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Return to Preinjury Sports Participation Following Anterior Cruciate Ligament Reconstruction: Contributions of Demographic, Knee Impairment, and Self-report Measures

STUDY DESIGN: Cross-sectional cohort.

OBJECTIVES: (1) To examine differences in clinical variables (demographics, knee impairments, and self-report measures) between those who return to preinjury level of sports participation and those who do not at 1 year following anterior cruciate ligament reconstruction, (2) to determine the factors most strongly associated with return-to-sport status in a multivariate model, and (3) to explore the discriminatory value of clinical variables associated with return to sport at 1 year postsurgery.

BACKGROUND: Demographic, physical impairment, and psychosocial factors individually prohibit return to preinjury levels of sports participation. However, it is unknown which combination of factors contributes to sports participation status.

METHODS: Ninety-four patients (60 men; mean age, 22.4 years) 1 year post–anterior cruciate ligament reconstruction were included. Clinical variables were collected and included demographics, knee impairment measures, and self-report questionnaire responses. Patients were divided into "yes return to sports" or "no return to sports" groups based on their answer to the question, "Have you returned to the same level of sports as before your injury?" Group differences in demographics, knee impairments, and self-report questionnaire responses were analyzed. Discriminant function analysis determined the strongest predictors of group classification. Receiver-operating-characteristic curves determined the discriminatory accuracy of the identified clinical variables.

RESULTS: Fifty-two of 94 patients (55%) reported yes return to sports. Patients reporting return to preinjury levels of sports participation were more likely to have had less knee joint effusion, fewer episodes of knee instability, lower knee pain intensity, higher quadriceps peak torque-body weight ratio, higher score on the International Knee Documentation Committee Subjective Knee Evaluation Form, and lower levels of kinesiophobia. Knee joint effusion, episodes of knee instability, and score on the International Knee Documentation Committee Subjective Knee Evaluation Form were identified as the factors most strongly associated with self-reported return-to-sport status. The highest positive likelihood ratio for the yes-return-to-sports group classification (14.54) was achieved when patients met all of the following criteria: no knee effusion, no episodes of instability, and International Knee Documentation Committee Subjective Knee Evaluation Form score greater than 93.

CONCLUSION: In multivariate analysis, the factors most strongly associated with return-to-sport status included only self-reported knee function, episodes of knee instability, and knee joint effusion.

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KEY WORDS: *ACL, kinesiophobia, return to sports*

Anterior cruciate ligament (ACL) injuries commonly occur during sports-related activities that require cutting and pivoting, with over 200 000 injuries reported in the United States each year.[23]

Most individuals elect to undergo surgical reconstruction following injury to restore knee function and facilitate return to sports participation.[51,56] Although ACL reconstruction is thought to provide the athlete with the best opportunity to return to preinjury levels of sports participation,[33] recent studies[1,2,21,30,38,57] reported that between 8% and 50% of those with ACL reconstruction did not return to the same sports after surgery, even with follow-up times of up to 5 years.[31] Moreover, as many as 70% of individuals previously involved in contact sports were unable to return to the same sports after sur-

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gery.[47] Of those individuals who did return to their prior sports, up to 21% were reported to have returned with major functional limitations that contributed to a reduced level of performance.[49] For example, a study of running backs and wide receivers in the National Football League found that almost 80% returned to competition after ACL injury, but player performance, measured by power ratings, was reduced by one-third.[10] Moreover, 22% of the athletes with ACL reconstruction in the National Basketball Association did not return to a sanctioned National Basketball Association game after surgery and, of those who did return, 44% experienced a decrease in standard statistical categories and player efficiency ratings.[9] It has been suggested that the high incidence of poor return-to-sport outcomes following ACL reconstruction may be due to a lack of standardized return-to-sport guidelines and incomplete resolution of physical and psychological impairments.[3,32,36,37]

