COMPARISON OF THE PERFORMANCE AND LOWER LIMB BIOMECHANICS OF DROP JUMP AND 10-5 REPETITVE REBOUND TESTS IN ACLR ATHLETES

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Double and single leg drop jump (DLDJ & SLDJ) assessments tend to be performed during the later stages of rehabilitation from an anterior cruciate ligament (ACL) injury due to the mechanical demands these assessments place on the lower limbs. Double and single leg 10-5 repetitive rebound tests (DLRJT and SLRJT) may be effective alternatives to examine lower limb mechanics at an earlier stage of rehabilitation. The purpose of this study was 1) to compare inter-limb performance and biomechanical differences within each jump test and 2) to compare biomechanical differences between the double and single leg versions of each test. Significant ($p<0.05$) inter-limb and between-jump differences were observed. Both the DLRJT and SLRJT can highlight inter-limb performance and biomechanical differences but are not as biomechanical demanding as the DLDJ and SLDJ.

KEYWORDS: 10-5 repetitive-rebound test, drop jumps, ACL injury, asymmetry, performance.

INTRODUCTION: Functional performance assessments such as drop jumps and repetitive-rebound jumps are commonly used by clinicians to assess lower limb strength and power qualities (Komi, 2003). Such tests are performed to monitor the rehabilitation of athletes who have sustained a lower limb injury such as an ACL injury and who are recovering from a subsequent surgical reconstruction (ACLR). Biomechanical assessments such as the double-leg and single drop jumps (DLDJ and SLDJ) have shown large asymmetries in peak vertical ground reaction forces and internal knee extension moments in ACLR athletes (King et al., 2018). These asymmetries in the DLDJ have been shown to persist in ACLR athletes 9-months post-surgery with significantly lower knee extension moment on the involved leg compared to the uninvolved leg (King et al., 2019). The SLDJ highlights greater performance and biomechanical asymmetries but there is a paucity of studies examining the biomechanics of the SLDJ. Repetitive rebound jumps such as the double leg and single leg 10-5 repetitive-rebound test (RJT and SLRJT) may also be effective for assessing performance and biomechanical asymmetries in ACLR athletes. The 10-5 repetitive-rebound test involves performing a countermovement jump immediately followed by 10 consecutive vertical hops. The 5 best jumps, based on the Reactive Strength Index (RSI) score are then selected for further analysis. Previous literature has examined the reliability of performance measures attained from the double-leg 10-5 repetitive-rebound test (Harper, Hobbs, Moore, 2011 and Stratford et al., 2020). However, no studies have specifically analysed the lower limb biomechanics of both a RJT and SLRJT and the potential biomechanical and performance asymmetries they could highlight in ACLR athletes. The RJT and SLRJT are becoming more frequently utilised by clinicians and thus it is important to demonstrate the possible inter-limb performance and biomechanical differences that these tests could highlight in ACLR athletes. The purpose of this study was to 1) compare inter-limb performance and biomechanical differences within each jump test and 2) assess biomechanical differences between the DLDJ and RJT and the SLDJ and SLRJT, respectively, in ACLR athletes.

METHODS: 22 recreational field-sport male athletes (age: 22.0 ± 3.4 years, height: 178.1 ± 10.4 cm, mass: 80.3 ± 14.6 kg), who underwent an ACLR and rehabilitation in the Sport Surgery Clinic (Dublin, Ireland) were recruited for this study. A cross-sectional study design was utilised to examine performance and biomechanical measures in the DLDJ, SLDJ, RJT and SLRJT as part of a whole-body biomechanical assessment. All physical testing was performed at approximately 6-8 months post-ACLR. After surgery, all participants underwent an accelerated rehabilitation protocol which involved the development of lower limb strength and power. All physical testing took place in a 13-camera 3D motion analysis laboratory (Bonita-B10; Vicon, UK) capturing at a frequency of 200 Hz. Motion capture data was recorded using 28 retro-reflective markers based on the Plug-in Gait model. This was synchronised with 2 force platforms (BP400600, AMTI, USA) recording at 1000 Hz. The DLDJ was performed from a 30cm box and the SLDJ was performed from a 20cm box. Participants were instructed to perform the drop jumps and repetitive rebound tests with maximal effort, jumping as high as possible with minimal ground contact time. Each participant performed three trials of the DLDJ and SLDJ. Only one trial was recorded for both the RJT and SLRJT as it has been previously shown to provide reliable performance measures with a single trial (Stratford, Santos, and McMahon, 2021). The three performance measurements assessed were jump height, ground contact time and Reactive Strength Index (RSI). Inter-limb performance asymmetries in the SLDJ and SLRJT were examined using a Limb Symmetry Index defined as: LSI= ((ACLR Limb) / (Non ACLR Limb)) ×100. Standard inverse dynamics were used to calculate hip and knee extension/flexion moments and ankle plantarflexion/dorsiflexion joint moments (reported as internal moments). Joint moments were normalised to 101 data points and compared across the entire stance phase of each of the jumps using 1-Dimensional Statistical Parametric Mapping. In the case of the RJT and SLRJT, performance and biomechanical measures were averaged over the 5 best jumps based on RSI scores as has been performed previously in the literature (Stratford, Santos, and McMahon, 2020). Paired t-tests were utilised to examine inter-limb performance differences.

