Relationship Between Isokinetic Knee Strength and Single-Leg Drop Jump Performance 9 Months After ACL Reconstruction

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Background: Deficits in knee strength after anterior cruciate ligament reconstruction (ACLR) surgery are common. Deficits in the single-leg drop jump (SLDJ), a test of plyometric ability, are also found.

Purpose: To examine the relationship between isokinetic knee strength, SLDJ performance, and self-reported knee function 9 months after ACLR.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Knee isokinetic peak torque, SLDJ jump height, contact time, and reactive strength index (RSI), as well as International Knee Documentation Committee (IKDC) scores were assessed in 116 male, field-sport athletes at 9.2 months after ACLR. SLDJ testing took place in a 3-dimensional biomechanics laboratory. Linear regression models were used to analyze the relationship between the variables.

Results: A significant relationship was found between ACLR-limb isokinetic knee extensor strength and SLDJ jump height ($P < .001$, $r^2 = 0.29$) and RSI ($P < .001$, $r^2 = 0.33$), and between ACLR-limb isokinetic knee flexor strength and SLDJ jump height ($P < .001$, $r^2 = 0.12$) and RSI ($P < .001$, $r^2 = 0.15$). A significant positive relationship was also found between knee extensor asymmetry and SLDJ jump height asymmetry ($P < .001$, $r^2 = 0.27$) and SLDJ reactive strength asymmetry ($P < .001$, $r^2 = 0.18$). Combined ACLR-limb jump height and contact time best predicted IKDC scores ($P < .001$, $r^2 = 0.12$).

Conclusion: Isokinetic knee extension strength explained approximately 30% of SLDJ performance, with a much weaker relationship between knee flexion strength and SLDJ performance. Isokinetic strength and SLDJ performance were weak predictors of variation in IKDC scores.

Keywords: anterior cruciate ligament reconstruction; return to sport; muscle strength; plyometric exercise; exercise test

Anterior cruciate ligament (ACL) injury is a common and disabling injury in both professional and amateur sports,[2,12] and many athletes who sustain an ACL rupture undergo surgery in the hope of returning to their preinjury level of sport.[1,4] However, return-to-sport (RTS) outcomes after ACL reconstruction (ACLR) are less than satisfactory, with approximately only 60% of nonelite and 83% of elite athletes returning to their preinjury level of performance.[3,24] Knee extensor strength is one of the main criteria used for determining readiness to RTS,[9] as marked quadriceps muscle inhibition and atrophy are frequently found after ACLR.[32,41] Impairment in knee flexor strength is also common after ACLR but is less consistently seen.[34]

In addition to strength deficits, impairments in plyometric performance are common after ACLR.[1,21,22] Plyometric movements are characterized by a stretch-shortening cycle, which involves a rapid eccentric stretch/load, followed by a brief amortization or transition phase, and then a powerful concentric muscle contraction.[10] Because it is preceded by an eccentric stretch, the ensuing concentric muscle contraction is more rapid and powerful than if it occurred in isolation.[10,27] Consequently, plyometric movements facilitate the force, power, and explosive ability that are needed for optimal performance of a variety of athletic tasks.[13,28] The drop jump is a plyometric movement that involves dropping from a height to the ground (causing eccentric stretch/load) and minimizing ground contact time (amortization phase)

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before jumping as high as possible (concentric contraction).[33] When incorporated into training, drop jumps have been shown to improve athletic performance.[33,38] Drop jump performance is typically quantified and assessed using jump height, ground contact time, and reactive strength index (RSI) as metrics. As the quotient of jump height and contact time, the RSI is considered a measure of reactive strength[6] or plyometric ability.[17]

Compared with other measures of explosiveness, such as the single-leg hop for distance and countermovement jump, which have a slower eccentric phase, drop jumps focus on a shorter ground contact time and are therefore a better test of plyometric ability.[17] The single-leg drop jump (SLDJ) is less commonly used for assessment of plyometric ability after ACLR than the double-leg drop jump, even though it is less susceptible to compensation by the uninjured limb. It also more closely simulates athletic tasks that involve an eccentric preload followed by propulsion off a single leg,[40] such as sprinting or a change of direction. Moreover, previous research suggests that the SLDJ is more likely to expose performance deficits in the late rehabilitation phase after ACLR than more commonly used jump and change-of-direction tests,[21,22] and SLDJ performance has recently been shown to be a key measure in predicting the risk of contralateral limb ACL rupture.[20] In light of this and the importance of plyometric ability to athletic performance, the SLDJ would appear to be a clinically relevant test at this time point.

