Reason Profiles for not Returning to Preinjury Activity Level Following Anterior Cruciate Ligament Reconstruction—A Latent Class Analysis With Subgroup Comparison of Patient-Reported Outcome Measures

Joseph D. Lamplot,*† MD, Erich J. Petushek,‡§ PhD, Camryn B. Petit,*‖ BS, Shayla M. Warren,*¶# BS, Kim D. Barber Foss,*¶# PhD, Alexis B. Slutsky-Ganesh,*¶#** PhD, Melanie Valencia,* BS, Charles D Kenyon,¶ DO, April L. McPherson,*¶# PhD, John W. Xerogeanes,*¶# MD, Gregory D. Myer,*¶#†††‡‡§§ PhD, and Jed A. Diekfuss,*¶#‖ ‖ PhD
Investigation performed at the Department of Orthopaedics, Emory University School of Medicine, Atlanta, Georgia, USA

Background: Given the high proportion of athletes who do not return to sports (RTS) after anterior cruciate ligament reconstruction (ACLR), strategies are needed to identify at-risk patients and optimize rehabilitation for successful RTS after ACLR.

Purpose/Hypothesis: This study used latent class analysis (LCA) to characterize a unique clustering of reasons why athletes do not return to their preinjury activity level after ACLR. We hypothesized that patients with high pain scores and high levels of fear would be less likely to return to their preinjury activity level.

Study Design: Cohort study; Level of evidence, 3.

Methods: All patients at a single institution who underwent primary ACLR between 2005 and 2021 were contacted to complete a survey via REDCap. Patients' ability to RTS and their preinjury activity level, reasons for inability to return to the preinjury activity level, and patient-reported outcome scores were collected from 981 patients. LCA was performed to identify and compare patterns among patients' reasons for not returning to the preinjury activity level.

Results: Of the 981 patients included, only 446 (45.5%) were fully able to return to their preinjury activity level. LCA categorized patients into 3 groups based on their reasons for not returning to preinjury activity levels: a high-function group (75.5%), which reported no barriers; a multisymptom group (16.1%), which cited pain, lack of strength, and instability; and a fear-limited group (8.4%), which reported fear as the sole reason. Among the high-function group, 86.2% reported RTS compared with <36.7% in the other classes. There was no difference in Knee injury and Osteoarthritis Outcome Score (KOOS) subscales—including Pain, Symptoms, or Activities of Daily Living—between the high-function and fear-limited groups; however, the multisymptom group presented with the lowest scores in all KOOS subscales ($P < .001$). In addition, patient characteristics, the time from the index ACLR to the follow-up, and subsequent revision ACLR were similar between groups; however, the multisymptom profile demonstrated the highest proportion of allograft ACLR ($P = .04$) and secondary ipsilateral surgery ($P < .001$). Overall subjective knee grade (1-100) and Marx scores were highest in the high-function group, followed by fear-limited and multisymptom groups ($P < .001$).

The Orthopaedic Journal of Sports Medicine, 13(2), 23259671241300300
DOI: 10.1177/23259671241300300

Conclusion: Patients were differentiated into 3 distinct classes after primary ACLR. Furthermore, those with patient-reported characteristics of pain, lack of strength, instability, or fear were significantly less likely to return to their preinjury activity level or sport.

Keywords: anterior cruciate ligament; knee ligaments; kinesiophobia; latent class analysis; patient-reported outcome measures; psychological readiness; return to sports

Anterior cruciate ligament (ACL) rupture is a common sport-related injury, particularly in activities that involve cutting and pivoting.[7,8] ACL reconstruction (ACLR) has been the recommended course of surgical intervention for most athletes who participate in cutting and pivoting sports before injury and wish to return to sports (RTS).[4,9,26] While good clinical outcomes regarding knee stability, quantitative function, and subjective patient-reported outcome measures (PROMs) have been reported after ACLR, reported rates of successful RTS are variable.[13,27] Only 65% to 85% of athletes RTS, with an even lower proportion returning to the same level of competition as before their ACL injury.[11] One meta-analysis indicated that only 44% of athletes return to competitive sports.[2] Furthermore, when counseling patients with an ACL injury before surgery and in the early postoperative period, it is imperative to identify those with elevated risk profiles for failure to RTS. However, the identification and assessment of such risk factors remains difficult. Given the high proportion of athletes who do not return to competitive sports after ACLR and the challenges of early risk profile identification, there is a clear need for strategies to identify these at-risk patients and develop strategies to optimize successful RTS after ACLR.

Although several objective tests have been described to assess readiness for safe RTS, no specific protocol demonstrates a reliable reduction of reinjury risk upon RTS. For example, muscle strength measurements—including isokinetic quadriceps strength and single-leg hop tests—have been employed to identify athletes who may be at a higher risk for reinjury with RTS.[5,11] Notably, these objective physical assessments fail to capture the influence of psychological readiness—including perceptions of current function and active symptoms on an athlete's ability to successfully RTS.[6] From the extant literature, there is an increasing appreciation that patient outcomes and return to activities are influenced by objective measures of symptoms and function that are intricately related to patient perception of symptoms and psychological influences such as fear of symptoms, kinesiophobia, and reinjury.[6,33,25,15]

An unacceptably high proportion of athletes are unable to successfully RTS after ACLR; however, the reasons for an inability to successfully RTS are not delineated.[2,11] Establishing risk profiles for RTS failure—including PROMs specific to patient perceptions of pain and function and psychological readiness—may increase the opportunity to identify at-risk athletes before surgery and in the early postoperative period. In doing so, targeted strategies to optimize RTS outcomes may be developed. Over the past several years, the application of advanced statistical techniques such as latent class analysis (LCA) has grown in popularity to guide more individualized management of specific medical conditions.[29] LCA is considered a person-centered mixture-modeling technique that aims to identify "distinct" classes or groups that share similar characteristics.[24,29] Applied to patient-reported outcome (PRO) data, LCA can be used to identify groups of patients who share similar patterns across multiple PROMs—such as symptoms, pain, fear, or function. LCA approaches can help determine the prevalence of various subgroups or patients and can also be used as a potential tool for developing targeted interventions.[23] For ACLR outcomes, LCA or similar approaches have not been widely used despite the potential benefits of the advanced statistical models.

