculated to determine the ability of the ACL-RSI and TSK-11 scores to discriminate between participants with and those without persistent knee symptoms after ACLR. The AUC was interpreted as 1.0 to 0.90, *excellent*; 0.90 to 0.80, *good*; 0.80 to 0.70, *fair*; and 0.70 to 0.60, *poor*. We confirmed linearity of the continuous variables with respect to the logit of the dependent variable using the Box-Tidwell procedure. Based on this assessment, the ACL-RSI and TSK-11 scores were linearly related to the logit of the dependent variable.[22] Significance was set a priori at $P < .05$. All statistical analyses were conducted using SAS (version 9.4; SAS Institute) except for the linearity testing, which was completed in SPSS (version 28; IBM Corp).

RESULTS

Twenty-nine participants (29%) met the criteria for persistent knee symptoms after ACLR. Body mass index and time since surgery did not differ between individuals with and those without persistent knee symptoms (Table 1). However, the participants with persistent knee symptoms were on average 1.3 years older than those without persistent knee symptoms ($P = .03$; Table 1). Significant associations were observed between psychological factors and persistent knee symptoms (Table 2). For every 1 SD lower in ACL-RSI score (overall SD = 22.6), a participant had 2.1 times greater odds of persistent knee symptoms (aOR = 2.1; 95% CI = 1.3, 3.6). For every 1 SD higher in TSK-11 score (overall SD = 4.8), a participant had 1.9 times greater odds of persistent knee symptoms (aOR = 1.9; 95% CI = 1.1, 3.3). Both models containing the ACL-RSI and TSK-11 scores were considered good at classifying persistent knee symptoms, as the adjusted AUC values were 0.78 and 0.73, respectively.

DISCUSSION

The purpose of our study was to examine whether worse levels of psychological readiness and injury-related fear were associated with persistent knee symptoms in individuals 6 to 12 months after ACLR. Our results showed that individuals with decreased psychological readiness and those with increased injury-related fear had greater odds of persistent knee symptoms after ACLR. Furthermore, questionnaires that measure psychological readiness (ie, ACL-RSI) and injury-related fear (ie, TSK-11) were good at discriminating between patients with and those without persistent knee symptoms after ACLR. Overall, these findings indicate that a biopsychosocial approach to patient care is needed to mitigate knee symptoms in patients after ACLR. Less psychological readiness includes factors such as

Table 2. Association Between Psychological Readiness Variables and Persistent Knee Symptoms

Psychological Readiness Score	Persistent Knee Symptoms, Mean ± SD		Adjusted[a]		Unadjusted	
	Present	Absent	Odds Ratio (95% CI)[b]	Area Under the Curve	Odds Ratio (95% CI)[b]	Area Under the Curve
Anterior Cruciate Ligament Return to Sport after Injury Scale (ACL-RSI)	59.5 ± 19.5	76.4 ± 22.0	2.1 (1.3, 3.6)[c]	0.78	2.2 (1.3, 3.4)	0.75
Tampa Scale of Kinesiophobia-11	20.9 ± 4.8	18.4 ± 4.6	1.9 (1.1, 3.3)[c]	0.73	1.8 (1.1, 2.8)[c]	0.65

[a] Adjusted for sex, age, body mass index, graft type, and time since surgery.
[b] The odds ratio for the ACL-RSI analysis is interpreted as the odds of having persistent knee symptoms per unit decrease equivalent to the overall group ACL-RSI SD (22.6), whereas the odds ratio for the Tampa Scale of Kinesiophobia-11 analysis is interpreted per unit increase equivalent to the overall group Tampa Scale of Kinesiophobia-11 SD (4.8).
[c] Statistically significant.

negative risk appraisal (ie, thoughts of sustaining a reinjury that may prevent sport participation), confidence, and emotions (ie, feelings of nervousness, frustration, and injury-related fear). Greater injury-related fear includes a fear of movement or fear of reinjury after ACLR. Therefore, a variety of biological, psychological, and social factors that may influence persistent knee symptoms after ACLR need to be investigated.[23]

We classified participants into those with or without persistent knee symptoms using modified Luyten et al criteria.[18] The original Luyten et al criteria include (1) assessments of knee pain, function, and symptoms using the KOSS; (2) clinical examination for joint line tenderness or crepitus; and (3) a KL grade of 0 or 1 based on knee radiographs.[18] As we did not have access to the clinical examinations or radiographs for the patients in our study, we used only the KOOS subscale scores to identify individuals with persistent knee symptoms and dichotomize them into groups. Although failing to include radiographic evidence may diminish our ability to best characterize whether a patient is exhibiting persistent knee symptoms associated with early knee OA illness, including radiographic evidence in clinical practice has drawbacks. Luyten et al[18] did not recommend the use of magnetic resonance imaging to aid in identifying early knee OA illness in routine clinical practice due to the high prevalence of structural changes in the knee joint observed with this technique.[18] Furthermore, our approach to consider only the KOOS subscale scores to identify individuals with persistent knee symptoms enhances the translation of our findings to aid clinical practice as access to repeat radiographs may not always be available after ACLR due to an array of factors, including obtaining approval from the patient's insurance company to cover additional films. Additionally, despite the importance of symptoms in defining early knee OA illness, it is difficult to recognize a patient's transition between normal unresolved post-ACLR symptoms and chronic symptoms that reflect the onset of early knee OA illness as no clear time frame exists to determine when unresolved symptoms become early knee OA illness.[23] Whether defined as early knee OA illness or persistent knee symptoms, our results highlight a gap in our clinical care that suggests psychological factors may influence a patient's perception of knee symptoms, pain, function, and quality of life.