RESULTS: The SLDJ and SLRJT highlighted significant ($p<0.05$) inter-limb (ACLR vs non-ACLR) differences in both performance and biomechanical variables (Table 1 and Figure 1). Knee extension moment was significantly larger ($p<0.05$) during mid-stance in the non-ACLR limb in all jump tasks (Figure 1).

Table 1: Mean ± SD of jump height, contact time and RSI of the 4 jump tests (DLDJ, SLDJ, DLRJT & SLRJT). The magnitude of differences was also reported using effect sizes (ES). Significant differences between ACLR and Non-ACLR limb (p<0.05) *. Significant differences in LSI values between SLDJ and SLRJT (p<0.05) **.

Performance Variables	DLDJ	SLDJ				DLRJT	SLRJT			
		ACLR	Non-ACLR	ES	LSI (%)		ACLR	Non-ACLR	ES	LSI (%)
Jump Height (m)	0.312 ± 0.054	0.125 ± 0.027	0.165 ± 0.032	-1.47*	76.8 ± 14.5	0.266 ± 0.054	0.103 ± 0.023	0.126 ± 0.026	-1.13*	83.1 ± 13.9
Contact Time (s)	0.263 ± 0.072	0.371 ± 0.091	0.343 ± 0.091	1.09*	108.6 ± 8.0	0.234 ± 0.108	0.321 ± 0.058	0.308 ± 0.077	0.42	104.9 ± 6.8
RSI (m/s)	1.237 ± 0.231	0.346 ± 0.073	0.507 ± 0.132	-1.57*	70.8 ± 13.6**	1.213 ± 0.275	0.329 ± 0.066	0.423 ± 0.111	-1.28*	79.7± 17.0

DLDJ- Double-leg drop jump, SLDJ- Single-leg drop jump, RJT- Double-leg 10-5 repetitive rebound test, SLRJT- Single-leg 10-5 repetitive rebound test, RSI- Reactive Strength Index, LSI- Limb symmetry Index