While the relationship between knee strength and hop test performance after ACLR has been investigated,[31,37] no study has evaluated the relationship between knee strength and SLDJ performance after ACLR. Understanding the extent of this relationship would highlight to what degree improvements in strength metrics should be expected to translate to improved SLDJ performance, and the extent to which the SLDJ needs to be specifically targeted in rehabilitation to improve plyometric performance before RTS. The primary aim of this study was therefore to assess the extent to which variation in isokinetic knee strength could explain variation in SLDJ performance measures 9 months after ACLR. In addition, while previous research[18,37] has investigated the relationship between knee strength and subjective knee function, plyometric ability has not been incorporated into these investigations. Thus, the secondary aim of this study was to assess whether SLDJ performance and knee strength would better explain the variation in self-reported knee symptoms and function as quantified by the International Knee Documentation Committee (IKDC) questionnaire than knee strength alone. We hypothesized that variation in knee extensor strength would explain a sizable portion of variation in drop jump performance, and more than variation in knee flexor strength would. We also hypothesized that the addition of SLDJ would better explain variation in IKDC scores than knee strength alone.

METHODS

Participants

Study participants were recruited from January 2014 to December 2015 from the preoperative caseloads of 2 orthopaedic surgeons whose practice consisted primarily of sport-related knee surgery. The number of athletes who fit the inclusion criteria during the study period determined the sample size. Participants were part of a longer-term research project,[21] and all provided written informed consent before participation. The study received ethical approval from the institution's research ethics committee.

Inclusion criteria for the study were male, multidirectional field athletes aged 18 to 35 years who were diagnosed with an ACL rupture. Athletes with multiple ligament reconstructions, those who had revision ACL surgery, and those who stated preoperatively that they did not intend to return to multidirectional sport after surgery were excluded from the study. All participants underwent ACLR surgery with a bone–patellar tendon–bone (BPTB) or semitendinosus and gracilis hamstring tendon (HT) autograft.

Study Design

After surgery all participants underwent a rehabilitation protocol consisting of weightbearing as tolerated on crutches for 2 weeks, followed by progressive blocks of strength, power, and plyometric exercises, and progressing to on-field running and change-of-direction drills.[22] Their local physical therapist oversaw and progressed the athlete through the rehabilitation program, and an orthopaedic surgeon reviewed the progression at regular intervals. For the purposes of this study, SLDJ performance testing and strength testing of the knee flexors and extensors using isokinetic dynamometry were conducted approximately 9 months (mean ± SD, 9.2 ± 0.5 months) after surgery. All participants completed the IKDC questionnaire assessing self-reported knee symptoms and function[19] on the same day as the physical testing.

SLDJ testing took place in a 3-dimensional biomechanics laboratory.[21,22] Participants were instructed to roll from

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a 20-cm step, land on 1 leg on a force platform (1000 Hz; BP400600; AMTI), and then jump as high as they could while minimizing the length of time in contact with the force platform. The force platform was synchronized with an 8-camera motion analysis system (200 Hz; Bonita-B10; Vicon) that recorded the trajectories of 24 reflective markers secured to the participant over anatomic landmarks.[21,22] Motion and force data were low-pass filtered using a zero-lag, fourth-order Butterworth filter (cutoff frequency, 15 Hz). The position of the body's center of mass (COM) was calculated from segment kinematics and inertial properties on a frame-by-frame basis as per the Vicon Plug-In Gait model (Vicon Motion Systems).[29]

For the jump to be valid, the participants had to keep their hands on their hips throughout the entire jump, exert maximum effort, and make full foot contact on the force platform. The participant had a rest period of 30 seconds between attempts, and the nonoperated limb was tested first. Participants performed 2 submaximal practice trials before testing. The mean of 3 valid attempts for each limb was used for further analysis. Contact time was defined as the time from the instant the ground-reaction force (GRF) first increased above 20 N to the instance of takeoff, when the GRF next dropped below 20 N. Jump height was measured as the displacement of the individual's COM from the moment of takeoff to the moment of maximal vertical height of the COM during the aerial phase of the jump. RSI was calculated as the quotient of jump height and contact time.

Isokinetic testing took place approximately 10 to 15 minutes after jump testing and was used to determine concentric knee extensor peak torque (KE) and knee flexor peak torque (KF) for both the ACLR and the contralateral, non-ACLR limb. Based on previous recommendations,[44] testing was carried out seated at an angular velocity of 60 deg/s through a knee flexion range of 0° to 100°, with a correction for gravity applied (model Cybex NORM; Computer Sports Medicine Inc). After a warm-up set, the athlete completed 2 maximal extension and flexion sets of 5 repetitions, during which they received verbal encouragement to give maximal effort. There was a 60-second rest period between sets. The maximum-effort set with the lowest coefficient of variance for peak torque was analyzed.