‖ ‖Address correspondence to Jed A. Diekfuss, PhD, Emory Sports Performance And Research Center, 4450 Falcons PKWY, Flowery Branch, Georgia, 30542, USA (email: jed.a.diekfuss@emory.edu).

*Emory Sports Performance And Research Center, Flowery Branch, Georgia, USA.

†Campbell Clinic Orthopedics, Germantown, Tennessee, USA.

‡Department of Psychology and Human Factors, Michigan Technological University, Houghton, Michigan, USA.

§Health Research Institute, Michigan Technological University, Houghton, Michigan, USA.

‖Medical College of Georgia, Augusta, Georgia, USA.

¶Emory Sports Medicine Center, Atlanta, Georgia, USA.

#Department of Orthopaedics, Emory University School of Medicine, Atlanta, Georgia, USA.

**Department of Kinesiology, University of North Carolina at Greensboro, Greensboro, North Carolina, USA.

††Wallace H. Coulter Department of Biomedical Engineering, Georgia Institute of Technology & Emory University, Atlanta, Georgia, USA.

‡‡The Micheli Center for Sports Injury Prevention, Waltham, Massachusetts, USA.

§§Youth Physical Development Centre, Cardiff Metropolitan University, Wales, United Kingdom.

Final revision submitted May 15, 2024; accepted June 11, 2024.

One or more of the authors has declared the following potential conflict of interest or source of funding: J.D.L. has received hospitality payments from Arthrex and Smith+Nephew and education payments from United Orthopedics, DePuy Synthes Products, Smith+Nephew, and Elite Orthopedics. J.W.X. has received a royalty or license from Arthrex; nonconsulting payments from Arthrex; consulting fees from Arthrex and Trice Medical; and education payments from United Orthopedics. G.D.M has current and ongoing reserach funding to his institution from Arthrex inc to evaluate ACL surgical treatment strategies. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Emory University (STUDY00003512).

This study aimed to use LCA to characterize a unique clustering of reasons why athletes do not return to their preinjury activity level after ACLR. Specifically, we hypothesized that patients with high pain scores and high levels of fear would be less likely to successfully return to their preinjury activity level.

METHODS

Patient Selection and Data Collection

All patients who underwent ACLR within a single orthopaedic department, with 11 sports medicine fellowship-trained orthopaedic surgeons, between January 1, 2005, and April 1, 2021, were identified using a custom query of Current Procedural Terminology code 29888 within institutional electronic medical records. From this query, 4346 patients who had a minimum of 1-year status after primary ACLR were contacted via email with a REDCap (Vanderbilt University) link and instructed to complete a follow-up survey regarding the outcomes of their primary ACLR. Out of the 4346 patients contacted, 1287 patients (30%) completed the survey after up to 4 contact efforts. A total of 306 patients who did not complete the full survey or who underwent nonprimary ACLR (ipsilateral or contralateral) were excluded from the analysis, as previous ACL injury is an independent risk factor for subsequent ACL injury.[30] A total of 981 primary ACLR patient survey responses were included in the present data analysis. Verification of data—such as graft type and incidence of secondary injury—was performed via chart review and quality control checks were performed. Institutional review board (IRB) approval was obtained by Emory University (STUDY00003512), and all patient participants provided electronic consent before completing the survey. The survey asked patients to identify their preinjury activity level in 1 of the following categories: competitive athlete; recreational athlete; heavy manual labor job; light manual labor job; active lifestyle; somewhat active; or sedentary. Patients also identified graft type used for primary ACLR, subsequent complications, pre-ACL injury sport participation, level of competition, and ability to RTS after ACLR. Postoperative PROMs—including the Knee injury and Osteoarthritis Outcome Score (KOOS) and the Marx Activity Scale questionnaire—were also collected, and scores were calculated for each respondent. Patients were also asked to give their knee a numeric rating score from 1 to 100, with 100 being the best.

As part of the survey, patients were specifically asked the following question: “Have you returned to the same level of activity as before your ACL injury?” Then, they were instructed to respond “yes” or “no.”

If the patient answered “no,” then they were asked to specify the reason, with responses that included the following: “pain,” “lack of strength,” "lack of range of motion," "fear," "instability," and “insecurity.” Patients were allowed to check multiple boxes when specifying reasons for their inability to return to their preinjury activity level. Moreover, patients were asked the following question: “Since your ACL surgery, have you been able to return to your sport?" Patients were allowed to respond “yes” or “no.”

Patients were also asked the following 3 questions: (1) “Do you feel like you can walk normally like you did before your ACL injury?” (2) “Do you feel like you can run normally like you did before your ACL injury?” (3) “Have you returned to your same level of activity as before your ACL injury?” Patients were allowed to respond “yes” or “no” to each question. The responses to these 3 questions were summed to create a postinjury activity composite score that was used for subsequent analyses. “Yes” was scored as 1 point and “No” was scored as 0 points. A composite score of 3 corresponded to “fully returned to activity”; 2 corresponded to “mostly returned to activity”; 1 corresponded to “slightly returned to activity”; and 0 corresponded to “did not return to activity.” Standardized factor loadings of the 3 items were all $>.75$, indicating good internal consistency and unidimensionality adding validity evidence for the composite score construction.