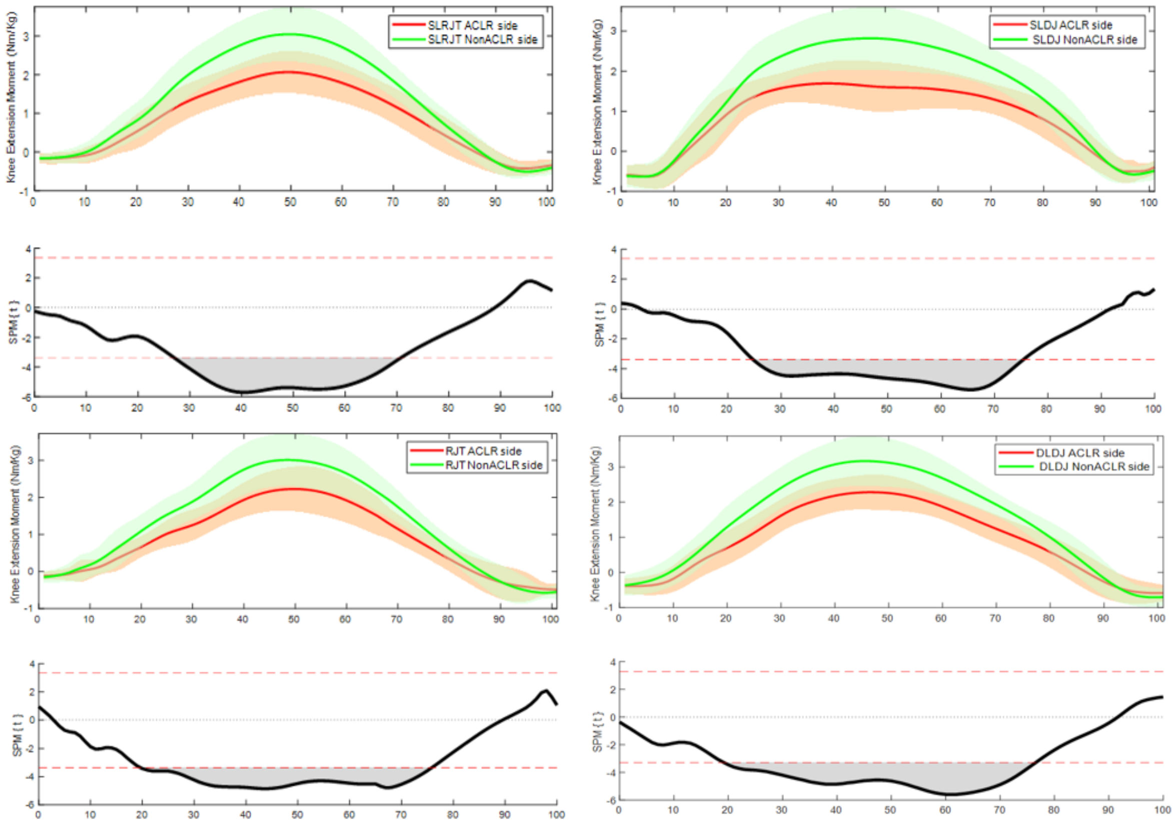

Figure 1: Knee extension moment over the entire stance phase (0-100%) of all 4 jump tasks (SLRJT, RJT, SLDJ, DLDJ) for the ACLR and non-ACLR limbs. An extension moment was defined as positive, and a flexion moment was defined as negative.

Table 2: Comparison of joint moments between the ACLR limb of the DLRJT versus the DLDJ and the ACLR limb of the SLRJT versus the SLDJ, respectively. Joint moments were reported as mean ± SD.

Biomechanical Variables	RJT vs DLDJ			SLRJT vs SLDJ		
	Start-End (%)	RJT ACLR	DLDJ ACLR	Start-End (%)	SLRJT ACLR	SLDJ ACLR
Ankle Plantarflexion Moment (Nm/kg)	1-21	0.42 ± 0.48	0.79 ± 0.70	1-18	0.78 ± 0.75	1.36 ± 0.97
	45-54	3.69 ± 0.09	2.72 ± 0.02	30-55	3.91 ± 0.09	3.17 ± 0.06
Knee Extension Moment (Nm/kg)	1-9	-0.06 ± 0.05	-0.35 ± 0.04	1-8	-0.16 ± 0.02	-0.60 ± 0.04
				21-27	0.86 ± 0.18	1.27 ± 0.15
Hip Extension Moment (Nm/kg)	1-76	0.49 ± 0.26	1.54 ± 0.47	1-8	0.54 ± 0.11	1.44 ± 0.16
				13-73	1.49 ± 0.55	2.618± 0.75

DLDJ- Double-leg drop jump, SLDJ- Single-leg drop jump, RJT- Double-leg 10-5 repetitive rebound test, SLRJT- Single-leg 10-5 repetitive rebound test

DISCUSSION: The primary aim of this study was to compare the inter-limb differences in performance and biomechanical variables between both the drop jump (DLDJ & SLDJ) and the 10-5 repetitive rebound tests (RJT & SLRJT). Previous literature has shown the ability of the DLDJ & SLDJ to detect both performance and joint-level biomechanical differences in ACLR athletes (King et al., 2018). This study showed that the SLRJT highlighted inter-limb differences with jump height and RSI being significantly less in the ACLR limb compared to the non-ACLR limb. There were no significant differences in LSI values for jump height and contact time between the SLDJ and SLRJT (Table 1). Knee extension moment was significantly less in the ACLR limb for all jumps compared to the non-ACLR limb (Figure 1). However, neither the ankle nor hip joint moments showed significant inter-limb differences throughout the stance phase for any of the jump assessments. The similarities between the inter-limb performance differences in the SLDJ and SLRJT and the similarities in the inter-limb biomechanical differences in all jump tasks indicates that clinicians could use the 10-5 repetitive rebound tests as effective alternatives to the drop jump tests.
Another aim of the study was to compare the joint-level mechanics between the DLDJ and RJT and, the SLDJ and SLRJT, respectively. Ankle plantarflexion moment was significantly greater in the early portion of stance for the DLDJ and SLDJ compared to the RJT and SLRJT. The RJT and SLRJT had significantly greater ankle plantarflexion moment during the middle portion of stance (Table 2). Hip extension moment was significantly greater throughout stance in the DLDJ and SLDJ compared to the RJT and SLRJT (Table 2). However, knee extension moment was significantly greater during the early stance phase of the both the RJT and SLRJT in the ACLR limb (Table 2). These results suggest that the 10-5 repetitive rebound tests are less demanding on the hip joint throughout the majority of the stance phase compared to the drop jump tests with the knee and ankle joints being the primary contributors to performance outcomes in the RJT and SLRJT. The 10-5 repetitive rebound tests could be utilised by clinicians at an earlier stage of ACLR rehabilitation to examine inter-limb differences in a jump-landing task.

CONCLUSION: The use of the 10-5 repetitive-rebound test has been increasing in popularity among clinicians in the assessment of lower limb function. Based on the current study, inter-limb performance differences could be identified by both the SLRJT and SLDJ. All jump assessments highlighted biomechanical differences at the knee joint. Drop jump assessments were more demanding on the lower limbs compared to the 10-5 repetitive rebound tests. The 10-5 repetitive-rebound tests may be another useful tool to expose biomechanical differences in ACLR athletes, but they are not as demanding as drop jump assessments and could be utilised as a jump-landing assessment at an earlier stage of ACLR rehabilitation.

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