Journal of Athletic Training 2018;53(5):464–474
doi: 10.4085/1062-6050-328-16

www.natajournals.org

Decision to Return to Sport Participation After Anterior Cruciate Ligament Reconstruction, Part II: Self-Reported and Functional Performance Outcomes

Jennifer L. Werner, MS, ATC*; Julie P. Burland, MS, ATC†; Carl G. Mattacola, PhD, ATC, FNATA‡; Jenny Toonstra, PhD, LAT, ATC§; Robert A. English, PhD, PT‡; Jennifer S. Howard, PhD, LAT, ATC¶

*Cincinnati Children's Hospital Medical Center, OH; †University of Connecticut, Storrs; ‡University of Kentucky, Lexington; §Bowling Green University, OH; ¶Appalachian State University, Boone, NC

Context: Anterior cruciate ligament (ACL) reconstruction (ACLR) is the most commonly used method for helping athletes regain function and return to preinjury activity levels after ACL injury. Outcomes after ACLR have suggested that athletes return to a level of function that would support a return to sport participation; however, in a recent meta-analysis, pooled return rates were only 55%. It is unclear whether this discrepancy is a result of functional impairments.

Objective: To compare patient-reported outcomes (PROs), dynamic balance, dynamic functional performance, strength, and muscular endurance in athletes who returned to sport (RTS) and athletes who did not return to sport (NRTS) after ACLR.

Design: Case-control study.

Setting: University research laboratory.

Patients or Other Participants: Two groups of participants with primary unilateral ACLR: 18 RTS individuals (7 males, 11 females; age = 23 ± 11 years, height = 163.58 ± 40.41 cm, mass = 70.00 ± 21.75 kg, time since surgery = 4.02 ± 3.20 years) and 12 NRTS individuals (5 males, 7 females; age = 26 ± 13 years, height = 171.33 ± 48.24 cm, mass = 72.00 ± 21.81 kg, time since surgery = 3.68 ± 2.71 years).

Intervention(s): The PROs consisted of the International Knee Documentation Committee Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score, Tegner Activity Scale, and Marx Activity Scale. Functional performance outcome measures were the anterior and posteromedial reach on the Star Excursion Balance Test, a battery of single-legged–hop tests, isokinetic quadriceps and hamstrings strength at 60°/s and 180°/s, and a novel step-down-to-fatigue test. All measures were taken during a single laboratory session.

Main Outcome Measure(s): The Limb Symmetry Index was calculated for all functional performance measures. Mann-Whitney *U* tests were used to compare measures between groups ($P < .10$).

Results: Compared with the RTS group, the NRTS group had lower scores on the International Knee Documentation Committee Subjective Knee Evaluation Form (RTS median = 92.52, range = 66.67–97.70; NRTS median = 82.76, range = 63.22–96.55; $P = .03$) and Knee Injury and Osteoarthritis Outcome Score Symptoms subscale (RTS median = 88, range = 54–100; NRTS median = 71, range = 54–100; $P = .08$). No differences were observed for any functional performance measures.

Conclusions: The NRTS athletes displayed lower PROs despite demonstrating similar function on a variety of physical performance measures. These results further support existing evidence that physical performance alone may not be the ideal postoperative outcome measure. Measures of patients' symptoms and self-perceived physical function may also greatly influence postoperative activity choices.

Key Words: patient-reported outcomes, Star Excursion Balance Test, single-legged–hop tests, isokinetic strength

Key Points

- The decision to return to sport participation after anterior cruciate ligament reconstruction may be influenced less by the physical capacity to perform sport-related tasks than by personal factors.
- Ongoing physical function was not influenced by the decision to return or not return to sport participation.
- Athletes who had returned to sport participation subjectively considered themselves to have a higher level of knee function than athletes who had not returned.
- Patient-reported outcomes instruments detected functional deficits that were not readily apparent, underscoring the importance of using a multidimensional approach to evaluate patient progress and outcomes.

Anterior cruciate ligament (ACL) injuries, specifically tears, are the most common ligamentous injuries to the knee requiring surgical repair.[1] These tears are most prevalent in the athletic population, with 53% of ACL injuries sustained by football players.[2] To maximize knee stabilization and function, ACL reconstruction (ACLR) is the standard of care for ACL-deficient athletes who want to return to sport participation.[3] Typically, athletes undergo arthroscopic reconstruction within weeks of injury, initiate rehabilitation immediately after surgery, and return to sport participation in 4 to 9 months.[4]

The rate at which athletes have returned to sport (RTS) participation is not well understood. Authors[5–7] of systematic reviews reported that 81% returned to some kind of sport participation, but only 55% returned to competitive sport participation. Of those who returned, 65% returned at their preinjury level,[5–7] but researchers[8] reported return to preinjury levels as low as 31%. Ardern et al[5] observed that the rate of return to competitive sport was higher in studies published after 2000 (56%) than before 2000 (44%). The Multicenter Orthopaedic Outcomes Network[1] examined high school and collegiate football players at least 2 years after ACLR. A total of 63% of high school and 69% of collegiate football players were able to return to sport participation.[1] Among all players combined, 43% returned at their self-described preinjury level, 27% returned at a lower level than preinjury, and 30% did not return to sport (NRTS).[1] Whereas some variability exists among studies, it appears that approximately 50% of athletes returned to competitive sport participation or to their self-described preinjury level after ACLR.[1,5–7,9–11]

Regardless of the rate of return, researchers have identified deficits in the involved limb after ACLR. Single-legged hop for distance and knee-flexor peak torque were reduced when compared with the contralateral limb.[12] These variables are generally reported as a Limb Symmetry Index (LSI; [involved limb/uninvolved limb] × 100), and ≥85% LSI is recommended after ACLR.[13] Wilk et al[14] reported that an LSI <85% was exhibited by 47%, 26%, and 44% of participants, respectively, on the single-legged hop-for-distance, single-legged–timed hop, and single-legged–crossover hop tests.[14] Furthermore, depending on the speed of the isokinetic test, 21% to 63% of participants demonstrated quadriceps strength of <80% LSI when tested 6 months after ACLR.[14] The authors[14] identified positive correlations among knee-extensor peak torque, self-reported knee rating, and the 3 single-legged–hop tests. Across the literature,[9,12,14–17] it is clear that deficits in both strength and functional performance are not uncommon, even years after ACLR.

Strength, functional performance, and self-reported knee function have been studied independently to identify whether any aspects differed between athletes who had and those who had not returned to sport after ACLR. Ardern et al[18] reported that, at 1 year after ACLR, athletes with a normal LSI on 4 single-legged–hop tests were more likely to return to competitive sport than those with an LSI <85%. In addition, knee-joint effusion, episodes of knee instability, and scores on the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form have been strongly associated with RTS status.[9] However, Gobbi and Francisco[19] found no differences using self-report measures, specifically the IKDC, Lysholm, Noyes, and Tegner Activity Scale knee-evaluation scales, when comparing athletes who RTS at their preinjury level of participation with those who RTS at a lower level of participation. As stated, various measures of function after ACLR have been explored; however, few researchers have specifically compared RTS with NRTS athletes after ACLR. Furthermore, dynamic balance, dynamic functional performance, strength, and muscular endurance have not been evaluated between these groups concurrently in a single study. Therefore, the purpose of our investigation was to document and compare multidimensional functional performance outcomes and compare self-reported outcomes between RTS and NRTS athletes a minimum of 1 year after ACLR. The following functional tests were used to measure dynamic balance, dynamic functional performance, strength, and muscular endurance, respectively: Star Excursion Balance Test (SEBT), 3 single-legged hop tests, isokinetic knee-flexor and knee-extensor strength, and a novel step-down-to-fatigue test. We hypothesized that the RTS athletes would demonstrate superior physical performance compared with the NRTS athletes. Specifically, the RTS group would demonstrate greater LSI on the SEBT, single-legged–hop test, quadriceps isokinetic test, and the step-down-to-fatigue test than the NRTS group. We also hypothesized that athletes in the RTS group would report higher self-reported functional outcome scores than those in the NRTS group.