Statistical Analysis

LCA was performed using binary manifest variables using the Polytomous Variable LCA package (Version 1.4.1) in RStudio (Posit, PBC).[19] The overall goal of LCA is to identify distinct “clusters” of individuals that respond similarly, in this case to the reasons for not returning to previous levels of activity. Variables included in the LCA were the aforementioned reasons for not returning to the same level of activity as before ACLR—ie, pain, lack of strength, lack of range of motion, fear, instability, and insecurity—as well as postinjury activity composite score. The optimal number of classes was determined by comparing the Bayesian Information Criterion (BIC) of 9 models with a varying number of classes (ie, 2-10). The solution identifying the number of classes with the lowest BIC was chosen. Each reason profile was labeled to reflect the probability of relevant manifest variables.

Secondary analyses were performed to determine whether age, years after ACLR, sex, graft type, preinjury activity level, subsequent ipsilateral revision ACLR or contralateral ACL injury, secondary ipsilateral knee surgery, Marx score, KOOS subscales, and ability to RTS differed between the groups. Chi-square tests were used for categorical variables and 1-way analysis of variance with post hoc Tukey Honest Significant Difference test for continuous variables. An a priori $P < .05$ was used for statistical significance.

RESULTS

Overall Cohort Characteristics

Overall, 981 patients were included in the analysis (52.7% women), with a mean age of 29.9 ± 12.6 years and a mean follow-up of 7.1 ± 4.2 years. Overall, 40.6% received allografts, 36.5% quadriceps tendons, 11.5% hamstring

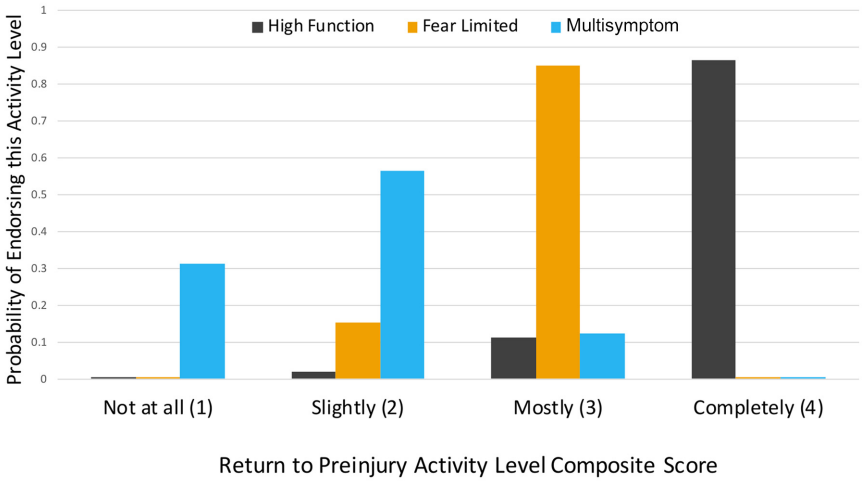

Figure 1. Return to the preinjury activity level by patient class.

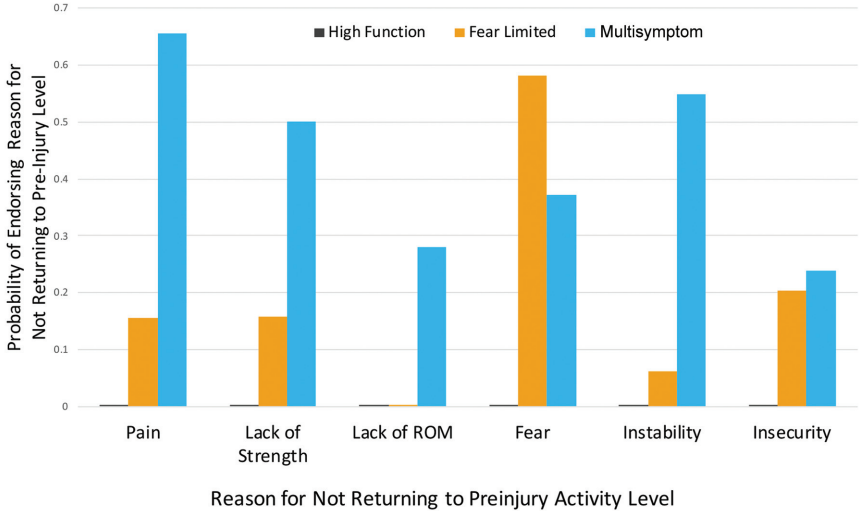

Figure 2. Reasons for not returning to the preinjury activity level by patient class. ROM, range of motion.

tendons, 9.7% bone-patellar tendon-bone allografts, and 1.7% other or unknown graft types. Overall, only 446 patients (45.5%) reported that they were fully able to return to their preinjury activity level, with the most common reasons for inability to return to the preinjury activity level being fear and pain, 12.4% and 12.2% of patients overall, respectively.

Classification of Patients

LCA identified a 3-class solution as the best fit for the data, based on the lowest BIC (4227). The classes were created by responses to the reasons for not returning to the same level of activity as before ACLR as well as postinjury activity composite scores and were differentiated as follows: the high-function group, comprising 75.5% of the cohort, with no barriers to returning and complete return to the preinjury activity levels; the multisymptom group, making up 16.1% of the cohort, characterized by pain, lack of strength, instability, and slightly back to the preinjury activity level; and the fear-limited group, constituting 8.4% of the cohort, where fear alone predominantly prevented returning to preinjury activities but were mostly back to preinjury levels. The probabilities of returning to preinjury activity levels across the identified groups are presented in Figure 1, while the reasons for not returning to preinjury activity levels are detailed in Figure 2. This information underpinned our group naming process. For example, we labeled the fear-limited group because they indicated they have not returned to preinjury levels of physical activity (ie, limited) and the reason for this limitation was predominantly due to fear (eg, 58.1% reported these reasons, depicted in Figure 2). Similarly, Figure 3 illustrates the typical responses to the specific questions used to classify patients using LCA.