The 2 isokinetic variables extracted were KE and KF relative to body mass. The SLDJ performance variables studied were jump height, contact time, and RSI. The data were analyzed with IBM SPSS Statistics (version 24, IBM Corp) software.

The limb symmetry index (LSI) for each isokinetic and SLDJ variable was calculated using the formula (ACLR-limb value × 100)/(non–ACLR-limb value).

Statistical Analysis

The means ± standard deviations of each isokinetic (KE and KF), SLDJ performance (jump height, contact time, and RSI), and corresponding asymmetry (LSI) variable were calculated. Initially, linear regression models were used to examine the relationship between the ACLR-limb isokinetic strength and strength LSI (predictor) variables and SLDJ performance (predictive) variables. Forward, stepwise multivariable regression models with incorporated significant individual predictor variables were then developed. Standardized coefficients and adjusted r^2 values were reported. Subsequent analysis examined the ability of each ACLR-limb isokinetic and SLDJ performance variable as well as each LSI variable to predict IKDC scores. Variables with statistically significant individual explanatory power for IKDC were included in the initial list of variables to consider for stepwise multivariable analysis. Variables were submitted to a multiple linear regression and assessed for collinearity using variance inflation factor (VIF) values. The variable with the highest VIF value was removed from the model, and this process was repeated iteratively until all VIF values were less than 5.[23] The variables remaining after this step were ACLR-limb SLDJ jump height, ACLR-limb SLDJ contact time, and ACLR-limb KE. These variables were added sequentially into the model.

TABLE 1
Performance Variables for the ACLR Limb, Non-ACLR Limb, and LSI[a]

Variable	ACLR	Non-ACLR	LSI, %
SLDJ JH, cm	9.4 ± 3.3	12.3 ± 2.8	75.7 ± 25.1
SLDJ CT, s	0.37 ± 0.10	0.36 ± 0.10	104 ± 13.7
SLDJ RSI, m/s	0.27 ± 0.11	0.36 ± 0.12	73.8 ± 41.4
KE, N·m/kg × 100	227.5 ± 51.6	271.4 ± 37.8	83.3 ± 13.6
KF, N·m/kg × 100	157.5 ± 30.7	161.5 ± 26.7	98.1 ± 14.5

[a]Data are reported as mean ± SD. ACLR, anterior cruciate ligament reconstruction; CT, contact time; JH, jump height; KE, isokinetic knee extensor peak torque; KF, isokinetic knee flexor peak torque; LSI, limb symmetry index; RSI, reactive strength index; SLDJ, single-leg drop jump.

RESULTS

A total of 116 eligible male participants (age, 24.3 ± 6.5 years; body mass, 83.8 ± 8.9 kg; height, 181 ± 6.0 cm) were recruited. The majority (n = 89) played Gaelic football, 20 played rugby, 17 played soccer, and 3 played other sports (some played more than one sport); 87 (75%) and 29 (25%) had received a BPTB or HT graft, respectively. The mean SLDJ performance and isokinetic results for both the ACLR and non-ACLR limbs are shown in Table 1. The LSIs for SLDJ jump height, RSI, and contact time were 75.7% ± 25.1%, 73.8% ± 41.4%, and 104% ± 13.7%, respectively. The LSIs for knee flexion and extension were 98.1% ± 14.5% and 83.3% ± 13.6%, respectively. The mean score on the IKDC questionnaire was 86.3 (± 10).

Relationship Between Isokinetic Strength and SLDJ Performance Variables for the ACLR Limb

The results from the linear regression analyses of ACLR-limb isokinetic and ACLR-limb SLDJ performance variables are presented in Table 2. A significant positive relationship was found between ACLR-limb KE and SLDJ jump height ($P < .001$, $r^2 = 0.29$) and RSI ($P < .001$, $r^2 = 0.33$) (Figure 1, A and B). Similarly, there was a significant positive relationship between ACLR-limb KF and SLDJ jump height ($P < .001$, $r^2 = 0.12$) and RSI ($P < .001$, $r^2 = 0.15$) (Appendix Figure A1, B and D). A significant negative relationship was observed between ACLR-limb KE and SLDJ contact time ($P < .001$, $r^2 = 0.10$), as well as between ACLR-limb KF and SLDJ contact time ($P = .003$, $r^2 = 0.08$) (Appendix Figure A1, A and C).

TABLE 2
r^2 Values for Linear Regression of ACLR-Limb Isokinetic Strength Against ACLR-Limb SLDJ Performance Variables[a]

Isokinetic Variable	SLDJ JH	SLDJ CT	SLDJ RSI
KE	0.29[c]	0.10[c]	0.33[c]
KF	0.12[c]	0.08[d]	0.15[c]
Combined KE and KF[b]	0.28[c]	0.10[c]	0.32[c]
	(0.49)	(–0.24)	(0.53)
	(0.08)	(–0.13)	(0.08)

[a]ACLR, anterior cruciate ligament reconstruction; CT, contact time; JH, jump height; KE, isokinetic knee extensor peak torque; KF, isokinetic knee flexor peak torque; LSI, limb symmetry index; RSI, reactive strength index; SLDJ, single-leg drop jump.

