# What Can the First 2 Months Tell Us About Outcomes After Anterior Cruciate Ligament Reconstruction?

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**Context:** Substantial research has been conducted on anterior cruciate ligament reconstruction (ACLR) to evaluate patient outcomes. However, little attention has been given to outcomes during the early phase of recovery and how early deficits affect both short- and long-term outcomes.

**Objective:** To identify relationships between demographic (age, sex, and body mass index [BMI]) and intraoperative (isolated ACLR versus primary ACLR + secondary procedures), and postoperative (range-of-motion [ROM] and peak isometric knee-extension force [PIF]) variables during the first 2 months after ACLR using self-reported outcomes.

Design: Cohort study.

Setting: Outpatient orthopaedic hospital.

**Patients or Other Participants:** A total of 63 patients (38 men, 25 women; age =  $33.0 \pm 12.1$  years; BMI =  $26.3 \pm 6.5$  kg/m<sup>2</sup>) who underwent ACLR.

**Main Outcome Measure(s):** Demographic, intraoperative, and postoperative variables were collected at 1 and 2 months after ACLR and were compared with International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form scores at 1, 2, and  $\geq$ 12 months.

**Results:** Significant relationships were identified between  $\geq$ 12-month IKDC scores and the 1-month (Pearson correlation, r=0.283,  $r^2=0.08$ ; P=.025) and 2-month (r=0.301,  $r^2=0.09$ ; P=.017) IKDC scores. After controlling for other variables, we found that the PIF ratio measures at 1 and 2 months were positively associated with 1- and 2-month IKDC scores (P < .001) and BMI was negatively associated with both 1- and 2-month IKDC scores were related to the 1-month difference in knee-flexion ROM (P = .04).

**Conclusions:** The IKDC scores during the first 2 months were positively correlated with patients' perceptions of function on long-term IKDC scores. It also appears that improvements in lower extremity strength and flexion ROM deficits were positively associated with short-term IKDC scores. Higher BMI was negatively associated with patients' perceptions of function on short-term IKDC scores.

*Key Words:* force output, knee, motion, rehabilitation, International Knee Documentation Committee

#### Key Points

- After anterior cruciate ligament reconstruction, patients' subjective International Knee Documentation Committee (IKDC) scores at both 1- and 2-month follow-ups had fair but significantly positive associations with the ≥12-month IKDC score.
- The ratio of surgical- to nonsurgical-limb measures of peak isometric knee-extension force at 1 and 2 months was
  positively associated with 1- and 2-month IKDC scores.
- The difference in flexion range of motion between the surgical and nonsurgical limbs had a significant positive relationship with 1-month IKDC score.
- Body mass index had a significant negative association with both 1- and 2-month IKDC scores.
- No significant relationships were noted between demographic, intraoperative, or postoperative variables during the first 2 months and IKDC scores at ≥12 months after anterior cruciate ligament reconstruction.

A nterior cruciate ligament reconstruction (ACLR) is a commonly performed surgical procedure in active individuals; injury to this ligament is more frequent in sports requiring multidirectional activities, with an estimated incidence of 81 per 100 000 persons.<sup>1–3</sup> Discrepancies in the literature exist when evaluating the effects of surgical intervention and rehabilitation on postoperative outcomes. Reconstruction of this ligament and postoperative rehabilitation have been shown to be effective in restoring functional stability of the knee,<sup>4</sup> minimizing the development of osteoarthritis (OA),<sup>5,6</sup> and returning patients to their previous level of function.<sup>5,7</sup> However, persistent lower extremity muscle weakness,<sup>8,9</sup> insufficient dynamic knee stability,<sup>10</sup> and increased risk of posttraumatic arthrosis<sup>3</sup> have also been reported. A considerable number of individuals are unable to return to competitive sports despite successful rehabilitation or ACLR with rehabilitation.<sup>11</sup> Though controversy lingers, substantial research has been conducted on specific surgical procedures, various graft options, and rehabilitation protocols in an attempt to identify prognostic risk factors and modifiable predictors to improve self-reported outcomes after ACLR.<sup>12,13</sup>

Although multiple authors have evaluated various factors related to returning individuals to their prior level of function, research identifying the effectiveness of early postoperative measures on self-reported outcomes after ACLR is lacking. Several self-efficacy studies have provided compelling evidence that a large number of patients are unable to return to their prior level of function in spite of an apparently successful surgery and rehabilitation.<sup>11</sup> Therefore, it is important to understand the psychosocial ramifications of the injury and monitor self-reported outcomes throughout the rehabilitation process to improve both short- and long-term function.