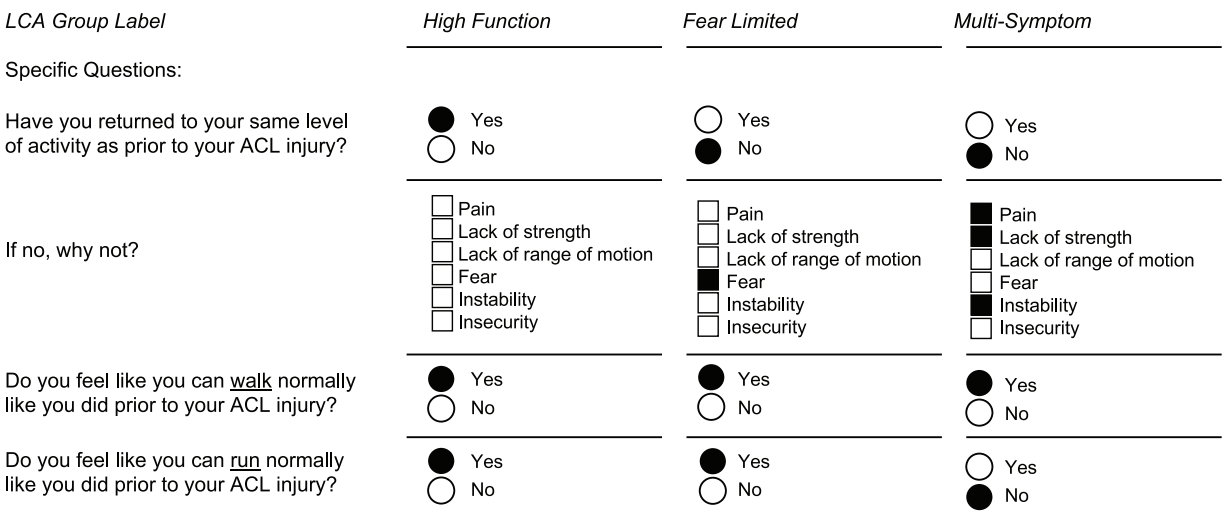

Figure 3. Typical responses to the questions used in the LCA-determined groups. ACL, anterior cruciate ligament; LCA, latent class analysis.

Demographic characteristics of the distinct groups—including the preinjury level of sports participation and graft type—can be seen in Table 1. The responses to the 3 questions that were summed to create the postinjury activity composite scores and other activity-based PROs can be seen broken down by group in Table 2.

When specifically asked about RTS ability, 86.2% of patients in the high-function group, 33.5% of patients in the multisymptom group, and 36.6% of patients in the fear-limited group were able to RTS ($P < .001$) (Table 2).

In response to the question, "Did your knee injury prevent you from returning to your previous level of sport or recreational activity?" 17.3% of patients in the high-function group, 67.1% of patients in the fear-limited group, and 82.3% of patients in the multisymptom group responded "yes" ($P < .001$) (Table 2).

Patient-Specific Factors

There was no association between sex or time since index ACLR and class between the 3 groups. There was a difference in age at the time of index ACLR when comparing the high-function and multisymptom groups (29.5 vs 32.2; $P = .035$) (Table 1). When specifically analyzing athletes, there was a higher proportion of young athletes (middle school/high school athletes) (29.1% vs 15.8%) and a lower proportion of recreational athletes (58.3% vs 67.1%) in the high-function group compared with the multisymptom group ($P = .017$) (Table 1). A higher portion of patients in the multisymptom group received allografts compared with all other graft choices (52.5% allograft; $P = .026$) (Table 1).

Subsequent Surgery

The mean follow-up time was 7.1 years for all groups ($P = .99$). The overall incidence of ipsilateral revision ACLR was 7.5%, and the incidence of contralateral ACL injury was 8.8%. No difference was observed in the incidence of ipsilateral revision ACLR or contralateral ACL injury according to class ($P = .22$ and $P = .43$, respectively) (Table 2).

The overall incidence of subsequent ipsilateral knee surgery—which included arthroscopic lysis of adhesions/manipulation under anesthesia, meniscectomy, meniscus repair, revision ACLR, and osteotomy—was 17.1%. A difference was observed in the incidence of secondary ipsilateral knee surgery between groups, with a higher proportion of patients in the multisymptom group undergoing subsequent ipsilateral knee surgery compared with those in the high-function and fear-limited groups (27.8% vs 15.1% and 14.6%, respectively; $P < .001$) (Table 2).

Overall Knee Rating Score

A difference was found in knee grade (rated between 0 and 100) between the high-function (89.7% ± 10.3%), fear-limited (82.5% ± 10.8%), and multisymptom (64.4% ± 20.1%) groups ($P < .001$).

Marx Activity Score

A difference was found in the final Marx Activity score, with a higher score in the high-function group compared with the multisymptom and fear-limited groups (8.8 vs 4.8 and 5.1, respectively; $P < .001$) (Table 2).