[b]For the multivariable regression, adjusted r^2 values are shown, and the standardized coefficients for significant relationships are in parentheses.

[c]Significant at $P < .001$.

[d]Significant at $P < .01$.

Multivariable regression analysis found a significant positive relationship between ACLR-limb isokinetic variables (KE and KF) and both SLDJ jump height ($P < .001$, $r^2 = 0.28$) and SLDJ RSI ($P < .001$, adjusted $r^2 = 0.32$). A significant negative relationship was observed between ACLR-limb isokinetic variables and SLDJ contact time ($P < .001$, adjusted $r^2 = 0.10$).

Relationship Between LSIs of Isokinetic Strength and SLDJ Performance Variables

The results from the linear regression analyses of LSIs for isokinetic strength and SLDJ performance variables are presented in Table 3. Significant positive relationships were observed between the LSIs for KE and SLDJ jump height ($P < .001$, $r^2 = 0.27$) and the LSIs for KE and SLDJ RSI ($P < .001$, $r^2 = 0.18$) (Figure 1, C and D). A significant negative relationship was observed between the LSIs for

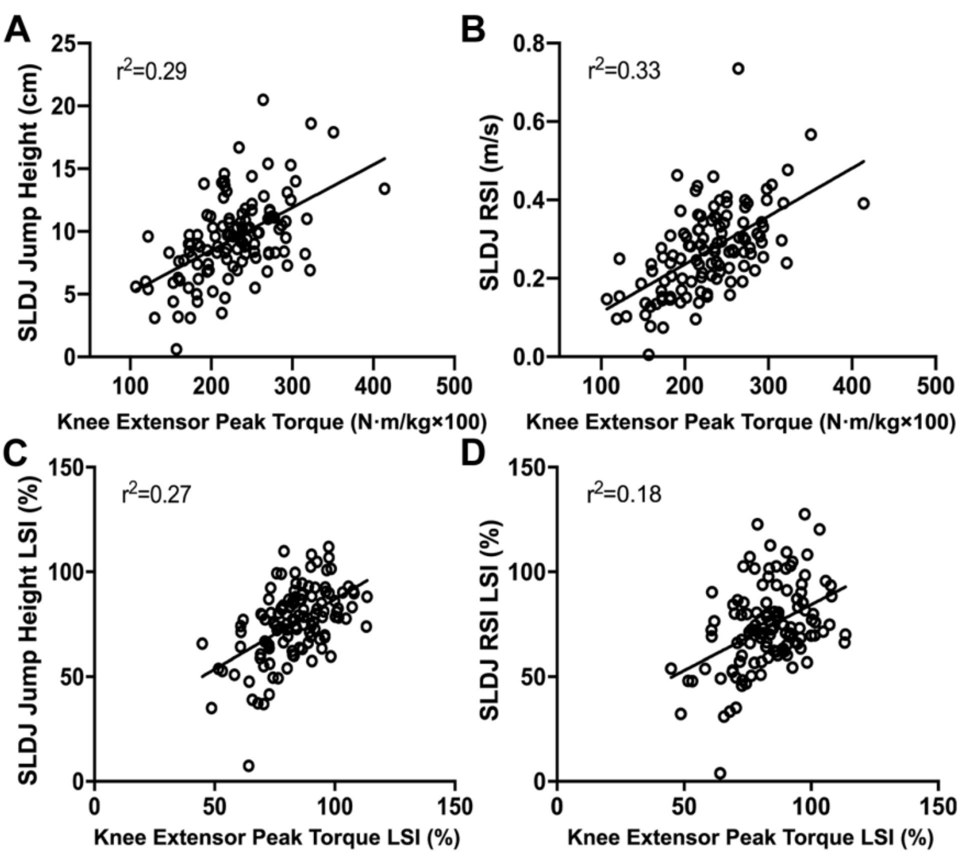

Figure 1. The relationship between knee extensor strength and (A) single-leg drop jump (SLDJ) jump height and (B) SLDJ reactive strength index (RSI), and the relationship between knee extensor strength limb symmetry index (LSI) and (C) SLDJ jump height LSI and (D) SLDJ RSI LSI. Each data point represents a participant.