The original Luyten et al[18] criteria were created to shift OA management to a more proactive approach that seeks to identifies people with earlier-stage OA.[18] The goal of rehabilitation specialists should be to provide clinical care that emphasizes secondary prevention practices so that patients do not need to seek additional care for their knee after primary ACLR. It is concerning that 29% of our participants presented with symptoms that met the persistent knee symptoms component of the original Luyten et al[18] criteria for early knee OA illness, especially because the time since surgery was 8.0 ± 1.7 months and the age of the cohort was 18.5 ± 2.7 years. This suggests that young-adult patients experience persistent knee symptoms throughout their recovery despite our best clinical efforts. These results highlight the need to identify knee symptoms throughout recovery after ACLR and to develop interventions, which may include a psychological component, to reduce knee OA after ACLR.

We also found that both the ACL-RSI and the TSK-11 were good at identifying patients with persistent knee symptoms. Interestingly, neither group showed average scores below the recommended clinical cutoffs (ie, $<$77 points on the ACL-RSI[5] and $\geq$17 points on the TSK-11[24]). However, the group with persistent knee symptoms exhibited worse scores on the ACL-RSI and the TSK-11 than the group without knee symptoms. Psychological surveys may help to identify a factor that is consistent among individuals with knee symptoms after ACLR, thereby making psychological factors an excellent target for intervention. Clinicians should therefore use these questionnaires, in conjunction with the KOOS, to monitor factors that may contribute to the development or resolution of persistent knee symptoms after ACLR. These questionnaires are valid and reliable measures of psychological readiness and injury-related fear and can be easily implemented into clinical practice.[12] Administering them takes less than 10 minutes, is less expensive than radiographs, and does not require an office visit for a clinical examination, which is helpful for patients with transportation barriers. In addition to the total score, individual items may pinpoint specific fears or areas of decreased confidence to address with the patient through psychologically informed practice strategies. Consequently, we have a clear and critical need to address knee symptoms, function, and quality of life after ACLR in conjunction with modalities beyond traditional physical interventions and under a psychologically informed practice lens.

As our cross-sectional study design limited our ability to state that psychological factors were causing worse knee symptoms, it is imperative to provide comprehensive health care to address psychological readiness, injury-related fear, and knee symptoms after ACLR. Interventions that directly target improving the biological aspects of recovery may also enhance psychological readiness and reduce injury-related fear. Nevertheless, our findings are clinically relevant in highlighting a potentially reciprocal relationship

between self-reported function and the psychological aspects of recovery after ACLR. *Psychologically informed practice* is a biopsychosocial approach to rehabilitation that incorporates behavioral strategies, in conjunction with physical rehabilitation, to address maladaptive cognitions, emotions, and behaviors and could help to target these knee-related deficits after ACLR that may not be responsive to physical intervention methods.[25] After the patient's psychological variables are assessed using the ACL-RSI or TSK-11, psychologically informed practice recommends intervening using appropriate behavioral interventions, such as graded exposure therapy and acceptance and commitment therapies (ACTs).[7]

Graded exposure therapy and ACTs are specific psychological interventions that may improve overall psychological health and decrease persistent knee symptoms in patients after ACLR. Graded exposure therapy has been used to improve psychological health by addressing psychological readiness and injury-related fear, self-reported symptoms, and physical function in other populations with musculoskeletal injuries.[7,26,27] Alternatively, an ACT such as mindfulness meditation is a psychological intervention that may enhance overall psychological health in patients after ACLR. In practicing mindfulness, the patient is aware of incoming thoughts and feelings, including knee pain or symptoms, but rather than reacting to them, accepts them.[28] Reframing of pain or symptoms through mindfulness practice could positively modify the persistent knee symptoms observed in this population.

Limitations

Several limitations should be considered when evaluating our results. The cross-sectional design restricted our ability to draw conclusions about causality. Although we captured patient-reported outcomes among a cohort of participants during a clinically important period of transition from clinical care to unrestricted activity, a future study investigating the association between changes in knee symptom status and psychological factors over time after ACLR is warranted. Furthermore, we used modified Luyten et al[18] criteria to identify individuals after ACLR with persistent knee symptoms, but these classification criteria have not been validated in this population. However, we hope that this is a first step in categorizing persistent knee symptoms after ACLR that may be related to early knee OA. Additionally, the original Luyten et al criteria include 3 components, yet we focused on only 1 aspect (ie, knee symptoms). Consequently, the lack of radiographic evidence prevents us from definitively determining whether the persistent knee symptoms were related to early knee OA illness rather than residual symptoms after ACLR. Future longitudinal research would benefit from the inclusion of a clinical and radiographic examination in concert with the patient-reported measure to examine early knee OA illness after ACLR.

CONCLUSIONS

Persistent knee symptoms were reported by 29% of individuals at 6 to 12 months after ACLR. Among our sample, less psychological readiness for return to sport and more injury-related fear were associated with persistent knee symptoms. These significant associations highlight the potential clinical benefit of a comprehensive, biopsychosocial approach to managing health and wellness in individuals after ACLR.

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