KOOS Scores and Knee Grade

KOOS subscales—including Symptoms, Pain, and Activities of Daily Living (ADL)—were each lower in the

TABLE 1
Patient Characteristics by Group[a]

	High Function	Fear Limited	Multisymptom	P^b
Total No. of patients	741	82	158	
Women (%)	52.5	45.1	57.6	.18
Men	47.5	54.9	42.4	
Age, y	29.5 (12.9)[d]	28.9 (10.5)	32.2 (11.8)	.04
Follow-up, y	7.1 (4.1)	7.1 (4.2)	7.1 (4.3)	.99
Graft type (%)				.04
Quadriceps tendon	38.5	39.0	25.9	
Hamstring tendon	11.7	14.6	8.9	
Bone-patellar tendon-bone	9.4	9.8	10.8	
Allograft	38.5	36.6	52.5[d,e]	
Other/unknown	1.9	0	1.9	
Preinjury sports participation, % yes	78.8	79.3	75.3	.61
Preinjury activity level (%)				<.001
Competitive athlete	36.7	24.4	29.7	
Recreational athlete	35.4	50.0[c,e]	31.6	
Active lifestyle	16.1	15.9	20.3	
Somewhat active	8.9	7.3	9.5	
Heavy manual labor job	0	1.2	2.5	
Light manual labor job	1.2	0	2.5	
Sedentary	1.5	1.2	3.8	
Preinjury sport level (%)				<.001
Middle/high school	29.1[d]	23.1	15.8	
Recreational	58.3	65.9	67.1	
Collegiate/professional	12.6	11.0	17.1	

[a]Data are presented as mean (SD) or % unless otherwise indicated. Tukey HSD, Tukey Honest Significant Difference.
[b]*P* values are for the chi-square test for categorical variables or 1-way analysis of variance for continuous measures. If $P < .05$, then follow-up comparisons were made and false discovery rate adjusted *P* values and Tukey HSD were used for categorical and continuous variables, respectively.
[c]The high-function group different from the fear-limited group.
[d]The high-function group different from the multisymptom group.
[e]The fear-limited group different from the multisymptom group.

TABLE 2
Postinjury Function Comparison[a]

	High Function	Fear Limited	Multisymptom	P^b
Returned to preinjury sport (% yes)	86.2[c,d]	36.6	33.5	<.001
Postinjury activity composite score questions				
Returned to preinjury activity (% yes)	93.7[c,d]	0	0	<.001
Walk as normal as preinjury (% yes)	98.4	98.8	68.4[d,e]	<.001
Run as normal as preinjury (% yes)	88.5	91.5	10.8[d,e]	<.001
Overall knee grade	89.7 (10.3)[c,d]	82.5 (10.8)[e]	64.4 (20.1)	
Marx score	8.8 (5.2)[c,d]	5.1 (4.5)	4.8 (5)	<.001
Did the knee injury prevent the patients from returning to their previous level of sport or recreational activity? (% yes)	17.3[c,d]	67.1[e]	82.3	<.001
ACL revision reconstruction (%)	6.7	8.5	10.8	.22
Contralateral ACL injury (%)	8.1	9.8	11.4	.43
Secondary ipsilateral knee surgery (%)	15.1	14.6	27.8[c,d]	<.001

[a]Data are presented as mean (SD) or %. ACL, anterior cruciate ligament; Tukey HSD, Tukey Honest Significant Difference.
[b]*P* values are for the chi-square test for categorical variables or 1-way analysis of variance for continuous measures. If $P < .05$, then follow-up comparisons were made and false discovery rate adjusted *P* values and Tukey HSD were used for categorical and continuous variables, respectively.
[c]The high-function group different from the fear-limited group.
[d]The high-function group different from the multisymptom group.
[e]The fear-limited group different from the multisymptom group ($P < .05$).

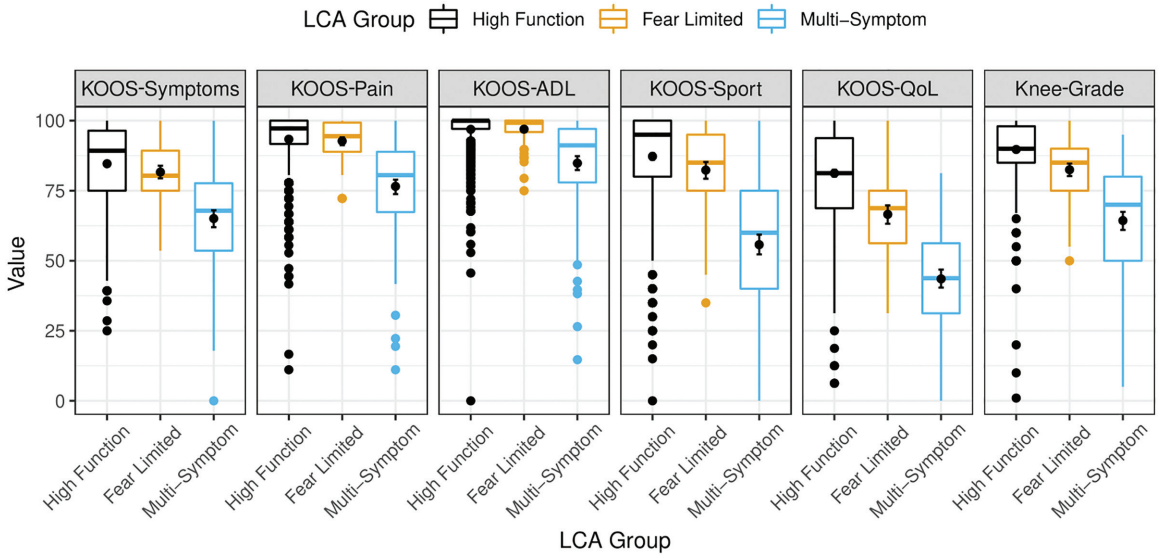

Figure 4. KOOS and knee grade scores by patient class. ADL, Activities of Daily Living; KOOS, Knee injury and Osteoarthritis Outcome Score; LCA, latent class analysis; Sport, Sports-specific; QoL, Quality of Life.

multisymptom group compared with the high-function and fear-limited groups ($P < .001$ for each) (Figure 4). KOOS subscales—including Symptoms, Pain, and ADL—were not different when comparing the high-function and fear-limited groups. Both KOOS Sports-Specific and Quality of Life subscales were increased in the high-function group compared with the fear-limited and multisymptom groups ($P < .001$ for each) (Figure 4).