Poor understanding of the important factors that determine a successful return to sports has contributed to variability in return-to-sport criteria.[4,29] Many criteria have been developed based on expert opinion, empirical evidence, or factors identified as contributors to postoperative self-reported disability following ACL reconstruction, including number of injured knee structures,[48] quadriceps strength,[32,45,58] knee pain intensity,[32,58] knee flexion range of motion (ROM),[32] single-leg hop performance,[48,55,58] and pain-related fear of movement/reinjury.[11,30-32] Although these factors have been associated with self-reported knee function, it is unclear if they influence return to preinjury levels of sports participation following ACL reconstruction. Furthermore, the relative importance of these factors is unknown. To our knowledge, no study to date has examined demographic, knee impairment, and psychosocial measures in a multivariate model to determine the most important factors associated with return to preinjury levels of sports participation.

Understanding differences between individuals who do or do not return to sport after ACL reconstruction is the next step toward developing evidence-based return-to-sport rehabilitation guidelines and participation criteria. The purposes of this study were (1) to examine differences in clinical variables (demographics, knee impairments, and self-report measures) between those who return to preinjury level of sports participation and those who do not at 1 year following ACL reconstruction, (2) to determine the factors most strongly associated with return-to-sport status in a multivariate model, and (3) to explore the discriminatory value of clinical variables associated with return to sport at 1 year postsurgery. Based on previous literature, we hypothesized that a combination of demographic, knee impairment, functional, and psychosocial measures would differ and discriminate between those who did and did not return to sports.

METHODS

Patients

Consecutive patients with ACL reconstruction seen for routine physician follow-up at 1 year postsurgery at the University of Florida Orthopaedics and Sports Medicine Institute, Gainesville, FL, were eligible to participate. Patients were enrolled over a 3-year period between September 2007 and September 2010. Inclusion criteria were (1) unilateral arthroscopic ACL reconstruction, (2) age between 15 and 50 years, (3) time from injury to surgery of 12 months or less, and (4) preinjury score of 5 or greater on the Tegner activity-level scale. Our age group was chosen to include individuals most likely to be involved in sports-related activities and undergo ACL reconstruction following ACL injury. We specified a preinjury Tegner activity level of at least 5 to target a population of patients who were, at a minimum, involved in recreational sports prior to injury. Potential patients were excluded if they had (1) bilateral knee injury, (2) prior knee ligament injury and/or surgery, (3) concomitant ligamentous injury greater than grade I, (4) articular cartilage repair procedure performed in conjunction with ACL reconstruction, or (5) inability to return to sports following surgery due to social reasons (too little time to participate in sports or a change in lifestyle).[31] In communities with a high prevalence of college students, such as the one from which the present sample was drawn, it has been observed that some individuals choose not to return to sport due to too little time to participate in sports or to a change in lifestyle (they attend graduate school, graduate, get a job, start a family, etc). As a result, many of these individuals may not have the motivation or potential to return to sport due to influences other than their physical or psychological capabilities. Other exclusion criteria were chosen because they represent additional injuries or surgical procedures that may significantly affect the course of rehabilitation or functional outcome.[48] Patients provided written informed consent, and the protocol for the study was approved by the University of Florida Institutional Review Board.

Surgical Procedure and Rehabilitation Program

All surgical procedures were performed arthroscopically by a board-certified orthopaedic surgeon (P.A.I. or M.W.M.), using autograft or allograft tissue. The autograft sources were bone-patellar tendon-bone or semitendinosus and gracilis tendons. The allograft sources were tibialis anterior, tibialis posterior, or Achilles tendon. The surgical procedure, as well as graft selection process, for our surgeons has been previously published.[13] Rehabilitation was not controlled in this study; however, the standard ACL reconstruction rehabilitation protocol used in our facility and given to patients undergoing rehabilitation at outside facilities allows for immediate weight bearing and knee motion as tolerated. The emphasis of the first 6 weeks of rehabilitation is on decreasing knee effusion, develop-