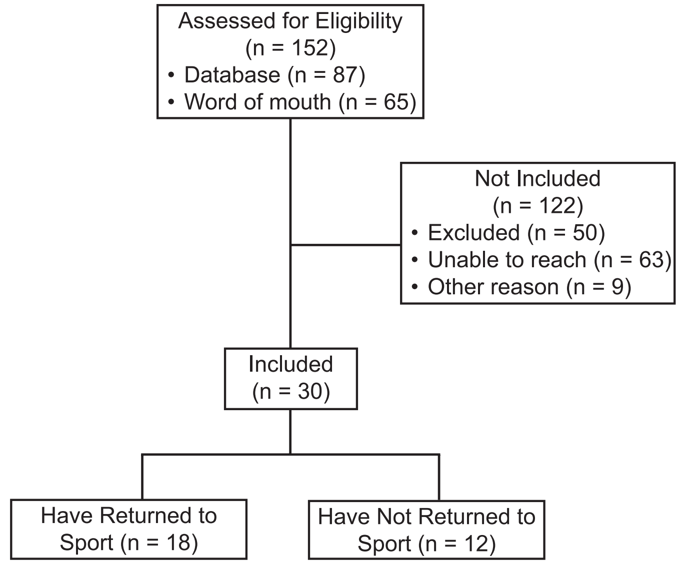

Figure 1. Participation recruitment diagram.

METHODS

Participants

Participants were primarily recruited between May 2013 and March 2015 from a preexisting patient-outcomes registry (University of Kentucky Cartilage and Ligament Patient Registry, established August 2007). Only those who had previously agreed to be contacted for future research were approached. Participants were also recruited via word of mouth and flyers placed in the campus community. Individuals identified as potential participants were contacted by telephone. After participants provided oral consent, they were screened for study eligibility and surveyed regarding their sport participation before and after the ACL injury (Figure 1).

Inclusion criteria were a minimum of 1 year since primary ACLR, 12 to 60 years of age, self-reported preinjury Tegner Activity Score[20] of 5 or greater, and preinjury self-reported activity level of "well trained, frequently participating in high-level competitive sports" or higher.[21] Exclusion criteria were a posterior cruciate ligament tear, any history of previous surgery to or injury of the contralateral lower extremity in the 6 months before the

Table 1. Sport-Participation Frequency by Group[a]

Sport	Group		
	Returned to Sport (n = 18)		Not Returned to Sport (n = 12)
	No. Participating Before ACLR	No. Participating After ACLR	No. Participating Before ACLR
Baseball	1	1	2
Basketball	4	4	4
Cheerleading	1	1	0
Cycling	1	1	1
Diving	0	0	1
Field hockey	1	0	0
Football	2	0	3
Golf	1	1	0
Gymnastics	0	0	1
Lacrosse	2	2	0
Racquetball	1	1	0
Rugby	1	1	0
Skiing	1	1	0
Soccer	9	8	4
Softball	0	0	2
Tennis	1	0	3
Ultimate	1	1	0
Volleyball	2	0	1
Water polo	0	1	0

Abbreviation: ACLR, anterior cruciate ligament reconstruction.

[a] Some athletes participated in multiple sports; therefore, the sport frequency is higher than the number of participants. In addition, some athletes in the returned-to-sport-participation group were active in multiple sports and may not have returned to participation in all sports after ACLR.

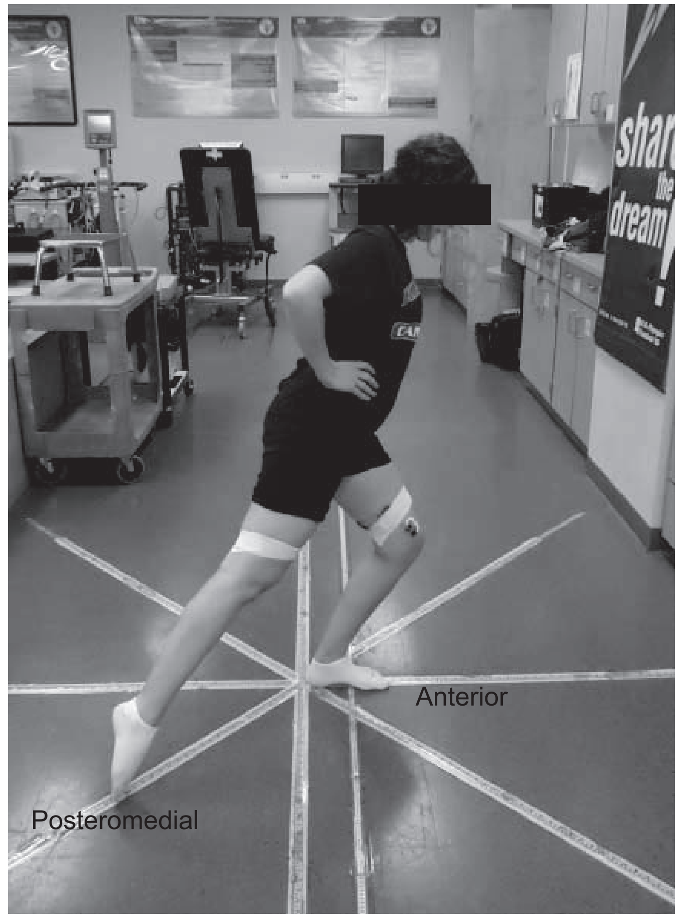

Figure 2. Star Excursion Balance Test of the left limb.

study, ACLR revision, fracture, or knee dislocation. For inclusion in the RTS group, athletes were required to have returned to at least 1 of the cutting or landing sports in which they were participating before the ACL injury. Athletes who changed to a noncutting sport, such as running, were not considered to have RTS (Table 1). Return-to-sport status was verified via participant interviews.

Overall, 30 participants who had a history of primary unilateral ACLR completed the study. The RTS group comprised 18 individuals (7 males, 11 females; age = 23 ± 11 years, height = 163.58 ± 40.41 cm, mass = 70.00 ± 21.75 kg), and the NRTS group comprised 12 individuals (5 males, 7 females; age = 26 ± 13 years, height = 171.33 ± 48.24 cm, mass = 72.00 ± 21.81 kg). Leg dominance was determined by asking the participants which limb they would have preferred to use for kicking a ball before their ACL injury. All participants provided written informed consent, and the study was approved by the University of Kentucky Institutional Review Board.

Testing Procedures

For this case-control study, eligible participants reported to the University of Kentucky laboratory for 1 testing session that lasted approximately 2 hours. All testing was completed by the primary author (J.L.W.), a certified athletic trainer who was not involved in any of the treatment or rehabilitation of the participants. Before testing, participants completed the following patient-reported outcomes (PROs) measures: Tegner Activity Scale,[20] Work and Sports Activity portions of the Cartilage Injury Standard Evaluation Form-2000,[21] IKDC,[22] Marx Activity Scale,[23] and the Knee Injury and Osteoarthritis Outcome Score (KOOS).[24] The testing session began with a 5-minute warm-up on a stationary bicycle (model 818; Monarch Exercise, Vansbro, Sweden). To ensure minimal fatigue and muscle soreness throughout the study, the order of tests was standardized for all participants, and participants were given a 3-minute rest between tests. Each test was performed on the uninvolved side and repeated on the involved side except for the step-down-to-fatigue test. For this test, the initial testing limb was counterbalanced to control for potential fatigue of the hip or core musculature, which might affect performance of the second limb tested. Participants were given directions and ample time to practice each test before their performance was measured.