DISCUSSION

The most important finding in this investigation was that the LCA of a cohort of patients who underwent primary ACLR resulted in 3 distinct classes of patients—high-function, fear-limited, and multisymptom groups. Although most patients within the high-function group were commonly able to fully return to their preinjury activity level, our hypothesis was supported in that most patients in the fear-limited group showed limited capacity to return to their preinjury activity level and most patients in the multisymptom group were unable to return to their preinjury activity level. Most measured PROMs were lower among patients in the multisymptom group compared with the other 2 groups, with the exception that the overall knee rating score and KOOS Sport and Quality of Life were lower among patients in the fear-limited group compared with the patients in the high-function group. Unexpectedly, there were no differences in patient characteristics or patient-specific factors—including age, sex, graft choice, preinjury activity level, preinjury level of sports competition, or secondary ACL injury—when comparing the high- function and fear-limited groups. These findings suggest that the high-function and fear-limited groups consisted of similar patient populations at the time of primary ACLR, but at some point during the rehabilitation process, delayed muscle recovery, faulty movement patterns, maladaptive behaviors, or flawed thought processes likely manifested into kinesiophobia or fear that prevented a return to the preinjury activity level.[10] Earlier identification of the subset of patients at risk for developing increased fear after ACLR may help facilitate interventions—such as targeted rehabilitation or sports psychology—to minimize or eliminate fear and improve these patients' ability to return to the preinjury activity level and sport.

PROMs are used extensively after ACLR, with recent investigations utilizing the ACL–Return to Sport After Injury (ACL-RSI) to assess psychological readiness for RTS and the KOOS to assess patient perceptions of symptoms—including pain and function.[6,33] The KOOS Pain score was associated with the ACL-RSI score and the ability to pass a single-leg hop test, suggesting that patients with higher pain levels have lower psychological and physical readiness for RTS.[6] Regarding fear of movement, lower scores on the Tampa Scale of Kinesiophobia (TSK-11) at the time of RTS clearance are associated with a nearly 4-fold likelihood to report decreased levels of physical activity, increased likelihood of objective functional asymmetry in single-leg hop and quadriceps strength testing, and ultimately an elevated risk of secondary injury within 24 months of ACLR.[25] Emerging validated tools—such as the ACL Reasons Survey—provide a lens into understanding patient-perceived barriers specific to return to activity after ACLR.[15] The outcomes of the ACL Reasons Survey showed that patient perceptions— specifically fear of knee symptoms, kinesiophobia, and fear of reinjury—were among the most common patient-reported reasons for altered physical activity levels after clearance after ACLR.

In the present study, we found that 45.5% of patients across the entire cohort were fully able to return to their

preinjury activity level. Regarding RTS, 79.7% of patients were fully able to RTS at some level. These results are comparable to previous investigations that reported 70% to 91% return to some level of sports, and 44% to 65% return to the preinjury level of competition.[1,18,20] Previous literature, along with the present investigation, demonstrate that although RTS is relatively high, up to ≥50% of patients do not return to the same level of activity as before their ACL injury. Previous investigations have indicated that 20% to 45% of athletes who do not RTS after ACLR cited fear as the main reason for not returning.[10,16,18,28,31] Two PRO scores that have been used to quantify injury-related fear in patients after ACLR include the ACL-RSI and the TSK-11.[12,17,32] One previous investigation found that <40% of patients met the criteria for psychological preparedness for RTS according to the ACL-RSI threshold of 75 points even after participating in an RTS training program.[22] Another recent investigation reported that the ACL-RSI score better identified fear intensity of fear-evoking tasks such as cutting, contact, and jumping when compared with the TSK-11 score.[21] PRO questionnaires have helped us better understand the relationship between fear and RTS after ACLR. Our findings are novel in that we describe a distinct group of fearful but generally well-functioning and minimally symptomatic patients after ACLR. While secondary injury risk is not a primary aim of the present investigation, a recently published cohort of 39 female athletes engaged in sports with high levels of cutting, jumping, and pivoting found an increased risk of reinjury within 24 months in athletes reporting better psychological readiness at the time of RTS as determined by the ACL-RSI, TSK-11, and KOOS Quality of Life.[34] There is a growing body of literature associating the relationship between psychosocial determinants of RTS and physical activity. Thus, it is important to emphasize that comprehensive management of an athlete after ACLR is multidimensional, accounting for patient goals, psychological factors, perceived barriers, and the demands of their sport and objective physical function throughout the rehabilitation continuum.

One related study used a longitudinal form of LCA to identify trajectory patterns of International Knee Documentation Committee scores after ACL injury and found that various factors—such as revision surgery, secondary knee injury, mental health, and preoperative pain—were associated with the group that had a less favorable rate-of-recovery pattern.[14] In addition, distinct subgroups of ACL-injured patients based on both PROMs and functional data were related to the prevalence of osteoarthritis (OA).[3] These data and analytical approaches reveal information relevant to the treatment of ACL injury and prevention of OA but also reveal information related to the complex associations across the various patient-reported and objectively measured outcome measures. A recently published validation investigation of the ACL Reasons Survey serves to better identify patient perceptions of barriers to physical activity.[15] In this investigation, participants ranked factors limiting their physical activity, psychological factors (eg, fear of knee symptoms or movement), and fear of reinjury among the most important barriers to physical activity. The ongoing development of patient-centered clinical tools (eg, the ACL Reasons Survey) may complement PROMs (eg, ACL-RSI and TSK-11) in improving our ability to not only identify the presence of psychological risk factors (eg, fear of symptoms, kinesiophobia, and reinjury) but also to understand how these variables impact the ability to return to activities and the perceived quality of function after ACLR. In doing so, future research may guide clinical practice as we communicate with patients to better understand psychosocial barriers to physical activity and individualize targeted interventions early in the postoperative rehabilitation process to optimize patient outcomes.