Accumulating evidence suggests that both demographic and intraoperative findings have a significant influence on patient outcomes after ACLR.<sup>5,14-20</sup> In particular, medial meniscectomy, residual ligamentous laxity, and femoral chondral defects have all been associated with subsequent degenerative arthrosis as seen on radiography.<sup>5,15,20</sup> Studies also suggest that demographic risk factors such as age, sex, and body mass index (BMI) might have a profound influence on self-reported outcomes after ACLR. Higher BMI scores might predict lower self-reported outcomes scores.<sup>12,13</sup> Also, the odds of successful outcomes are 0.35 times lower for persons over the traditional threshold for obesity (BMI  $\geq 30$  kg/m<sup>2</sup>).<sup>21</sup> Conflicting evidence exists on whether age and sex are associated with self-reported outcomes.<sup>14,16–19</sup> Whereas some studies<sup>14,17,18</sup> point to lower self-reported outcomes in women and older patients, others<sup>16,19</sup> indicate no difference in overall outcomes.

Postoperative rehabilitation is an integral component to a successful recovery after ACLR. The inability to restore symmetric range of motion (ROM)<sup>6,7</sup> and muscular strength<sup>7,22</sup> affects patient satisfaction. Postoperative ROM deficits have been associated with a higher incidence of OA changes and lower self-reported outcomes scores.<sup>5,6,19</sup> Additional research has shown that muscular weakness, specifically of the quadriceps femorie, is related to poorer functional outcomes.<sup>23–25</sup> Furthermore, establishing preoperative lower extremity strength<sup>7,22,26</sup> and restoring symmetric ROM<sup>6,7</sup> are important in increasing overall functional ability and improving self-reported outcomes after ACLR.

Although a significant body of literature has addressed the effects of demographic, intraoperative, and postoperative factors on long-term self-reported outcomes, little attention has been given to the association between these variables and outcomes during the early phase of recovery and how deficits affect long-term outcomes. Studies are needed to investigate correlations between clinical measures and self-reported outcomes during the early stages of recovery. Such studies will reveal the potentially important influences of these factors on both short- and long-term outcomes and will guide clinicians in making appropriate decisions regarding early-stage postoperative rehabilitation.

The purpose of our study was to identify relationships between demographic (age, sex, BMI), intraoperative (isolated ACLR versus primary ACLR + secondary procedures), and postoperative (ROM and peak isometric knee-extension force [PIF]) variables during the first 2 months after ACLR and self-reported outcomes as measured by the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form at 1, 2, and  $\geq 12$  months. First, we hypothesized that deficits in ROM and PIF during the first 2 months after surgery would be positively associated with IKDC scores at the equivalent time points and at  $\geq 12$  months postoperatively. Second, we proposed that IKDC scores during the first 2 months after surgery would be positively associated with IKDC scores at  $\geq$ 12 months. Third, we suggested that participant characteristics such as secondary surgical procedures, age, sex, and BMI would have significant influences on IKDC scores at 1, 2, and  $\geq$ 12 months after ACLR.

# METHODS

#### **Demographics**

We retrospectively identified participants who underwent primary arthroscopic ACLR between 2007 and 2011. Inclusion criteria for this study were age 15 to 65 years; autograft or allograft single- or double-bundle ACLR procedure; partial meniscectomy or chondroplasty procedures (chondral lesions with an Outerbridge grade<sup>27</sup> of  $\leq 2$ ) or both; and complete datasets, including comprehensive ROM and PIF testing at 1 and 2 months, as well as complete IKDC Subjective Knee Evaluation Forms at 1, 2, and >12 months postoperatively. Exclusion criteria were incomplete objective or subjective measurements, concurrent injury to the posterior cruciate ligament, grade III tear of either medial or lateral collateral ligament, meniscal repair, chondral lesion with an Outerbridge grade<sup>27</sup> of >2, involvement in a workers' compensation case, or a neurologic disorder (eg, multiple sclerosis, traumatic brain injury) that might impair postoperative rehabilitation. The institutional review board at Intermountain Healthcare Urban Central Region (Murray, UT) approved this study. All ACLRs were performed by 1 of 2 senior surgeons at The Orthopedic Specialty Hospital (Murray, UT).