Star Excursion Balance Test. Dynamic balance was evaluated using the SEBT.[25,26] We modified the grid from the original SEBT, using only the anterior and posteromedial lines at 0° and 135° (Figure 2), to minimize testing time based on previous results[26,27] and pilot data from our laboratory that demonstrated a large correlation between these directions and those not tested. Participants stood in the middle of the grid, which was marked with a 100-cm tape measure, with the great toe of the stance limb at 0° for the anterior reach and the heel of the stance limb at 0° for the posteromedial reach (Figure 2).[27] While maintaining stable single-legged balance, participants were instructed to reach as far as possible with their nonstance limb along each of the 2 lines, lightly touch the line, and return to the center of the grid.[25–27] They were instructed to keep their hands on their hips to standardize movements other than those of the trunk and limbs.[25–27] We took measurements from the most distal aspect of the reach limb's toes. Participants were given 4 practice trials and performed 3 test trials.[28] They began with the anterior-reach direction for both limbs and progressed to the posteromedial-reach direction. A trial was repeated if the investigator believed the participant shifted weight onto the reach limb, removed hands from the waist, or touched down off the grid.[27] The average of the 3 reach distances in each direction was normalized to limb length, which was measured from the anterior-superior iliac spine to the medial malleolus, and recorded as a percentage of limb length.[27]

Battery of Single-Legged–Hop Tests. Dynamic functional performance was evaluated using a battery of 3 single-legged–hop tests[29–31]: the single-legged hop for distance, the crossover hop for distance, and the 6-m timed hop. Each test was performed 3 times, with a 10-second recovery between trials. Participants were instructed that a *successful trial* included a stable landing on the test limb and holding the position for 3 seconds. The trial was repeated if the participant landed with early touchdown of the contralateral limb, lost balance, touched the surrounding area, or included additional hops after landing.[29,30] Participants were given ample time to practice each task, and testing was not performed until they reported and demonstrated understanding of each task.

For the single-legged hop-for-distance test, participants stood on 1 limb and jumped as far forward as possible, landing on the same limb. For the crossover hop-for-distance test, participants stood on 1 limb and hopped on 1 limb as far forward as possible 3 consecutive times while crossing over a 6-cm–wide strip on the floor with each hop. We recorded the total distance hopped, as measured from the starting line to the point of heel contact. For the 6-m timed-hop test, participants stood on 1 limb and were instructed to hop as fast as possible over the marked distance of 6 m. The time was recorded using a stopwatch, beginning when the heel left the floor and ending when participants passed 6 m.

Isokinetic Strength. Muscle strength was evaluated using an isokinetic dynamometer (model Cybex II; Lumex, Inc, Ronkonkoma, NY). The dynamometer arm was set to move from 90° of flexion to 10° of extension at speeds of 60°/s and 180°/s.[9,14,19,32] Participants were seated with the seat angle set at 85°, the knee axis of rotation aligned with the dynamometer shaft, and the lower edge of the resistance pad placed just superior to the medial malleolus.[32] The limb and hip were secured with stabilization straps at the thigh and calf. Participants performed 5 practice trials, rested for 1 minute, and then performed 5 maximal-effort trials at 60°/s and 8 maximal-effort trials at 180°/s. Concentric and eccentric knee-extensor and knee-flexor peak torque for each side for all trials was recorded.

Step-Down-to-Fatigue Test. We used a novel step-down-to-fatigue test to evaluate muscular endurance. The participants performed a step down from a platform 2- to 8-in (5.08- to 20.32-cm) high. The rate of movement was normalized using a metronome (model QT3 Quartz Metronome; Qwik Tune, Evets Corporation, Camarillo, CA) set to 75 beats/min. The platform height was standardized so that the support limb reached 60° of knee flexion when the heel of the contralateral limb touched. We determined the test rate and knee-flexion angle through pilot testing to ensure that the test was both challenging and feasible for the intended population. One repetition consisted of the down-limb heel making contact with the floor within 1 beat and returning to platform level within another beat. Participants were instructed that contact with the floor should only be a brush and not used to accelerate back onto the step and that hands must remain on the hips. Repetitions were counted until fatigue occurred. We defined *fatigue* as the point at which the participant missed 3 consecutive repetitions or the investigator noticed the step-down limb was used to propel the participant up 3 consecutive times despite oral coaching. Given that this test was to fatigue, only 1 trial per limb was completed. This test has been observed to be reliable (intraclass correlation coefficient = 0.87).[33]

Statistical Analysis

The mean performance values for the SEBT and battery of single-legged–hop tests, total repetitions, and peak torque for the involved and uninvolved limb were used to calculate the LSI (LSI = [involved/uninvolved] × 100) of these measures for each participant.[13,34] An LSI of ≥85% has been widely considered a clinical criterion for return to sport participation.[13,29,30,34] Descriptive statistics were generated for all performance and PRO variables. Given the non-normal distribution of measures (particularly PROs), we used the Mann-Whitney *U* tests to assess between-groups differences on PRO scores and LSI values for functional performance tests. An exploratory α level of ≤.10 was used to evaluate the results. The consequences associated with a type I error (ie, finding differences between groups where no true differences exist) in this study were minimal, and researchers[15,16,35–37] have demonstrated considerable variability among patients after ACLR for both performance and PRO measures, potentially limiting the statistical power or feasibility of this study. Therefore, we determined that a 10% chance of a type I error was acceptable for this initial study given that the final results would be discussed in the context of clinically meaningful differences (ie, LSI >85% and minimally clinically important differences [MCIDs] for PROs) between groups and the results of this study may support larger prospective investigations in the future. Study data were collected and managed using REDCap electronic data-capture tools hosted at the University of Kentucky. A secure, Web-based application, REDCap (Research Electronic Data Capture) is designed to support data capture for research studies.[38] All data analyses were performed using SPSS (version 20.0; IBM Corp, Armonk, NY).

RESULTS

All participants underwent ACLR in a similar fashion (Table 2). The mean time since surgery was 4.02 ± 3.20 years for the RTS group and 3.68 ± 2.71 years for the NRTS group (Table 2). No between-groups differences were observed preinjury for the Tegner Activity Scale ($P >$ .99) and Marx Activity Scale ($P = .66$) scores. However, the Tegner Activity Scale ($P = .02$) and Marx Activity Scale ($P = .005$) scores revealed between-groups differences for level of sport participation at the time of the study (Table

Table 2. Participants' Characteristics

Characteristic	Group		
	Returned to Sport (n = 18)	Not Returned to Sport (n = 12)	*P* Value
Time since surgery, y (mean ± SD)	4.02 ± 3.20	3.68 ± 2.71	.77
Dominant limb, No. (%)			
Right	15 (83)	9 (75)	
Left	3 (17)	3 (25)	
Concomitant surgery or injuries, No. (%)			
Meniscus repair	7 (39)	5 (42)	
Partial meniscectomy	1 (6)	1 (8)	
Medial collateral ligament	5 (28)	1 (8)	
Lateral collateral ligament	0 (0)	1 (8)	
Autograft, No. (%)			
Hamstrings	6 (33)	1 (8)	
Quadriceps tendon	1 (6)	0 (0)	
Ipsilateral patellar tendon	9 (50)	9 (75)	
Unknown	1 (6)	1 (8)	
Allograft	1 (6)	1 (8)	
Tegner Activity Scale score, median (range)			
Preinjury	8 (5–9)	8 (5–10)	>.99
Time of study	7 (5–9)	6 (4–8)	.02
Marx Activity Scale score, median (range)			
Preinjury	16 (0–16)	16 (12–16)	.66
Time of study	12 (6–16)	8 (1–13)	.005

2). Whereas most participants returned to some level of sport participation after ACLR, not all reported that they had returned to their preinjury level or higher. Among those in the RTS group, self-perceived sport-activity level based on the Cartilage Injury Standard Evaluation Form-2000 questionnaire showed that 33% (n = 6) indicated returning at a higher level of sport participation, 50% (n = 9) indicated returning at the same level, and 17% (n = 3) indicated returning at a lower level after ACLR. By comparison, 0% (n = 0) of the NRTS group reported returning at a higher level of sport participation, 17% (n = 2) reported returning at the same level, and 83% (n = 10) reported returning at a lower level after ACLR. As stated in the "Methods" section, athletes who returned to noncutting sports but did not return to the cutting or pivoting sports in which they participated before injury were considered to have not returned. The 2 participants in the NRTS group who reported having returned to the same level of sports as before injury both also marked that they had not returned. It is possible that these athletes considered participating in an activity, such as running or biking, to be returning to the same level of activity but not returning to sport participation.