TABLE 3
r^2 Values for Linear Regression Analyses of Isokinetic Strength LSI Against SLDJ Performance Variables' LSI[a]

Isokinetic Variable	SLDJ JH LSI	SLDJ CT LSI	SLDJ RSI LSI
LSI for KE	0.27[c]	<0.01	0.18[c]
LSI for KF	0.00	0.04[d]	0.00
Combined LSIs for KE and KF[b]	0.26[c,e] (0.52) (–0.00)	0.03[e]	0.15[c,e] (0.41) (0.03)

[a]CT, contact time; JH, jump height; KE, isokinetic knee extensor peak torque; KF, isokinetic knee flexor peak torque; LSI, limb symmetry index; RSI, reactive strength index; SLDJ, single-leg drop jump.

[b]For the multivariable regression, adjusted r^2 values are shown, and the standardized coefficients for significant relationships are in parentheses.

[c]Significant at $P < .001$.

[d]Significant at $P < .05$.

[e]Adjusted r^2 values.

KF and SLDJ contact time ($P = .04$, $r^2 = 0.04$) (Appendix Figure A2).

Multivariable regression analysis found a significant relationship between the LSIs for isokinetic variables (KE and KF) and SLDJ jump height ($P < .001$, adjusted $r^2 = 0.26$). The observed relationships were positive for KE and negative for KF. There was also a significant positive relationship between the LSIs for the isokinetic variables and SLDJ RSI ($P < .001$, adjusted $r^2 = 0.15$).

Relationship Between Isokinetic Strength or SLDJ Performance Variables and IKDC Scores

The results of linear regression analyses of isokinetic and SLDJ performance variables against IKDC scores are presented in Table 4. Significant positive relationships were observed between ACLR-limb SLDJ jump height ($P < .001$, $r^2 = 0.10$), SLDJ RSI ($P < .001$, $r^2 = 0.10$), and KE ($P = .016$, $r^2 = 0.05$) and IKDC scores; and between the LSIs for SLDJ jump height ($P = .002$, $r^2 = 0.08$), SLDJ RSI ($P < .001$, $r^2 = 0.10$), and KE ($P = .006$, $r^2 = 0.06$) and IKDC scores. A significant negative relationship was observed between ACLR-limb SLDJ contact time ($P = .007$, $r^2 = 0.06$) and SLDJ contact time LSI ($P < .001$, $r^2 = 0.09$) and IKDC scores. Scatterplots for the comparisons can be found in Appendix Figures A3 and A4.

Multivariable regression analysis identified the following variables as explaining the greatest proportion of variation in IKDC scores: ACLR-limb SLDJ jump height, ACLR-limb SLDJ contact time, and ACLR-limb KE. These variables were added sequentially into the regression model. A positive relationship was identified between combined ACLR-limb SLDJ jump height and SLDJ contact time, and IKDC scores ($P < .001$, adjusted $r^2 = 0.123$). When ACLR-limb KE was added, the adjusted r^2 value was slightly reduced (adjusted $r^2 = 0.116$).

TABLE 4
P Values and r^2 Values for Linear Regression Analyses of IKDC Scores Against Isokinetic Strength or SLDJ Performance Variables[a]

Performance Measure	P	r^2
SLDJ JH	<.001	0.10
SLDJ RSI	<.001	0.10
SLDJ CT	.007	0.06
KE	.016	0.05
KF	.217	0.01
LSI for SLDJ JH	.002	0.08
LSI for SLDJ RSI	<.001	0.10
LSI for SLDJ CT	<.001	0.09
LSI for KE	.006	0.06
LSI for KF	.200	0.01
Combined SLDJ JH and SLDJ CT[b]	<.001	0.12; (0.27); (–0.21)
Combined SLDJ JH and SLDJ CT and KE[b]	<.001	0.12; (0.27); (–0.21); (0.01)

[a]CT, contact time; IKDC, International Knee Documentation Committee; JH, jump height; KE, isokinetic knee extensor peak torque; KF, isokinetic knee flexor peak torque; LSI, limb symmetry index; RSI, reactive strength index; SLDJ, single-leg drop jump.

[b]For the multivariable regression, adjusted r^2 values are shown, and the standardized coefficients for significant relationships are in parentheses.