Surgical details were obtained from physician-dictated operative notes and included the type of primary procedure (single versus double bundle) and secondary procedures (partial meniscectomy or chondroplasty or both). Postoperative variables collected were the IKDC Subjective Knee Evaluation Form score, unilateral PIF, and knee flexionextension ROM. All patients participated in a standard 4phase rehabilitation protocol<sup>28</sup> at the same facility. Phase 1 (0 to 4 weeks) of the rehabilitation protocol consisted of passive, active-assist, and active ROM exercises; weight bearing as tolerated (axillary crutches as needed); stationary bicycling; muscle-activation exercises; and inflammation reduction. Phase 2 (4 to 8 weeks) emphasized progressive ROM exercises, muscle strengthening, neuromuscularcontrol training, and functional activities. Phase 3 (8 to 12 weeks) focused on restoring full, symmetric, passive ROM; muscle strengthening; higher-level neuromuscularcontrol tasks; and running. Phase 4 (12-24 weeks) involved progressive muscle strengthening, sport-specific neuromuscular-control training, plyometrics, sprinting, and cutting drills as appropriate.

#### **Outcomes Measures**

The IKDC Subjective Knee Evaluation Form is an 18item, site-specific instrument designed to measure symptoms related to function and sports activity in patients who have 1 or more knee conditions including ligament, meniscal, articular cartilage, OA, and patellofemoral injuries.<sup>29,30</sup> The IKDC is a reliable and valid instrument for measuring patient-oriented clinical outcomes pertaining to daily and sports function.<sup>31,32</sup> Test-retest reliability is



Figure. Single-legged strength testing of unilateral, closed chain, peak isometric knee-extension force production that was measured using a horizontal Plyo Press (Athletic Republic, Park City, UT).

adequate for groups of patients with knee injuries and mixed knee conditions.<sup>33</sup> The minimal clinically important difference has been reported to be between 11.5 and 20.5; the minimal detectable change, between 8.8 and 15.6; and the standard error of the measure, between 3.2 and 5.6.<sup>33</sup> We obtained all subjective IKDC scores at 1- and 2-month visits to outpatient physical therapy. Subjective IKDC scores at  $\geq 12$  months (20.7  $\pm$  5.1 months) after surgery were completed via telephone interviews.

A dual-arm goniometer (Chattanooga Medical Supply, Inc, Chattanooga, TN) was used to measure knee ROM similarity, as described by Shelbourne et al.<sup>6</sup> For knee extension, the heel of the seated patient was positioned on a bolster to allow the examiner to measure the amount of extension or hyperextension, if present. For knee flexion, the patient was instructed to bend the affected knee as far as possible toward the buttocks while seated. The differences in ROM (°) between the ACLR and nonsurgical knee were expressed as separate difference scores for flexion and extension. Unilateral knee ROM was recorded once at the beginning of the 1- and 2-month physical therapy visits, before any stretching or warm-up. The same examiner measured each patient to maintain consistency between limbs. Intratester reliability is high for knee flexion (intraclass correlation coefficient [ICC] = 0.997) and extension (ICCs = 0.972 to 0.985).<sup>34</sup> Intertester reliability is also high for knee flexion (ICCs = 0.977 to 0.982) and extension (ICCs = 0.893 to 0.926).<sup>34</sup>

Lower extremity strength was quantified by unilateral closed chain PIF production (feet-pounds) and was measured using a horizontal Plyo Press 625 III (Athletic Republic, Park City, UT). The reliability (ICC = 0.98) for the PIF measurement on the Plyo Press has been reported previously,<sup>35</sup> along with the testing procedures.<sup>36</sup> We measured Plyo Press output data from output signals obtained from a mounted force plate (model PPFP; Advanced Mechanical Technology, Inc, Watertown, MA). All data were sampled at 200 Hz with a low-pass filter at 10 Hz using DartPower software (version 2.0; Athletic Republic). Before every testing session, we zeroed and

load calibrated the force plate. The nonsurgical leg was tested first, followed by the surgical leg, in all patients. The order of the testing protocol was performed this way to ensure consistency among patients (Figure).