ing quadriceps control, and regaining full knee motion. The next 6 weeks of rehabilitation are focused on increasing lower extremity muscle strength, muscle endurance, and neuromuscular control. Straight-ahead running is permitted at 12 weeks if (1) quadriceps strength symmetry index is greater than 60%, (2) knee effusion is trace or less, (3) knee extension ROM is equal to the contralateral side, (4) knee flexion ROM is within 5° of the contralateral side, and (5) average knee pain is less than 2/10. Agility exercises are initiated at 18 weeks postsurgery following successful completion of a straight-ahead running program. Patients are allowed to return to sport when the following criteria are met: (1) knee ROM equal to the contralateral side, (2) quadriceps strength greater than 85% of the opposite knee based on isokinetic testing, (3) no knee effusion, and (4) completion of an agility and sport-specific program. These criteria are typically met around 6 months postsurgery.

Testing Overview

Patients were tested at a routine 1-year clinical follow-up visit. A standardized testing protocol consisted of the collection of demographic information, knee impairment measures, and self-report questionnaire responses. Testers were physical therapists with an average of 10.3 years (range, 5-17 years) of experience in sports physical therapy. Data were recorded on standard forms and entered into an electronic database (Microsoft Access 2007; Microsoft Corporation, Redmond, WA).

Demographic Information

Demographic information included age, sex, weight, time from injury to surgery, graft type (autograft or allograft), concomitant knee injuries, and time from surgery to follow-up. Concomitant injuries were diagnosed during the preoperative physician evaluation or during surgery, and included meniscal injuries, chondral lesions, and collateral ligament injuries.

Knee Impairment Measures

Knee Effusion Knee effusion was assessed with the stroke test and graded on a 5-point scale (none, trace, 1+, 2+, and 3+).[50] This method of assessing knee effusion has a substantial interrater reliability (κ = 0.75).[50]

Knee ROM Knee flexion and extension passive ROM were measured in both the nonsurgical and surgical sides using a standard goniometer. Side-to-side knee flexion and extension ROM deficits were calculated (nonsurgical-side ROM minus surgical-side ROM). Intertester reliability has been shown to be high for measurements of knee flexion ROM (intraclass correlation coefficient [ICC] = 0.98) and knee extension ROM (ICC = 0.89-0.93) using a standard goniometer.[8]

Knee Ligament Laxity Testing To assess the integrity of the ACL graft, anterior displacement of the tibia was measured with a KT1000 knee ligament arthrometer (MEDmetric Corporation, San Diego, CA). The tibia was pulled to the end point of anterior translation while the knee was flexed to approximately 30°. The amount of anterior displacement was recorded in millimeters. Two trials were performed on each side and averaged. The difference in values between the surgical and nonsurgical sides was recorded as the anterior knee joint laxity difference. The KT1000 has been shown to provide valid[44,46] and reliable measurements of anterior knee joint laxity (ICC = 0.91-0.93).[7]

Quadriceps Strength Testing Knee extensor (quadriceps) strength was assessed with an isokinetic dynamometer (Biodex System 3; Biodex Medical Systems, Shirley, NY). Prior to testing, patients were given a 5-minute warm-up on a stationary bicycle. They were then seated and stabilized with a lap-and-thigh belt. The dynamometer arm was set to move through a range of 90° to 0° of knee motion at a speed of 60°/s. Testing was conducted on the nonsurgical side first. Patients performed 2 practice trials followed by 5 maximal-effort trials. Testing was then repeated on the surgical side. The peak knee extensor torque of 5 trials was recorded for each side. Two separate measures of quadriceps muscle performance were calculated. First, a quadriceps symmetry index was calculated by normalizing the peak knee extensor torque on the surgical side to that of the nonsurgical side and multiplying by 100. Second, the knee extensor torque-body weight ratio was calculated by dividing knee extensor peak torque (ft·lb) of the surgical side by the subject's body weight (lb). Isokinetic strength testing has been shown to be a reliable method of quadriceps strength testing (ICC = 0.81-0.97)[7] and sensitive to strength changes in the first 2 years following ACL reconstruction.[45]