Despite generally favorable PROMs, the inability of the fear-limited group to return to the preinjury level of activity seemed to be attributed mainly to fear, which is generally not present in these patients before the injury. From a structural standpoint, the fear-limited group may have a well-functioning knee because their PROM scores were mostly superior to those of the multisymptom group and had similar reoperation rates as the high-function group. Patients in the fear-limited group could produce a clinical dilemma, as objective measures (eg, physical examination, knee laxity, and strength) and movement patterns (eg, limb symmetry during running, landing, and cutting activities) may be no different than those in the high-function group who were able to return to their preinjury activity level. In the subset of the patients in the fear-limited group with no objective findings that may be preventing them from returning to their preinjury activity level, clinicians may not be able to provide counseling or interventions to assist these patients in achieving their goal of returning to activity. With the fear-limited group appearing to be similar from a demographic standpoint to the high-function group, it may be difficult to identify them preoperatively. Rather, early identification of those at risk for fear-limited tendencies during the early stages of postoperative rehabilitation and subsequent targeted interventions may improve our ability to help these patients return to their preinjury activity level.

The multisymptom group represents postoperative ACLR patients with a poorly functioning knee that may be due to structural issues—such as posttraumatic arthritis, meniscal pathology, chondral pathology, graft laxity, or other associated problems. The multisymptom group comprised a small proportion of the investigation and had a higher incidence of ipsilateral knee surgery compared with the other 2 groups. While the multisymptom group can also have clinical challenges, this profile represents a well-established subset of patients undergoing ACLR. Mitigation strategies may be more difficult for the fear-limited group in which the knee is generally structurally sound, aside from appropriate patient selection, preoperative counseling, addressing concomitant pathologies at the time of surgery, and any subsequent injuries.

Limitations

There are several limitations to this investigation. First, there were no preoperative PROMs collected as a part of

this investigation, with all outcomes only collected at the final follow-up, preventing pre- to postsurgical analysis. Moreover, the final follow-up time varied among patients, and as such the time interval from primary ACLR to data collection was not uniform across patients. The multisymptom group had a higher mean age and a higher incidence of ipsilateral knee surgery than the other groups, which may have increased the incidence of posttraumatic OA, chondral pathology, and meniscal pathology among that group. Furthermore, the presence or absence of meniscal and/or chondral pathology for each patient was not collected, and these factors likely affect PROM scores. Further, patients did not rank or indicate a perceived primary reason for any limitations. Specifically, for the multisymptom group, further ranking and stratification of symptom importance may provide further insights into targeted areas for intervention in future research. There was a relatively low follow-up proportion, which may have introduced selection bias. Furthermore, the time elapsed between surgery and the follow-up may have introduced recall bias in some patients. Overall, the cohort included all patients undergoing primary ACLR who met the inclusion criteria, which may limit specific interpretations to highly competitive athletes.

CONCLUSION

Patients may be categorized into 3 distinct classes after primary ACLR, and those with patient-reported characteristics of pain, instability, and fear are significantly less likely to return to their preinjury activity level.

ORCID iDs

Erich J. Petushek https://orcid.org/0000-0001-6837-5229
Gregory D. Myer https://orcid.org/0000-0002-9983-8422
Jed A. Diekfuss https://orcid.org/0000-0003-3835-363X