DISCUSSION

Persistent deficits in SLDJ performance have been identified after ACLR,[21,22] and the RSI during SLDJ has recently been reported as a key variable in those that go on to experience a contralateral ACL injury after RTS.[20] Knee strength is a principal criterion for assessing readiness to RTS[9]; therefore, understanding the influence of knee strength on SLDJ performance after ACLR is paramount. To our knowledge, this is the first published study to specifically examine this relationship. Testing was carried out at a clinically relevant time (9.2 ± 0.5 months), given that most athletes have recently returned, or are planning to return, to sport at this time point.[5] Our results supported our first hypothesis, demonstrating that variability in isokinetic KE strength for the ACLR limb explained almost one-third of the variability in the SLDJ jump height and reactive strength. The corresponding LSI variables had a similar relationship between KE and jump height and a smaller relationship between KE and reactive strength. Linear regression analysis found a significant but weak relationship between KF strength and SLDJ performance measures, and the multivariable regression of combined KE and KF strength actually showed a (minimally) weaker relationship with SLDJ than the relationship of KE alone to SLDJ performance. These findings indicate that regaining KE, but not KF, strength is important to the recovery of SLDJ performance, and that additional factors beyond KE contribute considerably to SLDJ performance. Combined ACLR-limb SLDJ performance and KE strength were marginally better in predicting IKDC scores than knee strength alone, thus weakly supporting our second hypothesis.

However, both measures had little ability to predict IKDC scores, suggesting a lack of association between these metrics and self-reported knee function.

Given that concentric contraction of the knee extensors and ankle plantarflexors plays a key role in the upward propulsion of the body in the concentric phase of a drop jump,[7] it is intuitive that concentric KE explained a sizable portion of the jump height obtained. Previous research investigating the relationship between knee strength and performance on vertical jump tests observed that concentric KE, but not KF, explained 23% to 29% of the variance in jump height.[15,39,43] Although these studies all show the importance of knee extension strength for vertical jump performance, the difference in kinematic variables at the knee between the countermovement jump and the drop jump[7] and the bilateral nature of the jumps evaluated in these studies make direct comparisons to the current study challenging. Previous examinations of the relationship between knee strength and plyometric performance in athletes after ACLR have primarily focused on horizontal hop tests. In these studies, asymmetry in KE explained 14% to 25% of asymmetry in single-leg hop for distance performance and 9.2% of asymmetry in the triple hop for distance.[31,37] This is overall lower than the relationship between KE and SLDJ performance seen in the current study and may be explained by the relatively greater contribution of knee extension to performance on vertical jumps compared with horizontal jumps.[35] It may also partly explain the more rapid recovery of single-leg hop for distance performance in comparison with quadriceps strength and SLDJ performance after ACLR.[1,21,42]

Previous work[18] examining the predictive ability of knee extension for IKDC scores reported that knee extension torque variability, but not peak torque, predicted 14% of the variance in IKDC scores. In addition, knee extension strength asymmetry did not significantly differ with respect to IKDC scores between those with higher (≥90%) compared with lower (<85%) LSI measurements.[37] In the current study, similar to previous research, knee strength was observed to have poor predictive value for IKDC scores at 9 months post ACLR. SLDJ performance had weak predictive ability, and the combination of knee strength and SLDJ performance did little to improve the predictive value of IKDC scores over KE alone. This suggests that other factors, such as meniscal/chondral damage at the time of initial injury,[11] psychological factors,[25,36] or more demanding tests, such as change of direction, may better explain IKDC scores at this time point after surgery.

It is noteworthy that, in the current study, recovery of limb symmetry in SLDJ performance (LSIs, 73.8% ± 41.4% and 75.7% ± 25.1% for RSI and JH, respectively) was considerably less than recovery in KE strength symmetry (LSI, 83.3% ± 13.6%), indicating that recovery in plyometric ability after ACLR may lag behind that of maximal strength. This finding underscores the importance of recovering strength qualities beyond maximal strength to return athletes to high performance after injury.[6,8,26] Assessment and rehabilitation of these strength qualities, including reactive strength, are recommended in the later stage of ACLR rehabilitation, once sufficient maximum strength has been achieved.[8] In previous research examining the SLDJ after ACLR, the SLDJ jump height demonstrated ongoing asymmetry (LSI, 79%) at 9 months, despite the single-leg hop for distance returning to normal levels (LSI, 94%).[21] In another study[22] investigating biomechanical and performance variables across a battery of jump and change-of-direction tests in athletes 9 months after ACLR compared with healthy controls, SLDJ jump height was found to have the greatest asymmetry of all measured variables. These results and those of the current study all suggest that the SLDJ is a clinically relevant test in the later stage of rehabilitation after ACLR. Furthermore, drop jumps have resulted in improvements in sprinting, jumping, and change-of-direction ability, as well as running economy, when included in a training program,[33,38] indicating that recovery of drop jump performance after ACLR is important for optimization of athletic performance.

Limitations

This study evaluated performance variables in a specific cohort of male, multidirectional field-sport athletes, so the findings may not be generalizable to female or younger athletes. We examined the relationship between concentric peak extensor/flexor torques and plyometric performance but did not investigate other strength qualities that may also influence plyometric performance, such as rate of force development and eccentric strength.[14] Finally, the study cohort consisted of athletes who had received either a BPTB or HT autograft. Graft type has been found to be associated with knee strength and jump loading asymmetry metrics after ACLR,[16,30,45] so delimitation to a single graft type or the inclusion of alternative grafts may have altered our findings. Future research may explore other factors influencing SLDJ performance and interventions that may effectively address SLDJ performance deficits to optimize functional recovery after ACLR.