All patients warmed up on a recumbent bicycle for 10 minutes before strength testing. Patients were then placed in supine position with  $60^{\circ}$  to  $70^{\circ}$  of knee flexion. During the testing, patients were instructed and orally encouraged to exert pain-free maximal force against the mounted force plate for 5 seconds. We defined *PIF* as the highest resultant force produced during the 5-second test for each leg separately during a single trial. Peak isometric force measurements were recorded at 1 and 2 months, postoperatively. All scores were calculated as ratio scores by dividing the nonsurgical limb PIF output by the surgical limb PIF output.

# STATISTICAL ANALYSIS

# **Data Analysis**

We investigated relationships between patient-subjective IKDC scores at 1, 2, and  $\geq 12$  months with 2-tail Pearson correlation analyses. These correlational analyses gave an indication of whether the IKDC scores were related over time. Correlations from r = 0.25 to 0.5 were considered *fair*. whereas correlations ranging from r = 0.5 to 0.75 were regarded as moderate to good.37 We then carried out our primary analysis by evaluating relationships between subjective IKDC scores at 1, 2, and >12 months and postoperative variables at 1 and 2 months. Hierarchical regression was used to evaluate the influence of the postoperative variables on subjective IKDC scores after secondary procedure, age, sex, and BMI had already been considered. Thus, secondary procedure, age, sex, and BMI were entered into the regression analyses first, followed by the postoperative variables (difference in flexion-extension ROM and PIF ratio). Results from the regressions informed subsequent secondary analyses exploring relationships between dichotomized demographic variables and continuous outcomes. Secondary analyses were carried out with repeated-measures analyses-of-variance (ANOVAs) and independent-samples t tests.

# RESULTS

We screened a total of 76 patients. Sixty-three patients who satisfied our inclusion criteria were included in our study (Tables 1 and 2). According to the preliminary Pearson correlation analysis, the  $\geq$ 12-month IKDC scores had a fairly positive correlation with both the 1-month (r =0.283,  $r^2 = 0.08$ ; P = .025) and 2-month (r = 0.301,  $r^2 =$ 0.09; P = .017) subjective IKDC scores. Furthermore, there was also a good positive correlation between 1- and 2month IKDC scores (r = 0.671,  $r^2 = 0.45$ ; P < .001). The  $r^2$ values of 0.08 for 1- and >12-month IKDC scores and 0.09 for 2- and  $\geq$ 12-month IKDC scores suggest that 1- and 2month IKDC scores accounted for less than 10% of the variability in >12-month IKDC scores. Repeated-measures ANOVA revealed significant differences in IKDC scores across time. Scores on the IKDC for each follow-up period are outlined in Table 3.

Follow-up hierarchical multiple regressions to evaluate the relationship between postoperative variables (difference

Table 1. Baseline Demographics of Study Participants

Characteristic	No.
Participants	63
Sex	38 men, 25 women
	Mean $\pm$ SD
Age, y	33.0 ± 12.1
Height, cm	172.1 ± 10.3
Weight, kg	$80.8 \pm 22.5$
Body mass index, kg/m <sup>2</sup>	$26.3\pm6.5$

in knee ROM and PIF ratio) and subjective IKDC scores, after accounting for other variables (secondary procedure, age, sex, and BMI), can be seen in Table 4. Incremental Ftests of  $R^2$  changes were significant for both 1- and 2-month IKDC score hierarchical regressions, suggesting that postoperative variables were significantly associated with IKDC scores after taking demographic variables into consideration. One-month IKDC scores were significantly related to the 1-month postoperative variables' difference in flexion ROM (P = .04) and PIF ratio (P < .001). Specifically, with every 1° reduction in the 1-month difference in knee flexion, 1-month IKDC scores increased an average of 0.28 points, and with every 1-unit reduction in the 1-month PIF ratio, 1-month IKDC scores increased an average of 0.29 points. The amount of variability in 1month IKDC scores ( $R^2$  value) explained by predictor variability was 0.46 (adjusted  $R^2 = 0.39$ ). Two-month IKDC scores were significantly related to the 2-month PIF ratio (P < .001). With every 1-unit reduction in the 2month PIF ratio, 2-month IKDC scores increased an average of 0.32 points. However, 2-month IKDC scores were not significantly related to 2-month differences in flexion or extension ROM (P = .45 and .78, respectively). The amount of variability in 2-month IKDC scores  $(R^2)$ explained by predictor variability was 0.36 (adjusted  $R^2 =$ 0.28). Twelve-month IKDC scores were not significantly related to any of the 1- and 2-month postoperative variables  $(R^2 = 0.17; \text{ adjusted } R^2 = 0.01).$ 