Self-report Questionnaires

Tegner Activity-Level Scale The Tegner activity-level scale is an 11-point grading scale for work and sports activities.[52] The scale rates activity level from 0 (sick leave or disability pension because of knee problems) to 10 (competitive sports such as soccer, football, or rugby at the national or elite level). Level 5 indicates participation in sport-related activities at the lowest recreational level. The scale was initially developed to measure activity following knee ligamentous injury and has been validated for use following ACL injury.[6] The Tegner scale has demonstrated acceptable test-retest reliability (ICC = 0.80) after ACL reconstruction.[6] At the time of follow-up testing, patients were asked to rate their current level of sports participation as well as to recall their preinjury level of sports participation.

Knee Pain Intensity Knee pain intensity was assessed with an 11-point visual numeric rating scale. Pain intensity ratings ranged from 0 (no pain) to 10 (worst imaginable pain). Patients were asked to rate their worst and best pain levels over the past 24 hours. They were also asked to rate their current level of pain. All 3 pain ratings were averaged to get a composite knee pain intensity score. The numeric rating scale has been shown to be a reliable method of pain intensity assessment (ICC = 0.74-0.76).[14,34]

Episodes of Knee Instability Patients were asked, "How many episodes of giving way or buckling at the knee have occurred since your surgery?" Possible answers included 0, 1, 2 to 5, and greater than 5.

Tampa Scale for Kinesiophobia Kinesiophobia, or fear of movement/reinjury, was measured with the shortened version of the Tampa Scale for Kinesiophobia (TSK-11).[59] Response items are related to somatic sensations (eg, "Pain always means I have injured my body") and activity avoidance (eg, "I'm afraid that I might injure myself if I exercise"). Scores on the TSK-11 range from 11 to 44 points, with higher scores indicating greater pain-related fear of movement/reinjury. Good test-retest reliability (ICC = 0.81 and 0.93)[20,59] has been reported for the TSK-11 in patients with chronic low back pain. The TSK-11 is a psychometrically stable instrument to assess fear of movement/reinjury in the later stages of rehabilitation following ACL reconstruction.[19]

International Knee Documentation Committee Subjective Knee Evaluation Form Knee function was measured with the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC). The IKDC contains 10 items related to knee symptoms and physical function.[26] Scores range from 0 to 100, with higher scores indicating less disability. An ICC of 0.94 and a standardized response mean of 0.94 have been reported for the IKDC across a broad range of knee pathologies, including ACL injury and ACL reconstruction.[26,27]

Return-to-Sport Status All patients were asked 2 questions regarding their return-to-sport status: (1) "Have you returned to sports or recreational activities since your surgery?" and (2) "Have you returned to the same level of sports as before your injury?" Because our purpose was to specifically examine return to preinjury levels of sports participation, patients were divided into return-to-sport-status groups based on their answer to the question, "Have you returned to the same level of sports as before your injury?" Those who indicated that they had returned to the same level of preinjury sports participation were designated Y-RTS (yes return to sports), and those who reported that they had not returned to the same level were designated N-RTS (no return to sports). Patients who reported that they had not returned to preinjury levels of sports participation were asked to pick their primary reason for not having returned from a list of options that included pain, swelling, fear of injury or lack of confidence, knee instability, muscle weakness, not yet cleared from doctor to return to sports, too little time to participate or had a change in lifestyle, and other. This answer represented the subject's perceived reason for not being able to return to the preinjury level of sports participation.

TABLE 1 Demographic Variable Means and Distributions for Y-RTS and N-RTS Groups*

Measure	Y-RTS (n = 52)	N-RTS (n = 42)	Total (n = 94)	*P* Value†
Injury to surgery, d	70.6 ± 56.6	80.4 ± 66.5	75.0 ± 61.0	.44
Preinjury Tegner score	8.4 ± 1.6	8.3 ± 1.6	8.4 ± 1.5	.76
Postsurgical Tegner score	8.3 ± 1.6	6.6 ± 1.8	7.5 ± 1.9	<.001
Surgery to follow-up, wk	50.9 ± 4.0	49.5 ± 5.7	50.2 ± 4.8	.17

Abbreviations: N-RTS, patients indicating they had not returned to preinjury levels of sports participation; Y-RTS, patients indicating they had returned to preinjury levels of sports participation.
**Values are mean ± SD.*
†Significance of difference between Y-RTS and N-RTS group means.