CONCLUSION

This study demonstrated that ACLR-limb KE strength could explain approximately 30% of SLDJ performance in male athletes 9 months after ACLR, with a much weaker relationship between KF and SLDJ performance. SLDJ performance variables and knee strength had little ability to explain variation in IKDC scores. These findings suggest that knee extensor strength should be targeted in post-ACLR rehabilitation to improve SLDJ performance, but that additional exercises to improve plyometric ability may be needed to optimally restore athletic performance before RTS.

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APPENDIX

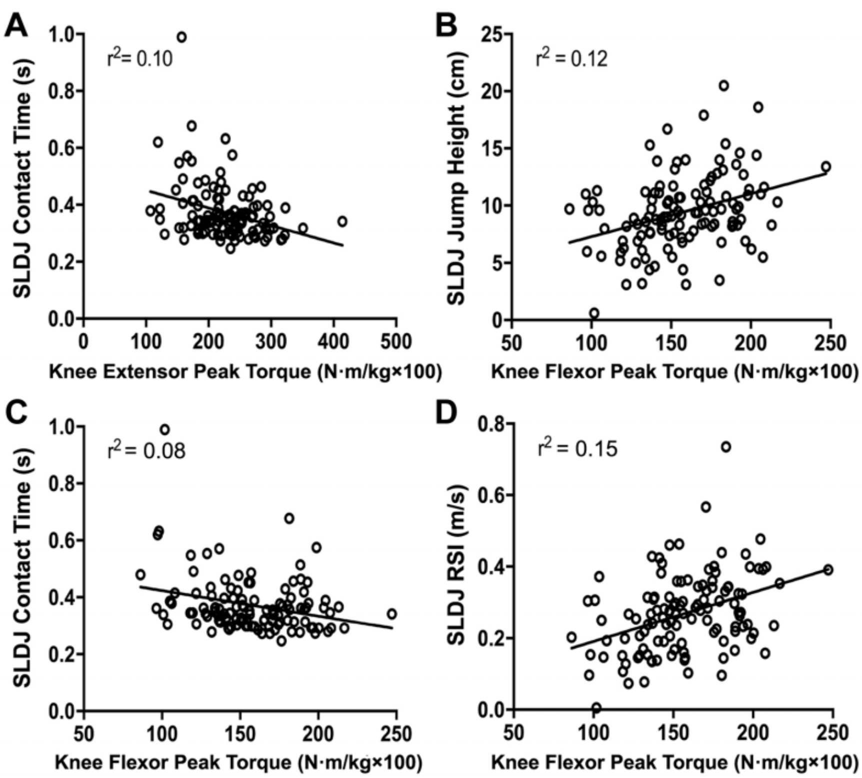

Figure A1. The relationship between (A) knee extensor strength and single-leg drop jump (SLD) contact time, and the relationship between knee flexor strength and (B) SLDJ jump height, (C) SLDJ contact time, and (D) SLDJ reactive strength index (RSI). Each data point represents a participant.

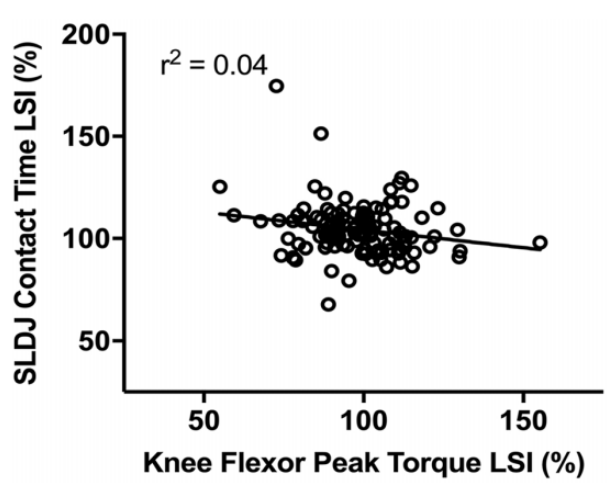

Figure A2. The relationship between knee flexor strength limb symmetry index (LSI) and single-leg drop jump (SLDJ) contact time LSI. Each data point represents a participant.