A few demographic variables were significantly related to 1- and 2-month IKDC scores. Body mass index had a significant negative relationship with 1- and 2-month IKDC scores (P = .01 and .03, respectively). Secondary procedure coded as a binary variable (*yes* versus *no*) was significantly related to the 1-month IKDC score (P = .01) but not to the 2-month IKDC score (P = .34). We found that patients after ACLR with a secondary procedure demonstrated, on average, an increase of 9.44 in 1-month IKDC score compared with the isolated ACLR group. The influences of age (P = .07 [1 month] and .16 [2 month]) and sex (P = .07

	Table 2.	Surgical Procedures	Performed	on	Participants
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Surgical Procedure(s)	n (%)
Isolated ACLR	23 (36.5)
Primary ACLR + secondary procedure(s)	40 (63.5)
Partial medial meniscectomy	17 (27.0)
Partial lateral meniscectomy	13 (20.6)
Partial medial and lateral meniscectomies	1 (1.6)
Chondroplasty	7 (11.1)
Partial meniscectomy and chondroplasty	2 (3.2)
Total	63 (100)

Abbreviation: ACLR, anterior cruciate ligament reconstruction.

Table 3. International Knee Documentation Committee (IKDC) Score Data Over Time

Time	IKDC Score, Mean ± SD	Mean Difference Between Time Points (95% Confidence Interval) <sup>a</sup>	P Value <sup>b</sup>
1 mo	$51.9\pm15.3$		
versus 2 mo		-11.5 (-15.1, -8.0)	<.001
versus $\geq$ 12 mo		-37.2 (-42.1, -32.2)	<.001
2 mo	$63.0\pm12.7$		
versus 1 mo		11.5 (8.0, 15.1)	<.001
versus $\geq$ 12 mo		-25.6 (-29.9, -21.3)	<.001
≥12 mo	$89.0\pm10.5$		
versus 1 mo		37.2 (32.2, 42.1)	<.001
versus 2 mo		25.6 (21.3, 29.9)	<.001

<sup>a</sup> Overall repeated-measures analysis of variance ( $F_{1.78,110.05} = 236.31$ , P < .001).

<sup>b</sup> All pairwise comparisons using Bonferroni correction were significant at <.001.

[1 month] and .15 [2 month]) were not significant. Twelvemonth IKDC scores were not significantly related to any of the patient demographic variables.

Finally, we explored the influence of age and BMI on IKDC scores with *t* tests. Differences in IKDC scores were evaluated against age by dividing the cohort into 2 categories: age  $\leq$ 34 years and >34 years. Patients  $\leq$ 34 years of age had a statistically higher mean IKDC score at 1