Multidimensional Functional Outcomes

For the SEBT, no differences between groups were observed for either the anterior ($U = 106.0$, $P = .95$) or posteromedial ($U = 78.0$, $P = .22$) reach direction (Table 3, Figure 3). We noted no differences between groups for the battery of single-legged–hop tests: single-legged hop for distance ($U = 101.0$, $P = .79$), crossover hop for distance ($U = 94.0$, $P = .57$), and 6-m timed hop ($U = 97.0$, $P = .66$; Table 3). For both groups, median LSI values on all single-legged–hop tests were >85%. No differences were evident for the concentric or eccentric phases of knee-extensor or knee-flexor strength at 60°/s and 180°/s (Table 3, Figure 4). However, for both groups, the median peak torque LSI was <85% for eccentric knee-flexor and concentric knee-flexor strength at 60°/s. Median peak torque LSIs <85% were identified for concentric and eccentric knee-extensor strength at 60°/s and 180°/s. We found no between-groups difference for LSI on the novel step-down-to-fatigue test ($U = 104.0$, $P = .88$), and the median LSI for repetitions exceeded 85% for both groups.

Table 3. Multidimensional Functional Outcome Results of Percentage Limb Symmetry Index (Median [Range])

Measure	Group		
	Returned to Sport (n = 18)	Not Returned to Sport (n = 12)	*P* Value
Star Excursion Balance Test			
Anterior reach direction	100 (89–136)	99 (89–111)	.95
Posteromedial reach direction	100 (92–140)	96 (87–105)	.22
Hop test			
Single-legged hop for distance	98 (60–109)	97 (63–121)	.79
Cross-over hop for distance	95 (55–110)	96 (65–130)	.57
6-m timed hop	96 (61–113)	93 (74–121)	.66
Peak quadriceps torque			
60°/s concentric	83 (44–143)	101 (69–113)	.11
60°/s eccentric	88 (34–119)	84 (54–126)	.88
180°/s concentric	86 (26–129)	80 (51–139)	.81
180°/s eccentric	75 (26–180)	87 (64–109)	.58
Peak hamstrings torque			
60°/s concentric	81 (56–108)	76 (59–196)	.71
60°/s eccentric	82 (56–124)	79 (64–179)	.98
180°/s concentric	86 (59–143)	92 (67–160)	.61
180°/s eccentric	85 (65–118)	91 (65–175)	.47
Step-down-to-fatigue test	93 (9–141)	87 (64–120)	.88

Self-Reported Outcomes

Between-groups differences existed on the IKDC ($U = 57.5$, $P = .03$), with the NRTS group (median = 82.76; range = 63.22–96.55) demonstrating lower scores than the RTS group (median = 92.52; range = 66.67–97.70; Table 4). We observed group differences on the KOOS Symptoms subscale between the RTS (median = 88, range = 54–100) and NRTS (median = 71, range = 54–100; $U = 66.0$, $P = .08$) groups. No differences were present for the KOOS Pain ($U = 103.5$, $P = .85$), Activities of Daily Living ($U = 86.0$, $P = .37$), Sport ($U = 89.0$, $P = .44$), or Quality of Life ($U = 82.0$, $P = .29$; Table 4, Figure 5) subscales.

DISCUSSION

The purpose of our study was to compare and document multidimensional functional performance outcomes and compare self-reported outcomes between RTS and NRTS athletes a minimum of 1 year after ACLR. We hypothesized that participants in the RTS group would display superior functional performance compared with those in the NRTS group. We also hypothesized that the RTS group would demonstrate higher self-reported function than the NRTS group. Overall, our results did not support our hypotheses regarding differences in functional performance

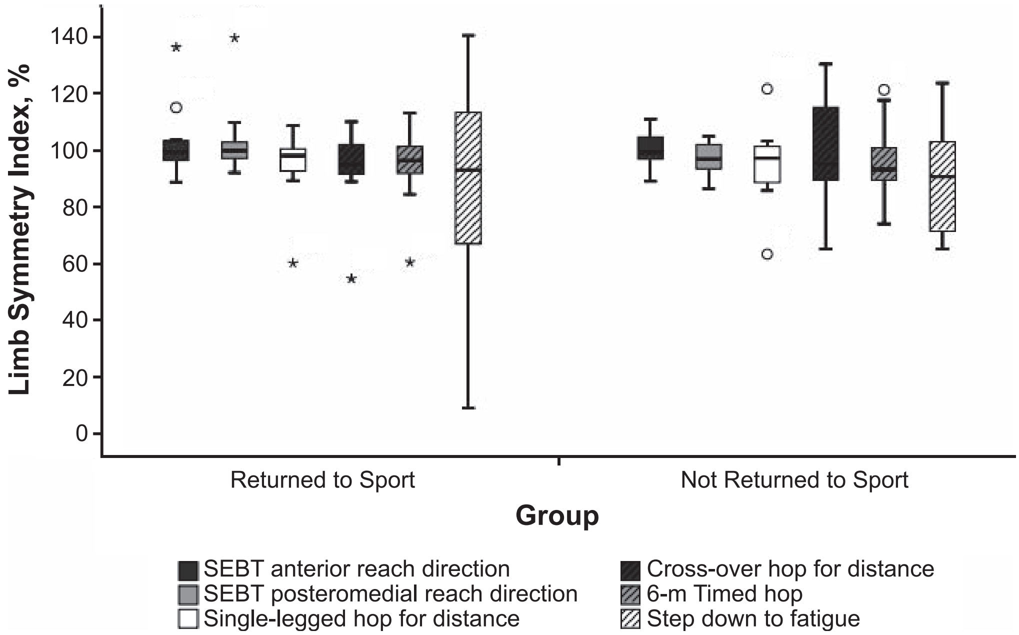

Figure 3. Multidimensional functional outcome results of percentage of Limb Symmetry Index (median ± interquartile range [IQR]). The box whiskers represent 1.5× the IQR or the maximum or minimum values observed, based on whichever is less. The circles represent outliers (values beyond the box whiskers). The asterisks represent extreme outliers (values beyond the box ends by 3× IQR). Abbreviation: SEBT, Star Excursion Balance Test.

between groups. We noted mixed results for self-reported function with differences between groups on the IKDC and KOOS Symptoms subscale; however, no differences were identified on the other KOOS subscales. The Tegner Activity Scale and Marx Activity Scale scores confirmed similar preinjury activity levels between groups and greater activity levels at the time of the study in the RTS than in the NRTS group.

Functional Performance Testing

We found no differences between groups for any of the functional performance tests conducted. Furthermore, except for isokinetic strength testing, median LSIs for all tests exceeded 85%, and only the LSI for the step-down-to-fatigue test in the NRTS group was <90%. These results are similar to other findings for restoration of physical performance capacity in the first year after ACLR.