TABLE 2 Distribution of Self-reported Primary Reasons for Not Returning to Preinjury Levels of Sports Participation

	Primary Reason, n	N-RTS, %
Pain	5	12
Swelling	3	7
Fear of injury or lack of confidence	19	45
Knee instability	4	10
Muscle weakness	5	12
Not yet cleared from doctor to return to sports	5	12
Other	1	2

Abbreviation: N-RTS, patients indicating they had not returned to preinjury levels of sports participation.

Statistical Analysis

Statistical analyses were conducted with SPSS for Windows Version 13.0 (SPSS Inc, Chicago, IL). Descriptive statistics were generated for all variables. We analyzed the data in the following steps: (1) identification of clinical factors that differed between groups based on return-to-sport status, (2) determination of the factors most strongly associated with return-to-sport status in a multivariate model, and (3) testing the discriminatory value of clinical variables associated with return-to-sport group allocation. An alpha level of .05 was used for inferential analyses.

For the first step, independent-samples *t* tests determined group differences (Y-RTS versus N-RTS) in continuous variables, and chi-square tests were used for categorical variables. If any individual cells were below 5, we used the Fisher exact test instead of chi-square analysis. A 2-way repeated-measures analysis of variance was used to analyze preinjury-to-postsurgical changes in Tegner score

TABLE 3 Means and Group Differences for Demographic, Knee Impairment, and Self-report Variables*

Measure	Y-RTS (n = 52)	N-RTS (n = 42)	*P* Value
Age, y	20.9 ± 8.3	24.2 ± 8.8	.066
Tegner change score†	−0.1 ± 0.4	−1.9 ± 1.6	<.001
Concomitant injuries	0.9 ± 0.8	0.8 ± 0.9	.533
KT1000 difference, mm	2.3 ± 1.2	2.5 ± 1.3	.357
Extension ROM deficit, deg	0.7 ± 1.4	0.9 ± 2.0	.630
Flexion ROM deficit, deg	2.2 ± 3.9	2.1 ± 3.3	.858
Quadriceps index, %	91.2 ± 11.3	86.6 ± 17.3	.150
Knee extensor torque/body weight, %	81.5 ± 17.2	73.9 ± 19.8	.050
Average knee pain intensity	0.4 ± 0.6	1.0 ± 1.1	.005
IKDC	93.8 ± 6.3	78.0 ± 15.6	<.001
TSK-11	15.3 ± 4.1	19.6 ± 4.7	<.001
Sex, n			.934
Male	33	27	
Female	19	15	
Knee joint effusion, n			.005‡
Yes	1	9	
No	51	33	
Graft type, n			.271
Allograft	25	25	
Autograft	27	17	
Knee instability, n			.004
Yes	23	31	
No	29	11	

Abbreviations: IKDC, International Knee Documentation Committee Subjective Knee Evaluation Form (0-100); N-RTS, patients indicating they had not returned to preinjury levels of sports participation; ROM, range of motion; TSK-11, shortened version of Tampa Scale for Kinesiophobia (11-44); Y-RTS, patients indicating they had returned to preinjury levels of sports participation.
**Data are mean ± SD unless otherwise indicated.*
†The postsurgical follow-up Tegner score minus the preinjury Tegner score.
‡Fisher exact test analysis.

between groups based on return-to-sport status.