Table 4. Hierarchical Regression Results

	В	t	Р
Predictors	Coefficient	Statistic	Value
Secondary procedure	9.44	2.82	.01ª
Age	-0.25	-1.89	.07
BMI	-1.00	-2.86	.01ª
Sex	6.35	1.83	.07
1-mo FE difference	0.28	2.08	.04 <sup>b</sup>
1-mo EXT difference	0.01	0.03	.98
1-mo PIF difference	0.29	3.31	<.001
Secondary procedure	2.87	0.96	.34
Age	-0.17	-1.44	.16
BMI	-0.71	-2.19	.03 <sup>b</sup>
Sex	4.70	1.46	.15
2-mo FE difference	0.13	0.77	.45
2-mo EXT difference	0.11	0.29	.78
2-mo PIF Difference	0.32	3.88	<.001
Secondary procedure	3.52	1.20	.24
Age	-0.13	-1.05	.30
BMI	-0.24	-0.74	.46
Sex	-4.78	1.54	.13
1-mo FE difference	-0.48	-0.26	.80
1-mo EXT difference	-0.24	-0.67	.51
1-mo PIF difference	-0.01	-0.04	.97
2-mo FE difference	0.25	0.95	.35
2-mo EXT difference	-0.31	-0.71	.48
2-mo PIF difference	0.12	0.89	.38
	Predictors Age BMI Sex 1-mo FE difference 1-mo FE difference 1-mo PIF difference Secondary procedure Age BMI Sex 2-mo FE difference 2-mo PIF Difference 2-mo PIF Difference Secondary procedure Age BMI Sex 1-mo FE difference 1-mo FE difference 1-mo FE difference 2-mo FE difference 2-mo FE difference 2-mo FE difference 2-mo FE difference 2-mo FE difference 2-mo FE difference	B           Predictors         Coefficient           Secondary procedure         9.44           Age         -0.25           BMI         -1.00           Sex         6.35           1-mo FE difference         0.28           1-mo FE difference         0.28           1-mo FE difference         0.29           Secondary procedure         2.87           Age         -0.17           BMI         -0.71           Sex         4.70           2-mo FE difference         0.13           2-mo FE difference         0.13           2-mo FE difference         0.32           Secondary procedure         3.52           Age         -0.17           Sex         -4.78           1-mo FIF difference         0.32           Secondary procedure         3.52           Age         -0.13           BMI         -0.24           Sex         -4.78           1-mo FE difference         -0.48           1-mo FE difference         -0.24           1-mo PIF difference         0.25           2-mo FE difference         0.25           2-mo FE difference         0.25	B         t           Predictors         Coefficient         Statistic           Secondary procedure         9.44         2.82           Age         -0.25         -1.89           BMI         -1.00         -2.86           Sex         6.35         1.83           1-mo FE difference         0.01         0.03           1-mo FE difference         0.29         3.31           Secondary procedure         2.87         0.96           Age         -0.17         -1.44           BMI         -0.71         -2.19           Secondary procedure         2.87         0.96           Age         -0.17         -1.44           BMI         -0.71         -2.19           Sex         4.70         1.46           2-mo FE difference         0.13         0.77           2-mo FE difference         0.13         0.77           2-mo FE difference         0.32         3.88           Secondary procedure         3.52         1.20           Age         -0.13         -1.05           BMI         -0.24         -0.74           Sex         -4.78         1.54           1-mo FE difference

Abbreviations: BMI, body mass index; EXT difference, difference in extension range of motion, ratio of surgical to nonsurgical limb; FE difference, difference in flexion range of motion, ratio of surgical to nonsurgical limb; PIF difference, difference in peak isometric knee-extension force, ratio of surgical to nonsurgical limb.

<sup>a</sup> Significant at .05.

<sup>b</sup> Significant at .01.

month (P = .01; 95% confidence interval [CI] of difference, 3.46 to 18.12) and a trend toward a higher mean IKDC score at 2 months (P = .07; 95% CI of difference, -0.39 to 11.77) compared with patients >34 years. We also explored differences in IKDC outcomes against BMI scores with traditional obesity demarcation thresholds. This was conducted by dividing the cohort into 2 categories: BMI <30 and BMI ≥30. Although BMI was a significant predictor in the regression analyses, none of the *t* tests were significant, suggesting that the traditional obesity threshold does not influence 1- and 2-month IKDC scores.

# DISCUSSION

In this retrospective study, we identified demographic, intraoperative, and postoperative variables associated with self-reported outcomes after ACLR. The principal findings were (1) patients' subjective IKDC scores at both 1- and 2-month follow-ups had a fairly significant positive association with the  $\geq$ 12-month IKDC score; (2) the ratio of surgical- to nonsurgical-limb PIF measures at 1 and 2 month had a significant positive association with 1- and 2-month IKDC scores; (3) BMI had a significant negative association with both 1- and 2-month IKDC scores; (4) the difference in flexion ROM had a significant positive relationship with 1-month IKDC score; and (5) demographic, intraoperative, and postoperative variables during the first 2 months were not associated with IKDC scores at  $\geq$ 12 months after ACLR.