REFERENCES

1. Ardern CL, Taylor NF, Feller JA, Webster KE. Fifty-five per cent return to competitive sport following anterior cruciate ligament reconstruction surgery: an updated systematic review and meta-analysis including aspects of physical functioning and contextual factors. *Br J Sports Med*. 2014;48(21):1543-1552.
2. Ardern CL, Webster KE, Taylor NF, Feller JA. Return to sport following anterior cruciate ligament reconstruction surgery: a systematic review and meta-analysis of the state of play. *Br J Sports Med*. 2011;45(7):596-606.
3. Arhos EK, Pohlig RT, Di Stasi S, et al. Clinically relevant subgroups among athletes who have ruptured their anterior cruciate ligaments: a Delaware-Oslo Cohort Study. *Arthritis Care Res (Hoboken)*. 2023;75(9):1914-1924.
4. Barber-Westin S, Noyes FR. One in 5 athletes sustain reinjury upon return to high-risk sports after ACL reconstruction: a systematic review in 1239 athletes younger than 20 years. *Sports Health*. 2020;12(6):587-597.
5. Barber-Westin SD, Noyes FR. Factors used to determine return to unrestricted sports activities after anterior cruciate ligament reconstruction. *Arthroscopy*. 2011;27(12):1697-1705.
6. Betsch M, Hoit G, Dwyer T, et al. Postoperative pain is associated with psychological and physical readiness to return to sports one-year after anterior cruciate ligament reconstruction. *Arthrosc Sports Med Rehabil*. 2021;3(6):e1737-e1743.
7. Buller LT, Best MJ, Baraga MG, Kaplan LD. Trends in anterior cruciate ligament reconstruction in the United States. *Orthop J Sports Med*. 2015;3(1):2325967114563664.
8. Csintalan RP, Inacio MC, Funahashi TT. Incidence rate of anterior cruciate ligament reconstructions. *Perm J*. 2008;12(3):17-21.
9. Failla MJ, Arundale AJ, Logerstedt DS, Snyder-Mackler L. Controversies in knee rehabilitation: anterior cruciate ligament injury. *Clin Sports Med*. 2015;34(2):301-312.
10. Flanigan DC, Everhart JS, Pedroza A, Smith T, Kaeding CC. Fear of reinjury (kinesiophobia) and persistent knee symptoms are common factors for lack of return to sport after anterior cruciate ligament reconstruction. *Arthroscopy*. 2013;29(8):1322-1329.
11. Gokeler A, Dingenen B, Hewett TE. Rehabilitation and return to sport testing after anterior cruciate ligament reconstruction: where are we in 2022? *Arthrosc Sports Med Rehabil*. 2022;4(1):e77-e82.
12. Gokeler A, Welling W, Zaffagnini S, Seil R, Padua D. Development of a test battery to enhance safe return to sports after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(1):192-199.
13. Grassi A, Pizza N, Al-Zu'bi BBH, et al. Clinical outcomes and osteoarthritis at very long-term follow-up after ACL reconstruction: a systematic review and meta-analysis. *Orthop J Sports Med*. 2022;10(1):23259671211062238.
14. Gursoy S, Clapp IM, Perry AK, et al. Patients follow 3 different rate-of-recovery patterns after anterior cruciate ligament reconstruction based on International Knee Documentation Committee Score. *Arthroscopy*. 2022;38(8):2480-2490.e2483.
15. Kuenze C, Lisee C, Triplett A, et al. Validation of a survey to characterize barriers to physical activity after anterior cruciate ligament reconstruction. *J Athl Train*. 2023;58(10):841-848.
16. Kvist J, Ek A, Sporrstedt K, Good L. Fear of re-injury: a hindrance for returning to sports after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2005;13(5):393-397.
17. Leeuw M, Goossens ME, Linton SJ, et al. The fear-avoidance model of musculoskeletal pain: current state of scientific evidence. *J Behav Med*. 2007;30(1):77-94.
18. Lentz TA, Zeppieri G, Tillman SM, et al. Return to preinjury sports participation following anterior cruciate ligament reconstruction: contributions of demographic, knee impairment, and self-report measures. *J Orthop Sports Phys Ther*. 2012;42(11):893-901.
19. Linzer DA, Lewis J. PoLCA: polytomous variable latent class analysis. *J Stat Softw*. 2011;42(10):1-29.
20. Mascarenhas R, Tranovich MJ, Kropf EJ, Fu FH, Harner CD. Bone-patellar tendon-bone autograft versus hamstring autograft anterior cruciate ligament reconstruction in the young athlete: a retrospective matched analysis with 2-10 year follow-up. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(8):1520-1527.
21. Meierbachtol A, Obermeier M, Yungtum W, et al. Injury-related fears during the return-to-sport phase of ACL reconstruction rehabilitation. *Orthop J Sports Med*. 2020;8(3):2325967120909385.
22. Meierbachtol A, Yungtum W, Paur E, Bottoms J, Chmielewski TL. Psychological and functional readiness for sport following advanced group training in patients with anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther*. 2018;48(11):864-872.
23. Mori M, Krumholz HM, Allore HG. Using latent class analysis to identify hidden clinical phenotypes. *JAMA*. 2020;324(7):700-701.
24. Oberski D. Mixture models: latent profile and latent class analysis. In: Robertson J, Kaptein M, eds. *Modern Statistical Methods for HCI*. Springer International Publishing; 2016:275-287.
25. Paterno MV, Flynn K, Thomas S, Schmitt LC. Self-reported fear predicts functional performance and second ACL injury after ACL reconstruction and return to sport: a pilot study. *Sports Health*. 2018;10(3):228-233.
26. Rahardja R, Zhu M, Love H, et al. Effect of graft choice on revision and contralateral anterior cruciate ligament reconstruction: results

from the New Zealand ACL Registry. *Am J Sports Med*. 2020; 48(1):63-69.
27. Randsborg PH, Cepeda N, Adamec D, et al. Patient-reported outcome, return to sport, and revision rates 7-9 years after anterior cruciate ligament reconstruction: results from a cohort of 2042 patients. *Am J Sports Med*. 2022;50(2):423-432.
28. Ross CA, Clifford A, Louw QA. Factors informing fear of reinjury after anterior cruciate ligament reconstruction. *Physiother Theory Pract*. 2017;33(2):103-114.
29. Sinha P, Calfee CS, Delucchi KL. Practitioner's guide to latent class analysis: methodological considerations and common pitfalls. *Crit Care Med*. 2021;49(1):e63-e79.
30. Smith HC, Vacek P, Johnson RJ, et al. Risk factors for anterior cruciate ligament injury: a review of the literature-part 2: hormonal, genetic, cognitive function, previous injury, and extrinsic risk factors. *Sports Health*. 2012;4(2):155-161.
31. Truong LK, Mosewich AD, Holt CJ, et al. Psychological, social and contextual factors across recovery stages following a sport-related knee injury: a scoping review. *Br J Sports Med*. 2020;54(19):1149-1156.
32. Vlaeyen JWS, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. *Pain*. 2000; 85(3):317-332.
33. White K, Zeni J, Snyder-Mackler L. ACL-RSI and KOOS measures predict normal knee function after ACL-SPORTS training. *Orthop J Sports Med*. 2014;2(7)(suppl 2):2325967114S2325900111.
34. Zarzycki R, Cummer K, Arhos E, et al. Female athletes with better psychological readiness are at higher risk for second ACL injury After primary ACL reconstruction. *Sports Health*. 2024;16(1):149-154.