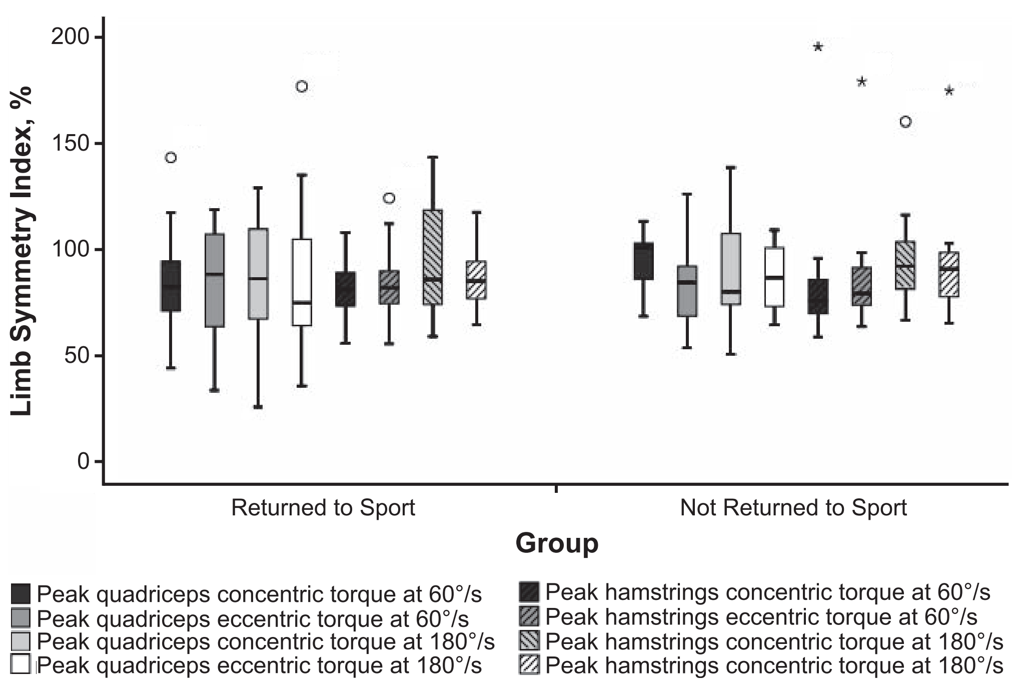

Figure 4. Continued multidimensional functional outcome results of percentage of Limb Symmetry Index (median ± interquartile range [IQR]). The box whiskers represent 1.5× the IQR or the maximum or minimum values observed, based on whichever is less. The circles represent outliers (values beyond the box whiskers). The asterisks represent extreme outliers (values beyond the box ends by 3× IQR).

Table 4. Self-Reported Outcome Results

Measure	Group (Median [Range]) Returned to Sport (n = 18)	Not Returned to Sport (n = 12)	P Value
International Knee Documentation Committee Subjective Knee Evaluation Form score	92.52 (66.67–97.70)	82.76 (63.22–96.55)	.03
Knee Injury and Osteoarthritis Outcome Score subscale score			
Pain	89 (36–100)	97 (54–100)	.85
Symptoms	88 (54–100)	71 (54–100)	.08
Activities of Daily Living	100 (94–100)	100 (94–100)	.37
Sport	90 (75–100)	90 (70–100)	.44
Quality of Life	88 (63–100)	75 (44–100)	.29

Specifically, using a variety of testing methods, such as proprioception,[39–41] balance,[40–42] overall joint position sense,[12,40,41,43] and hopping performance,[14,37] researchers have observed restoration of physical performance capacity to values similar to those of the uninvolved limb at an average of 8 to 12 months after ACLR.[37] Our participants' results at an average of 4 years after ACLR were consistent with the previous literature, as no between-groups differences were observed. Functional capacity, as evaluated by the SEBT, hop testing, and step-down-to-fatigue test, did not appear to influence or be affected by an individual's RTS status after ACLR. These quantitative findings support the qualitative findings presented in Part I[44] of this study, suggesting that personal factors may play a greater role than physical ability in an athlete's decision to return to sport.

Sport-specific training is more demanding than performing a single-legged hop test. In our study, the single-legged–hop test did not identify meaningful deficits in dynamic functional performance across groups. However, throughout the testing process, participants reported being apprehensive or having "less confidence" in their involved limb, regardless of whether this battery of tests was used throughout their rehabilitation. Specifically, we informally observed that participants demonstrated the most oral and physical hesitancy with the crossover hop-for-distance test, as it involves both forward and side-to-side movements. This hesitancy may be a clinical expression of the theme of *hesitation and lack of confidence led to self-limiting tendencies* identified during the qualitative portion of this investigation.[44] Whereas the dynamic functional performance values exceeded the normal limb symmetry considered acceptable for sport activity, the hesitancy expressed by participants may support the continued use of single-legged–hop assessments during late-stage rehabilitation to regain patient confidence and facilitate the transition to return to sport.

We included a novel muscle-endurance step-down-to-fatigue test in this study to explore the relationship between muscular endurance and a history of having RTS. This test did not identify any differences in limb symmetry for repetitions between groups. Most participants in both groups demonstrated performance values around 85% LSI, with participants reaching fatigue at an average of 2 minutes and 30 seconds of testing. However, as shown in

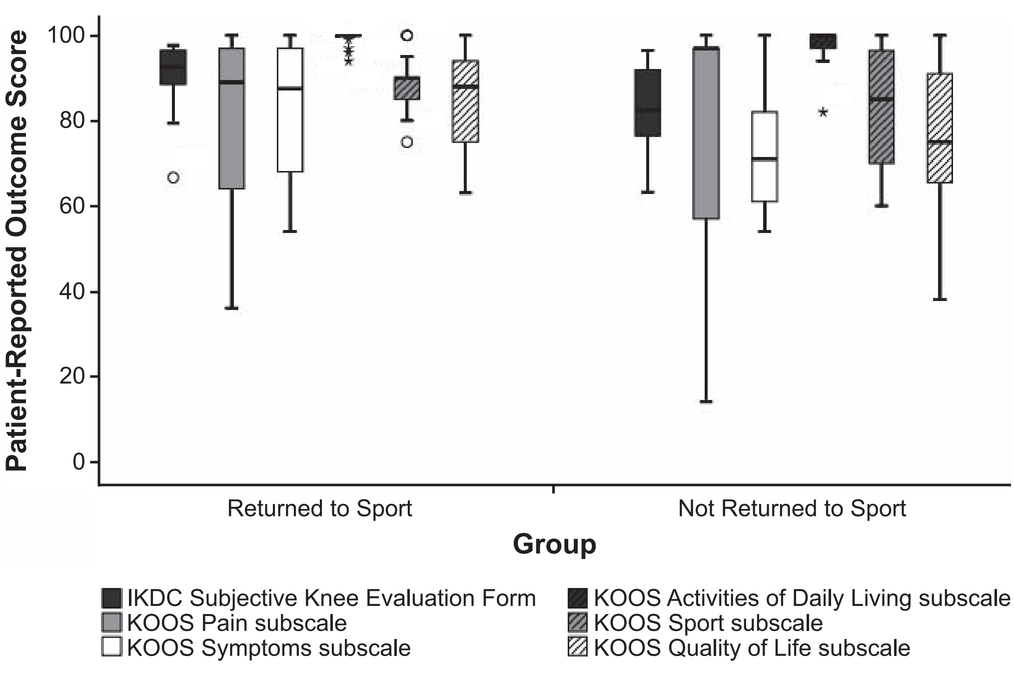

Figure 5. Self-reported outcome results (median ± interquartile range [IQR]). The box whiskers represent 1.5× the IQR or the maximum or minimum values observed based on whichever is less. The circles represent outliers (values beyond the box whiskers). The asterisks represent extreme outliers (values beyond the box ends by 3× IQR). Abbreviations: IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score.

Figure 3, greater variability was observed for this test than for the other functional performance measures. This variability suggests that tests of muscular endurance may be relevant at the individual patient level and may represent a component of function not addressed in the other tests.