For the second step, discriminant function analysis (DFA) was performed to investigate which of the factors identified by comparative analysis in the first step were predictors of group status in a multivariate model. To avoid excluding any potentially discriminating factors, a liberal statistical criterion ($P \leq .15$) was used to determine factors that would be entered into the DFA. Briefly, DFA is a technique that classifies variables into separate functions based on how linear combinations of the variables predict differences in functions. In this analysis, DFA was used to identify a parsimonious set of variables that contributed to determining a function. Specifically, we were interested in including variables in the prediction model with standardized coefficients of 0.3 or greater in predicting the derived functions.

For the third step, we tested the ability of the multivariate model identified by DFA to discriminate between return-to-sport status groups. An a priori decision was made to use receiver operating characteristic (ROC) curve analyses from prior unpublished pilot data to determine the cutoff value for each continuous and categorical clinical variable that best differentiated the 2 return-to-sport outcome groups.

For statistical analysis, values on the more favorable side of the cutoff score for each variable were coded as 1, and the less favorable values were coded as 0. Group allocation for return-to-sport outcome was coded as 1 for Y-RTS and 0 for N-RTS. The number of criteria met for the multivariate model was determined for each subject. The accuracy of this model was then determined by computing positive and negative likelihood ratios.

RESULTS

A total of 94 patients were included in the study (60 men, 34 women; mean ± SD age, 22.4 ± 8.6 years). Demographic information for these patients is presented in **TABLE 1**. Eighty-six patients (91%) reported they had returned to some form of sports or recreational activity since their surgery; however, only 52 (55%) reported returning to preinjury levels of sports participation, and these were included in the Y-RTS group. Forty-two patients (45%) reported they had not returned to their preinjury level of sports participation and were included in the N-RTS group. Of those patients reporting N-RTS, 45% (19/42) reported fear of reinjury/lack of confidence as a primary reason for not returning to preinjury levels of sports participation, and knee joint symptoms (pain, swelling, instability, muscle weakness) collectively accounted for an additional 40% (17/42). Pain (5/42 [12%]) and muscle weakness (5/42 [12%]) were the most frequently reported knee joint symptoms. The distributions of primary reasons for not returning to preinjury sports participation are presented in **TABLE 2**.

Group differences in demographics, knee impairments, and self-report questionnaire scores are presented in **TABLE 3**. There was no significant difference in age between groups ($P = .07$). Tegner activity-level scores decreased from preinjury to follow-up in both groups; however, this

TABLE 4 Multivariate Model Analysis*

Criteria Met, n	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	Patients Meeting Criteria, n: Y-RTS Group	Patients Meeting Criteria, n: N-RTS Group
0	1.00	0.00	1.00	Undefined	1	5
1	0.98	0.12	1.11	0.16	6	23
2	0.87	0.67	2.60	0.20	27	13
3	0.35	0.98	14.54	0.67	18	1

Abbreviations: N-RTS, patients indicating they had not returned to preinjury levels of sports participation; Y-RTS, patients indicating they had returned to preinjury levels of sports participation.
**Variables included in the model: no knee joint effusion, no episodes of knee instability, International Knee Documentation Committee Subjective Knee Evaluation Form (0-100) score greater than 93 (area under curve, 0.815; P<.001).*

decrease was found to be statistically significant in the N-RTS group only. Patients in the Y-RTS group had less presurgical-to-postsurgical change in Tegner score (P<.001), lower grade of knee joint effusion (P = .005), fewer episodes of knee instability (P = .004), lower knee pain intensity (P = .005), higher quadriceps peak torque-body weight ratio (P = .050), higher IKDC score (P<.001), and lower TSK-11 score (P<.001).

The clinical variables entered into DFA were knee joint effusion, episodes of knee instability, knee pain intensity, quadriceps peak torque-body weight ratio, IKDC score, and TSK-11 score. In this analysis, a statistically significant function for determination of return-to-sport status was determined (Wilks' λ = .571, P<.001). Investigation of the standardized coefficients indicated that the strongest contributors to this function were knee joint effusion (.519), episodes of knee instability (.357), and IKDC score (–.788).