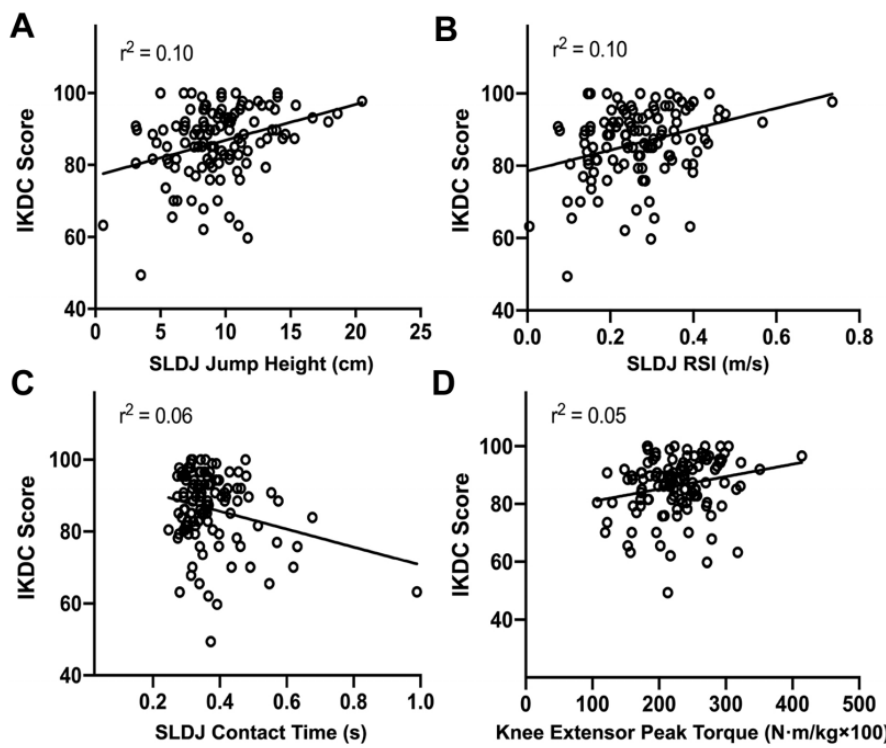

Figure A3. The relationship between (A) single-leg drop jump (SLDJ) jump height, (B) SLDJ reactive strength index (RSI), (C) SLDJ contact time, and (D) knee extensor strength and International Knee Documentation Committee (IKDC) score. Each data point represents a participant.

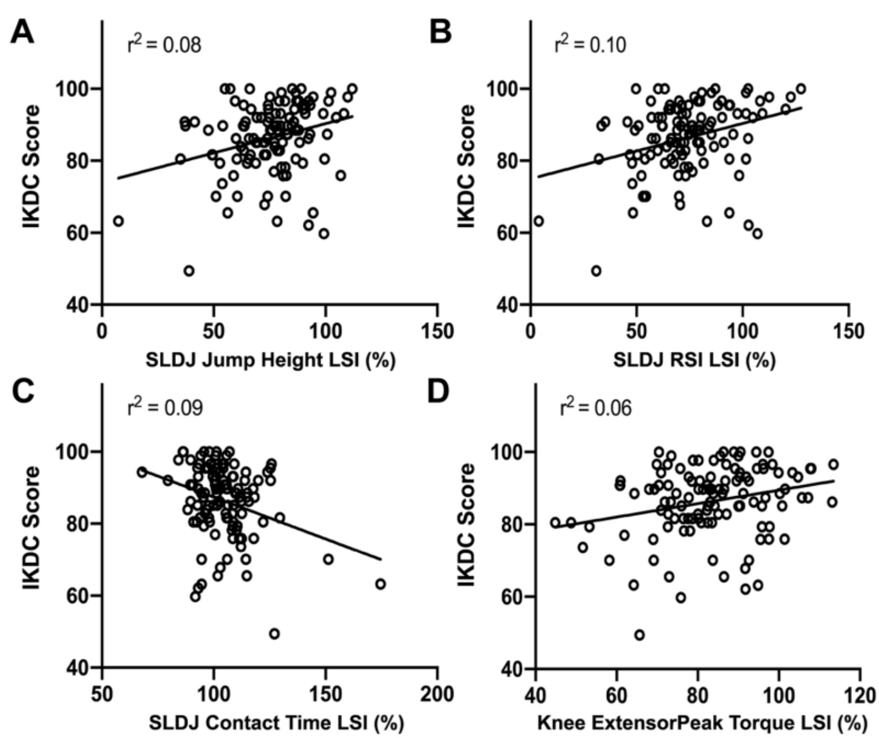

Figure A4. The relationship between (A) single-leg drop jump (SLDJ) jump height limb symmetry index (LSI), (B) SLDJ reactive strength index (RSI) LSI, (C) SLDJ contact time LSI, and (D) knee extensor strength LSI and International Knee Documentation Committee (IKDC) score. Each data point represents a participant.