Outcomes after ACLR are typically evaluated through objective means, as measured by clinical examination, ligamentous laxity, and radiography; however, patients are typically more concerned with symptom reduction and functional ability.<sup>38</sup> Therefore, self-reported outcomes should be paramount in determining the response to recovery after ACLR. Traditionally, patients have been studied preoperatively and several months after surgery to determine the effects of ACLR.<sup>2,4,6,12,21,24,25,39,40</sup> This leads one to question the influence that early postoperative stages of recovery have on self-reported outcomes. Our results showed significant associations between patients' subjective IKDC scores during the first 2 months postoperatively and the >12-month IKDC score. This finding suggests that patients' self-reported outcomes during the first 2 months might influence their long-term perceptions of function. Limited research has been conducted to evaluate patients' self-reported outcomes during the earlier stages of recovery and their association with long-term outcomes. Thomee et al<sup>41</sup> concluded that patients' perceived self-efficacy appears to be an important factor associated with subjective physical function and quality of life. Although several factors contribute to patients' self-reported outcomes scores at various times within the recovery process, more attention should likely be placed on the determination, ambition, and effort put into the rehabilitation by the patient, both when designing the treatment program and during the course of the rehabilitation.41

In a recent systematic review, Te Wierike et al<sup>11</sup> reported that athletes with lower levels of fear of reinjury demonstrated better self-reported knee outcomes after ACLR. Furthermore, the investigators found a positive association between goal setting and rehabilitation adherence. Patients with higher adherence scores experienced fewer knee symptoms, indicating that adherence to a rehabilitation program had a positive effect on recovery after ACLR.<sup>11</sup> This information is relevant in setting realistic expectations and educating patients on the importance of early-stage recovery in overall recovery.

After controlling for demographic variables (secondary procedures, age, sex, and BMI), we found that ratio differences in the 1- and 2-month PIFs were significantly related to corresponding IKDC scores, suggesting that muscular-strength recovery was related to the perception of function. It appears that as the difference in lower extremity strength resolves during the first 2 months postoperatively, patients tend to report improved function. The literature is limited when evaluating the relationship of early postoperative muscular strength to patients' perceptions of lower extremity function after ACLR. Gerber et al<sup>42</sup> noted that the quadriceps femoris muscle of the surgical limb could atrophy up to 30% just 3 weeks after ACLR, indicating the importance of resistive training immediately after surgery in an effort to mitigate atrophy and weakness. Other investigators<sup>8,9</sup> showed that at 6 months postoperatively, individuals can experience a loss of up to 50% of quadriceps strength relative to the contralateral limb and persistent limb weakness after returning to the previous activity level. Other evidence suggests that mitigating muscular atrophy may reduce the risk of rerupture, minimize patellofemoral pain, lessen mobility deficits, and return athletes to sport more quickly after ACLR.<sup>8,10,43–45</sup> Several researchers<sup>2,39</sup> concluded that aberrant weakness preoperatively is associated with poorer functional outcomes at 6 months after surgery. Although factors including swelling, pain, muscular inhibition, and mobility deficits directly affect postoperative muscle function,46 previous work42,47,48 has indicated that early resistive muscle overloading promotes more optimal strength and volume, which in turn is associated with improved self-reported outcomes. Our findings show an association between lower extremity strength and patientreported function, further promoting the idea that early muscular strength training prevents atrophy and improves self-reported outcomes after ACLR.

Furthermore, our analysis indicates that BMI had a significant influence on patients' 1- and 2-month IKDC scores. This finding is in accordance with previous studies<sup>12,13,17</sup> in which similar functional outcomes were seen in patients with higher BMI scores after ACLR. Overall, we observed that a higher BMI was associated with lower subjective IKDC scores at 1 and 2 months, but this effect did not necessarily occur when the traditional obesity threshold was used as a cutoff point (nonobese = BMI < 30, obese = BMI  $\geq$ 30). The association between obesity and lower self-reported outcomes has been well documented in long-term studies,<sup>21,49</sup> but little is known about the effect of BMI on patient function during the early phases of recovery. Our results indicate that BMI had a direct association with patient-reported function as early as the first 2 months after surgery. We also noted that patients <34 years of age demonstrated significantly higher IKDC scores at 1 month (P = .01) and somewhat higher IKDC scores at 2 months (P = .07) compared with patients >34 years. We evaluated differences in IKDC outcomes against age through means previously described<sup>50</sup> but we altered them so that we could assess the differences between

younger and older subgroups. No difference was seen between the subgroups at  $\geq 12$  months, a finding that is consistent with the literature.<sup>51</sup> Based on the current evidence, age alone should not be used to determine whether a patient is an appropriate candidate for ACLR,<sup>51</sup> but it may be a factor in relative self-reported outcomes during the early stages of recovery. Additional studies with larger sample sizes are needed to determine whether age and BMI definitively influence IKDC scores at these time points.