The accuracy for the final multivariate model (range of clinical variables, 0-3) is reported in **TABLE 4**. Based on prior unpublished data, the following cutoff scores were set for each variable in the final multivariate model: effusion rated as none, no episode of instability, and IKDC score greater than 93. Likelihood ratio analysis indicated that meeting all 3 of the criteria resulted in a large shift (positive likelihood ratio, 14.54) in post-test probability of being associated with Y-RTS status. Alternatively, meeting only 1 of the criteria reduced the post-test probability of being associated with Y-RTS status compared to pretest probability (negative likelihood ratio, 0.16).

DISCUSSION

The purposes of this study were (1) to examine differences in clinical variables (demographics, knee impairments, and self-report measures) between those who return to preinjury level of sports participation and those who do not at 1 year following ACL reconstruction, (2) to determine the factors most strongly associated with return-to-sport status in a multivariate model, and (3) to explore the discriminatory value of clinical variables associated with return to sport at 1 year postsurgery. Although the majority of patients in our study had returned to sports following ACL reconstruction, only 55% reported they had returned to preinjury levels of sports participation at 1 year. We hypothesized that a combination of demographic, physical impairment, and psychosocial measures would differ and discriminate between those who reported participation in sports-related activities at preinjury levels and those who did not. This study identified a variety of factors that differed between groups based on return-to-sport status, with knee impairment and self-reported function measures as the factors most strongly associated with returning to preinjury sports participation. These factors are potentially modifiable and should be considered when developing return-to-sport rehabilitation guidelines and participation criteria following ACL reconstruction.

Many of the factors that differed between return-to-sport-status groups in this study, such as quadriceps strength, knee pain intensity, self-reported knee function, and fear of movement/reinjury, have also been associated with knee function in prior studies.[11,19,30-32,45,58] The lack of group differences in demographics indicates that nonmodifiable factors, such as age, sex, and concomitant injury, or potentially modifiable factors, such as graft type and time from injury to surgery, may not play a significant role in return-to-sport status. These findings support prior studies that have failed to show a strong relationship between demographic measures and function.[5,16,18,25,28,35,39,44,47] An interesting finding in this study was that quadriceps peak torque on the surgical side normalized to body weight differed between return-to-sport-status groups, but quadriceps symmetry index did not differ between groups. Prior studies have reported inconsistent results regarding the influence of quadriceps performance on functional outcomes.[22,32,48,58] This inconsistency appears to be closely tied to the method by which quadriceps performance is measured or the outcome used[22,32,48,58] and may be influenced by variability in rehabilitation programs. The results of this study indicate that though quadriceps strength normalized to body weight may be an important consideration when determining ability for return to sports, quadriceps strength asymmetry is not a discriminating factor between return-to-sport groups. The importance of quadriceps symmetry, however, and its implication for reinjury should not be overlooked. Prior studies have demonstrated the predictive value of strength asymmetries for risk of rein-

jury,[43] and it is commonly suggested that these asymmetries should be resolved prior to initiation of sports activities.[36,41,42]

Although some variables previously associated with function following ACL reconstruction, such as knee pain intensity,[32,58] fear of movement/reinjury,[11,30-32] and quadriceps strength,[32,45,58] had bivariate associations with return to preinjury sport participation, they were not retained in multivariate analysis. Perhaps the most unexpected finding was the exclusion of fear of movement/reinjury from the model, because this has been strongly associated with return to sports participation in prior studies[29,31] and was the most prevalent reason cited for not returning to sport in our sample. Some authors have speculated that psychosocial factors, such as fear of movement/reinjury, may help to explain the discrepancy between generally favorable knee scores and poor return-to-sport rates following surgery.[2,3] It is plausible that fear of movement/reinjury may mediate the relationship between activity restrictions and factors included in the model (ie, instability or self-reported function), yet not be identified as a significant individual factor in multivariate analysis. Thus, concurrent assessment of pain-related fear of movement/reinjury and clinical measures may be unnecessary for prediction of return-to-sport status, because no further variance was explained by inclusion of this construct in the multivariate model.