Clinical measures of strength, particularly isokinetic strength, are commonly used after ACLR to evaluate strength and help determine limb symmetry.[14,45] Often, these strength measurements help the clinician decide if an individual is physically prepared to begin a gradual RTS participation. Noyes et al[13] suggested that individuals should obtain ≥85% LSI after ACLR. We observed no isokinetic strength differences between the RTS and NRTS groups. However, on 6 different testing measures, at least 1 group demonstrated strength deficits less than the recommended LSI of 85%, indicating that, regardless of RTS status, lower extremity strength deficits were still present at an average of 4 years after ACLR. Researchers[37,46,47] have reported varying results regarding muscle-strength deficits after ACLR, with some demonstrating successful strength recovery and others finding long-term deficits. This variability in the results may reflect variations in study populations, surgical techniques, rehabilitation protocols, and testing protocols. The variability in strength measures that we observed combined with the mixed results for strength recovery in the literature suggest that the recovery of quadriceps and hamstrings strength cannot be assumed and should be evaluated postoperatively.[37,46,47]

Based on our findings of functional performance outcomes after ACLR, the isokinetic strength measures provided information regarding quadriceps and hamstrings strength deficits that persisted 4 years after ACLR. Unlike the SEBT, the battery of single-legged–hop tests, or the step-down-to-fatigue test, isokinetic testing can isolate and test 1 or more specific muscle groups. It is possible that the dynamic balance and dynamic functional performance tests were not specific enough in targeting these strength deficits, as other muscle groups and the kinetic chain may have compensated for chronic deficits. Furthermore, strength deficits were identified in both groups 4 years after ACLR, regardless of the level or type of sport participation. Despite normal dynamic functional performance, the potential risk for further injury and long-term problems secondary to these ongoing strength deficits remains unclear.

Self-Reported Outcomes

The PROs used in this study have been established as valid and reliable measures of symptoms,[24,48–50] function,[20,24,49] or activity levels[20,24,49] in people with knee disorders and are useful for monitoring overall knee improvement beginning with preoperative status.[19,23,49,51] Within our sample, few between-groups differences were identified for the PROs. However, clinically meaningful differences were observed. Based on the Tegner Activity Scale and Marx Activity Scale scores, both groups reported similar preinjury levels of sport participation (Table 2). Furthermore, the Tegner Activity Scale and Marx Activity Scale scores validated the difference between groups for level of sport participation at the time of the study (Table 2).

Our hypothesis that the RTS group would report higher function on the IKDC was supported (RTS: median = 92.52, range = 66.67–97.70; NRTS: median = 82.76, range = 63.22–96.55; $P = .03$). These results are in agreement with comparisons of IKDC scores between those who returned to their preinjury level of sport participation and those who had NRTS participation at 1 year after ACLR (RTS = 93.8 ± 6.3; NRTS = 78.0 ± 15.6; $P < .001$).[9] The IKDC values that we observed were similar to previously reported[29] IKDC scores at 6 months (83.0 ± 12.9) and 1 year after ACLR (90.8 ± 11.1), suggesting that IKDC scores after primary ACLR may not change substantially beyond the first year. Based on our study, at an average of 4 years after ACLR, the evaluation of function and symptoms during sport participation and daily activities via the IKDC identified more functional limitations and symptoms in those who had not returned to sport than in those who had returned.

Overall, when looking at simple medians between the groups, the NRTS group reported lower scores on 2 of the 5 KOOS subscales (Symptoms and Quality of Life), whereas the RTS group demonstrated lower scores than the NRTS group on the KOOS Pain subscale. Large observed variances among both groups for the KOOS Quality of Life and Pain subscale scores likely limited the ability to identify differences between groups. However, the noted differences met or exceeded the proposed MCID of 8 to 10 points for the KOOS subscales,[52] suggesting that, in addition to experiencing a greater level of signs and symptoms related to knee injury, the NRTS group experienced a decreased knee-related quality of life and the RTS group may have experienced more clinically meaningful pain. Based on previously established criteria for the KOOS,[53] 22% (n = 4) of the RTS group and 50% (n = 6) of the NRTS group would be categorized as having a symptomatic knee at an average of 4 years after ACLR because of their Pain, Symptoms, Sport, and Quality of Life subscale scores. These findings further support the possibility that PROs may be able to detect ongoing symptoms affecting patients' wellbeing that cannot be fully detected using traditional functional test batteries.

Whereas it cannot be determined from our study, these clinically meaningful symptoms may be an early indicator of posttraumatic osteoarthritis in some patients.[54,55] Similarly, the lower pain scores in the RTS group call into question whether continued sport participation at the preinjury level is ideal for the long-term knee health of these individuals. Among both groups, it is apparent that numerous participants perceived they were experiencing suboptimal knee health despite a relatively high level of functional capacity as demonstrated by performance testing. Based on the responses to the PROs and the qualitative portion of this study,[44] patients appeared to experience subjective functional changes, heightened awareness, changing expectations and assumptions, and a general "coming to terms" with their ACL injuries. This overall process may result in individuals defining a "new normal" for knee function. For many patients, this new normal seems to involve changes in symptoms, activity, and pain. Therapeutic interventions, such as bracing, physical rehabilitation,[17,56,57] activity modification, psychological counseling (to address fear of reinjury or lack of self-efficacy of knee function),[58–60] or biologic or pharmacologic therapies[61,62] could potentially improve the quality of life for these patients by reducing pain and symptoms related to their knees.[36,63–68] However, it is not unusual or inappropriate for patients to be told that their knee will never be the same after ACLR, and therefore, patients who experience symptoms may be unlikely to seek treatment and instead resign themselves to altering their activity levels or living with the status quo. Furthermore, in the absence of evaluation by PROs, it appears unlikely that treatment would be offered to these patients given their normal functional capacity shown on many of the standard performance-based outcomes. Regardless of return-to-sport status, if only traditional disease- and performance-based measures of knee function and their associated criteria are used to assess patients, these ongoing symptoms could be missed, resulting in a lost opportunity to intervene and improve the patient's quality of life.

Strengths and Limitations

To our knowledge, our study is one of the first to compare multidimensional functional performance and self-reported outcomes based on return-to-sport status after ACLR. Capturing the participants' dynamic balance, dynamic functional performance, strength, and muscular endurance when they were deciding whether to return to sport participation may provide the best evidence for the influence of functional differences on decision making. Given the limitations of time and budget, we did not conduct a prospective, longitudinal study. However, our case-comparison study does suggest that, at midterm follow-up, physical performance capabilities did not differ between those who had RTS and those who had NRTS.

One year is generally considered an appropriate time to predict return-to-sport status after ACLR.[9] Other investigators[37] have identified 5 to 7 months as more timely for identifying differences, when participants may be released from formal rehabilitation. Researchers should validate the multidimensional functional performance and self-reported outcome measures via a longitudinal study that follows patients through rehabilitation to the time when return-to-sport participation is decided. This would allow clinicians to properly identify any deficits in functional performance or self-perceived function that are affecting or influencing the decision to return. Strategies to correct those deficits, particularly as related to self-perceived function, also warrant further research.

Whereas participant recruitment was mostly accomplished using a previously established registry from 3 sports medicine fellowship-trained orthopaedic surgeons, and distributions of graft type and concomitant injuries were similar between groups (Table 2), we could not completely control for these differences or differences in rehabilitation protocols. Similarly, we concede that larger sample sizes may have enabled us to identify more statistical differences between groups; however, because we used established LSI and MCID values, these differences would not have changed the clinical interpretation or meaningfulness of our results. Finally, the NRTS group may have been biased, as participants were aware of the study procedures and expectations, specifically that they would be expected to jump and land, before consenting to join the study. This may have resulted in athletes with more severe deficits in physical function declining to participate. However, only 1 potential participant cited hesitancy related to the physical demands of the testing as the reason for declining to volunteer.

CONCLUSIONS

Our results support the growing body of literature demonstrating that the decision to return to sport participation may be influenced less by the physical capacity to perform sport-related tasks than by other more personal factors, such as changes in priorities or expectations, occupational demands, loss of motivation or interest, perception of self-efficacy, change in competition level, patient age, individual talent, or fear of reinjury.[10,11,19,36,58,59,63,64] In fact, many of these personal factors were discussed by participants in the qualitative portion of this study.[44] The lack of statistically or clinically meaningful differences between groups for numerous functional and strength tests further suggests that ongoing physical function was not influenced by the decision to return or not return to sport after ACLR. However, based on the IKDC and KOOS scores, patients who had returned to sport appeared to subjectively consider themselves to have a higher level of knee function than those who had not returned. These PRO instruments detected functional deficits in both groups that were not otherwise apparent, underscoring the importance of using a multidimensional approach to evaluate patient progress and outcomes.