Previous authors have concluded that the inability to restore symmetric knee motion may adversely affect patients' perceptions of function and increase the risk of developing OA.<sup>5,6</sup> Our findings indicate that knee-flexion deficits at 1 month were positively associated with lower IKDC scores at the same time point. However, this association did not carry through to the 2- and >12-month follow-up measures. Hence, although mobility deficits during the first month of recovery may influence patientreported function during the early phase of recovery, they do not appear to influence long-term subjective outcomes. These mobility findings contradict our original hypothesis. Because others<sup>5–7</sup> have shown that restoring full mobility relative to the contralateral limb improves long-term subjective outcomes scores and lower extremity strength, while minimizing the risk of developing OA, we recommend continued emphasis on initiating early mobility in postoperative rehabilitation. Studies are needed to confirm the influence of early mobility deficits on subjective selfreported outcomes scores in patients after ACLR.

In the current study, ligament reconstruction with secondary procedures such as partial meniscectomy or chondroplasty or both resulted in significantly higher 1-month IKDC scores. Yet previous studies<sup>20,52,53</sup> have shown lower 12-month, self-reported outcomes scores in patients with ACLR in conjunction with meniscal or articular cartilage damage. It is possible that our patients with concomitant injuries to the knee may have benefitted psychologically from having the damaged tissue managed surgically. These patients might have also demonstrated lower overall function due to pain, limited mobility, or weight-bearing status, as well as poorer preoperative IKDC scores due to the degree of injury, resulting in the perception of vast improvements at 1 month, comparatively speaking.

Our results suggest that in a cohort of patients recovering from ACLR, subjective IKDC scores during the first 2 months had a fairly positive association with IKDC responses at  $\geq 12$  months. However, because 1- and 2month scores accounted for less than 10% of the variability in >12-month scores, they are not ideal indicators of longterm subjective outcomes. Thus, patients who struggle in the early phase of recovery after ACLR may have the potential to improve their long-term self-reported outcomes scores with additional time and continual rehabilitation. Our findings also demonstrate that lower extremity strength deficits and higher BMI may negatively influence patients' insights on physical function during the early phase of recovery. Whereas further research is necessary to explicitly identify factors that directly influence patientperceived function after ACLR, we believe that understanding how specific variables influence outcomes during early recovery is important in developing both a foundation for future clinical trials and a structured, criteria-based rehabilitation protocol for improving functional outcomes. This line of research has not been thoroughly explored and could hold value in improving our understanding of the importance of early-stage recovery to both short- and longterm self-reported outcomes scores.

The present study has noteworthy limitations. First, our sample was small and comprised a heterogeneous group of surgical procedures. Although our sample represents a realistic population of patients, the multitude of secondary procedures may have affected the results. Second, the IKDC scores were obtained by 2 different means throughout this project. Scores were acquired in person during the first 2 months of rehabilitation and by phone interviews for the >12-month follow-up. The variations in data-collection modes may have introduced bias. Third, the strength-testing protocol required only 1 trial for each lower extremity to determine PIF production. Multiple trials would potentially provide a more accurate interpretation of force output. Fourth, preoperative assessments of muscular strength on the nonsurgical limb and  $\geq$ 12-month postoperative ROM and PIF measurements were not obtained.

# CONCLUSIONS

Patients' IKDC scores during the first 2 months had a fairly positive correlation with long-term IKDC scores. Lower extremity strength and knee-flexion ROM deficits were positively associated with short-term IKDC scores. Higher BMI had a negative association with patients' perception of function on short-term IKDC scores. No demographic, intraoperative, or postoperative variables had an influence on long-term IKDC scores after ACLR.

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