A strength of this study is that it is the first, to our knowledge, to study the contributions of demographic, knee impairment, and psychosocial factors in a multivariate analysis for the determination of return-to-sport status at 1 year postsurgery. This is an important step toward creating evidence to guide the development of rehabilitation programs and return-to-sport criteria to improve outcomes following ACL reconstruction. There are several limitations of this study to consider when interpreting the results. This is a cross-sectional design; therefore, it remains to be proven if the variables identified in this study will longitudinally predict return-to-sport status at 1 year postsurgery. One year is generally considered a short follow-up period after ACL reconstruction; however, it has been shown that, of those patients who return to sports, most do so within the first year.[49] Furthermore, although most patients were released to return to sport at 6 months postsurgery, data on the timing of return to sport for each individual patient were not collected or analyzed. Therefore, some patients might have had more or less time to be exposed to sport activities than others, which should be considered when interpreting the results.

The results of our study may not be applied universally to all patients following ACL reconstruction. Patient status as a coper or noncoper was not assessed, and it is plausible that different factors underlie functional recovery between these groups.[17,24] Our exclusion criteria omitted those patients with concomitant ligamentous and articular cartilage damage requiring surgical procedures. Furthermore, patients who did not return for surgeon follow-up at 1 year postsurgery were not tested. This inherent selection bias should be considered when interpreting these results.

A final limitation of our study is the use of a nonvalidated self-report measure of return to sports participation. Most studies utilize self-report-of-function questionnaires that measure knee performance across a wide spectrum of constructs,[11,31,32,45,48,58] and comparisons are not often drawn between the ability to return to preinjury levels of sports participation and the ability to return to sports, even at a reduced level.[54] Objective clinical comparison of preinjury to postsurgery levels of sports participation or performance also has its limitations due to variable measurements of professional, amateur, and recreational athletic performance across sports. Although our methodology has not been validated, it has the potential to provide a more accurate estimation of sport-related function compared to preinjury levels.

Future studies should test the longitudinal validity of this model for prediction of return-to-sport status, as well as examine other potentially important physical performance measures, impairment variables, and psychological barriers related to return to sport. This study only examined 1 psychosocial construct directly, and it is possible that other psychosocial factors may contribute more significantly to function in multivariate models.[15,60] One such factor, self-efficacy, has been shown to be a preoperative predictor of outcome 1 year after ACL reconstruction,[53] and is predictive of improvements in knee pain intensity and self-reported function in the first 12 weeks following surgery.[12] Future studies should examine the relationship of fear of movement/reinjury and other psychosocial constructs, such as self-efficacy, longitudinally and at follow-up times longer than 1 year to determine which constructs best predict return-to-sport status.

CONCLUSION

This study provides further insight into clinical variables that empirically discriminate between individuals in return-to-sport groups. Results suggest that ongoing knee symptoms following ACL reconstruction are associated with individuals returning to preinjury sports participation levels. These potentially modifiable factors represent important targets for rehabilitation. Findings from this study should be considered in future longitudinal studies aimed at the development of return-to-sport rehabilitation guidelines and participation criteria. ◉

KEY POINTS

FINDINGS: Patients reporting return to preinjury levels of sports participation had less knee joint effusion, fewer episodes of knee instability, lower knee pain intensity, higher quadriceps peak torque-body weight ratio, higher IKDC scores, and lower TSK-11 scores. The strongest contributors to return-

to-sport status allocation were self-reported knee function (IKDC score), frequency of knee instability, and knee joint effusion.

IMPLICATIONS: Self-report and knee impairment variables differentiate those who are able to return to preinjury levels of sports participation from those who are not at 1 year postsurgery, possibly identifying targets to address during rehabilitation.

CAUTION: This study included only patients with primary ACL reconstruction, without concomitant ligamentous or articular cartilage damage requiring repair. Thus, the results of our study may not be applied universally to all patients following ACL reconstruction. The variables identified in this study should be tested in longitudinal studies to determine their ability to predict sport-related outcomes.

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