The overall findings of this 2-part, mixed-methods study underscore the importance of practicing patient-centered care at both the patient and population level. Whereas a cause-and-effect link cannot be determined from our study, the decision to return or not return to sport participation may be limited to factors other than functional performance capacity; furthermore, this decision does not appear to result in increased differences in functional performance over time. At the population level, it may not be appropriate to evaluate the success of ACLR treatment based on return-to-sport status, as it is now apparent that returning to the same level of performance may not be the goal for many patients after ACLR, even when they have the physical capacity to do so. On the patient level, clinicians need to monitor not only the changes in a patient's physical ability and condition but also the patient's perception of function; access to a support network; self-efficacy; and changing priorities, expectations, and goals. Using a biopsychosocial strategy is recommended to treat and evaluate patients to address both objective and subjective deficits so that health-related quality of life can be optimized.

ACKNOWLEDGMENTS

The study was supported by the National Athletic Trainers' Association, District 2 Research Endowment (J.L.W. and J.P.B.). In addition, we used services supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through Grant No. UL1TR000117 (The University of Kentucky Center for Clinical and Translational Science). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or the National Athletic Trainers' Association Research & Education Foundation.

REFERENCES

1. McCullough KA, Phelps KD, Spindler KP, et al. Return to high school- and college-level football after anterior cruciate ligament reconstruction: a Multicenter Orthopaedic Outcomes Network (MOON) cohort study. *Am J Sports Med*. 2012;42(3):2523–2529.

2. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train*. 2007;42(2):311–319.
3. Hewett TE, Di Stasi SL, Myer GD. Current concepts for injury prevention in athletes after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2012;41(1):216–224.
4. Myklebust G, Bahr R. Return to play guidelines after anterior cruciate ligament surgery. *Br J Sports Med*. 2005;39(3):127–131.
5. 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.
6. Ardern CL, Taylor NF, Feller JA, Whitehead TS, Webster KE. Sports participation 2 years after anterior cruciate ligament reconstruction in athletes who had not returned to sport at 1 year: a prospective follow-up of physical function and psychological factors in 122 athletes. *Am J Sports Med*. 2015;43(4):848–856.
7. 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.
8. Ardern CL, Taylor NF, Feller JA, Whitehead TS, Webster KE. Psychological responses matter in returning to preinjury level of sport after anterior cruciate ligament reconstruction surgery. *Am J Sports Med*. 2013;41(7):1549–1558.
9. Lentz TA, Zeppieri G Jr, 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.
10. Ardern CL, Taylor NF, Feller JA, Webster KE. Return-to-sport outcomes at 2 to 7 years after anterior cruciate ligament reconstruction surgery. *Am J Sports Med*. 2012;40(1):41–48.
11. Daruwalla JH, Greis PE, Hancock R, ASP Collaborative Group, Xerogeanes JW. Rates and determinants of return to play after anterior cruciate ligament reconstruction in NCAA Division 1 college football athletes: a study of the ACC, SEC, and PAC-12 Conferences. *Orthop J Sports Med*. 2014;2(8):2325967114543901.
12. Mattacola CG, Perrin DH, Gansneder BM, Gieck JH, Saliba EN, McCue FC III. Strength, functional outcome, and postural stability after anterior cruciate ligament reconstruction. *J Athl Train*. 2002; 37(3):262–268.
13. Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *Am J Sports Med*. 1991;19(5):513–518.
14. Wilk KE, Romaniello WT, Soscia SM, Arrigo CA, Andrews JR. The relationship between subjective knee scores, isokinetic testing, and functional testing in the ACL-reconstructed knee. *J Orthop Sports Phys Ther*. 1994;20(2):60–73.
15. Thomeé R, Neeter C, Gustavsson A, et al. Variability in leg muscle power and hop performance after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(6): 1143–1151.
16. Thomeé R, Petersen CL, Carlsson L, Karlsson J. Return to sports after anterior cruciate ligament reconstruction in women. *Sports Orthop Traumatol*. 2013;29(1):22–28.
17. Della Villa S, Boldrini L, Ricci M, et al. Clinical outcomes and return-to-sports participation of 50 soccer players after anterior cruciate ligament reconstruction through a sport-specific rehabilitation protocol. *Sports Health*. 2012;4(1):17–24.
18. Ardern CL, Webster KE, Taylor NF, Feller JA. Return to the preinjury level of competitive sport after anterior cruciate ligament reconstruction surgery: two-thirds of patients have not returned by 12 months after surgery. *Am J Sports Med*. 2011;39(3):538–543.
19. Gobbi A, Francisco R. Factors affecting return to sports after anterior cruciate ligament reconstruction with patellar tendon and hamstring graft: a prospective clinical investigation. *Knee Surg Sports Traumatol Arthrosc*. 2006;14(10):1021–1028.
20. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res*. 1985;198:43–49.
21. Brittberg M, Aglietti P, Gambardella R, et al; for the Clinical Münchenwiler Evaluation Group. *ICRS Cartilage Injury Evaluation Package*. Schloss Münchenwiler, Switzerland: International Cartilage Repair Society; 2000. https://cartilage.org/content/uploads/2014/10/ICRS_evaluation.pdf. Accessed April 16, 2018.
22. Irrgang JJ, Anderson AF, Boland AL, et al. Development and validation of the International Knee Documentation Committee Subjective Knee Form. *Am J Sports Med*. 2001;29(5):600–613.
23. Marx RG, Stump TJ, Jones EC, Wickiewicz TL, Warren RF. Development and evaluation of an activity rating scale for disorders of the knee. *Am J Sports Med*. 2001;29(2):213–218.
24. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee injury and Osteoarthritis Outcome Score (KOOS): development of a self-administered outcome measure. *J Orthop Sports Phys Ther*. 1998;28(2):88–96.
25. Gribble PA, Hertel J. Considerations for normalizing measures of the Star Excursion Balance Test. *Meas Phys Educ Exerc Sci*. 2003;7(2): 89–100.
26. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train*. 2012;47(3):339–357.
27. Gribble PA, Kelly SE, Refshauge KM, Hiller CE. Interrater reliability of the Star Excursion Balance Test. *J Athl Train*. 2013; 48(5):621–626.
28. Robinson RH, Gribble PA. Support for a reduction in the number of trials needed for the Star Excursion Balance Test. *Arch Phys Med Rehabil*. 2008;89(2):364–370.
29. Logerstedt D, Grindem H, Lynch A, et al. Single-legged hop tests as predictors of self-reported knee function after anterior cruciate ligament reconstruction: the Delaware-Oslo ACL Cohort Study. *Am J Sports Med*. 2012;40(10):2348–2356.
30. Noyes FR, Barber SD, Mooar LA. A rationale for assessing sports activity levels and limitations in knee disorders. *Clin Orthop Relat Res*. 1989;246:238–249.
31. Reid A, Birmingham TB, Stratford PW, Alcock GK, Giffin JR. Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. *Phys Ther*. 2007;87(3):337–349.
32. Hamilton RT, Shultz SJ, Schmitz RJ, Perrin DH. Triple-hop distance as a valid predictor of lower limb strength and power. *J Athl Train*. 2008;43(2):144–151.
33. Chamberlain AM, Whale CE, Howard JS. Reliability of a novel step-down-to-fatigue test. *J Athl Train*. 2015;50(suppl 6):S-219.
34. Barber SD, Noyes FR, Mangine RE, McCloskey JW, Hartman W. Quantitative assessment of functional limitations in normal and anterior cruciate ligament-deficient knees. *Clin Orthop Relat Res*. 1990;255:204–214.
35. Ithurburn MP, Paterno MV, Ford KR, Hewett TE, Schmitt LC. Young athletes with quadriceps femoris strength asymmetry at return to sport after anterior cruciate ligament reconstruction demonstrate asymmetric single-leg drop-landing mechanics. *Am J Sports Med*. 2015;43(11):2727–2737.
36. Jang SH, Kim JG, Ha JK, Wang BG, Yang SJ. Functional performance tests as indicators of returning to sports after anterior cruciate ligament reconstruction. *Knee*. 2014;21(1):95–101.
37. Abrams GD, Harris JD, Gupta AK, et al. Functional performance testing after anterior cruciate ligament reconstruction: a systematic review. *Orthop J Sports Med*. 2014;2(1):2325967113518305.
38. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap): a metadata-driven

methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377–381.
39. Lee BI, Kwon SW, Kim JB, Choi HS, Min KD. Comparison of clinical results according to amount of preserved remnant in arthroscopic anterior cruciate ligament reconstruction using quadrupled hamstring graft. *Arthroscopy*. 2008;24(5):560–568.
40. Mohammadi F, Salavati M, Akhbari B, Mazaheri M, Khorrami M, Negahban H. Static and dynamic postural control in competitive athletes after anterior cruciate ligament reconstruction and controls. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(8):1603–1610.
41. Risberg MA, Holm I, Myklebust G, Engebretsen L. Neuromuscular training versus strength training during first 6 months after anterior cruciate ligament reconstruction: a randomized clinical trial. *Phys Ther*. 2007;87(6):737–750.
42. Rudroff T. Functional capability is enhanced with semitendinosus than patellar tendon ACL repair. *Med Sci Sports Exerc*. 2003;35(9): 1486–1492.
43. Pfeifer K, Banzer W. Motor performance in different dynamic tests in knee rehabilitation. *Scand J Med Sci Sports*. 1999;9(1):19–27.
44. Burland JP, Toonstra J, Werner JL, Mattacola CG, Howell DM, Howard JS. Decision to return to sport after anterior cruciate ligament reconstruction, part I: a qualitative investigation of psychosocial factors. *J Athl Train*. 2018;53(5):452–463.
45. Knezevic OM, Mirkov DM, Kadija M, Milovanovic D, Jaric S. Evaluation of isokinetic and isometric strength measures for monitoring muscle function recovery after anterior cruciate ligament reconstruction. *J Strength Cond Res*. 2014;28(6):1722–1731.
46. Petschnig R, Baron R, Albrecht M. The relationship between isokinetic quadriceps strength test and hop tests for distance and one-legged vertical jump test following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther*. 1998;28(1):23–31.
47. Tourville TW, Jarrell KM, Naud S, Slauterbeck JR, Johnson RJ, Beynnon BD. Relationship between isokinetic strength and tibiofemoral joint space width changes after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2014;42(2):302–311.
48. Filbay SR, Ackerman IN, Russell TG, Macri EM, Crossley KM. Health-related quality of life after anterior cruciate ligament reconstruction: a systematic review. *Am J Sports Med*. 2014;42(5): 1247–1255.
49. Collins NJ, Misra D, Felson DT, Crossley KM, Roos EM. Measures of knee function: International Knee Documentation Committee (IKDC) subjective knee evaluation form, Knee Injury And Osteoarthritis Outcome Score (KOOS), Knee Injury And Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities Of Daily Living Scale (KOS-ADL), Lysholm Knee Scoring Scale, Oxford Knee Score (OKS), Western Ontario And McMaster Universities Osteoarthritis Index (WOMAC), Activity Rating Scale (ARS), and Tegner Activity Score (TAS). *Arthritis Care Res (Hoboken)*. 2011;63(suppl 11):S208–S228.
50. Anderson AF, Irrgang JJ, Kocher MS, Mann BJ, Harrast JJ. The International Knee Documentation Committee Subjective Knee Evaluation Form: normative data. *Am J Sports Med*. 2006;34(1): 128–135.
51. Letchford R, Button K, Sparkes V, van Deursen RWM. Assessing activity participation in the ACL injured population: a systematic review of activity rating scale measurement properties. *Phys Ther Rev*. 2012;17(2):99–109.
52. The 2012 User's Guide to: Knee Injury and Osteoarthritis Outcome Score KOOS. KOOS Web site. http://www.koos.nu/KOOSusersguide2012.pdf. Updated August 2012. Accessed August 8, 2016.
53. Englund M, Roos EM, Lohmander LS. Impact of type of meniscal tear on radiographic and symptomatic knee osteoarthritis: a sixteen-year followup of meniscectomy with matched controls. *Arthritis Rheum*. 2003;48(8):2178–2187.
54. Culvenor AG, Collins NJ, Guermazi A, et al. Early knee osteoarthritis is evident one year following anterior cruciate ligament reconstruction: a magnetic resonance imaging evaluation. *Arthritis Rheumatol*. 2015;67(4):946–955.
55. Luc B, Gribble PA, Pietrosimone BG. Osteoarthritis prevalence following anterior cruciate ligament reconstruction: a systematic review and numbers-needed-to-treat analysis. *J Athl Train*. 2014; 49(6):806–819.
56. Yabroudi MA, Irrgang JJ. Rehabilitation and return to play after anatomic anterior cruciate ligament reconstruction. *Clin Sports Med*. 2013;32(1):165–175.
57. Fransen M, McConnell S, Harmer AR, Van der Esch M, Simic M, Bennell KL. Exercise for osteoarthritis of the knee: a Cochrane systematic review. *Br J Sports Med*. 2015;49(24):1554–1557.
58. 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.
59. Tripp DA, Stanish W, Ebel-Lam A, Brewer BW, Birchard J. Fear of reinjury, negative affect, and catastrophizing predicting return to sport in recreational athletes with anterior cruciate ligament injuries at 1 year postsurgery. *Rehabil Psychol*. 2007;52(1):74–81.
60. Ardern CL, Kvist J. What is the evidence to support a psychological component to rehabilitation programs after anterior cruciate ligament reconstruction? *Curr Orthop Pract*. 2016;27(3):263–268.
61. Anderson DD, Chubinskaya S, Guilak F, et al. Post-traumatic osteoarthritis: improved understanding and opportunities for early intervention. *J Orthop Res*. 2011;29(6):802–809.
62. Bannuru RR, Schmid CH, Kent DM, Vaysbrot EE, Wong JB, McAlindon TE. Comparative effectiveness of pharmacologic interventions for knee osteoarthritis: a systematic review and network meta-analysis. *Ann Intern Med*. 2015;162(1):46–54.
63. Feller J, Webster KE. Return to sport following anterior cruciate ligament reconstruction. *Int Orthop*. 2013;37(2):285–290.
64. Dunn WR, Spindler KP, MOON Consortium. Predictors of activity level 2 years after anterior cruciate ligament reconstruction (ACLR): a Multicenter Orthopaedic Outcomes Network (MOON) ACLR cohort study. *Am J Sports Med*. 2010;38(10):2040–2050.
65. McAlindon TE, Bannuru RR, Sullivan MC, et al. OARSI guidelines for the non-surgical management of knee osteoarthritis. *Osteoarthritis Cartilage*. 2014;22(3):363–388.
66. Zhang W, Moskowitz R, Nuki G, et al. OARSI recommendations for the management of hip and knee osteoarthritis, part I: critical appraisal of existing treatment guidelines and systematic review of current research evidence. *Osteoarthritis Cartilage*. 2007;15(9):981–1000.
67. Lai CCH, Ardern CL, Feller JA, Webster KE. Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: a systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes. *Br J Sports Med*. 2018;52(2):128–138.
68. Gobbi A, Karnatzikos G, Lad DG. Factors affecting return to sport after ACL reconstruction. In: Donal MN, ed. *Sports Injuries: Prevention, Diagnosis, Treatment and Rehabilitation*. 2nd ed. Berlin, Germany: Springer; 2015;1059–1066.

Address correspondence to Jennifer S. Howard, PhD, LAT, ATC, Appalachian State University, 111 Rivers Street, PO Box 32071, Boone, NC 28608. Address e-mail to howardjs@appstate.edu.