PERFORMANCE ASSESSMENTS OF THE MIDDLE AND LATE PHASE OF REHABILITATION FOLLOWING LOWER LIMB INJURY IN PROFESSIONAL RUGBY UNION PLAYERS

Molly F. McCarthy-Ryan[1], Stephen D. Mellalieu[1], Adam Bruton[2] and Isabel S. Moore[1]

[1]Cardiff School of Sport and Health Sciences, Cardiff Metropolitan University, Cardiff, UK, [2]School of Life and Health Sciences, Whitelands College, University of Roehampton, UK.

The purpose of this study was to characterise the kinetic profile of the jumping strategy employed in rugby union players during the middle and late phases of rehabilitation following lower limb injury. Nine players from a professional rugby union team (height 1.80±0.06 m; mass 96.1±13.2 kg; age 25±3 years) were included in this study. The mean duration of the middle and late phases of rehabilitation were 10±5 weeks and 6±2 weeks respectively. Unilateral drop jump and unilateral lateral hurdle hop were used to characterise the middle and late phases respectively. The variables of interest were Initial peak landing force, ground contact time, net impulse, Instantaneous loading rate, flight time and second peak landing force. Differences were observed in kinetic jump profiles between uniplanar and multiplanar movements. A change in kinetic jumping strategy to attain the same performance magnitudes across both phases of rehabilitation was also observed. The results highlight the importance of practitioners using a range of functional assessments in return to play testing.

KEYWORDS: drop jump, hurdle hop, RTP, kinetics, jump strategy

INTRODUCTION: Rugby union players are required to perform dynamic movements such as landing from a jump, change of direction and side stepping, which have been previously found to be associated with mechanism of lower limb injury (Alentorn-Geli et al. 2009). Following a lower limb injury, the rehabilitation processes a player's progresses through to ensure they safely return to play (RTP) is complex. However, due to the absence of clear RTP criteria in the applied practice literature the test used during the middle phase may vary across clinical teams (van Melick et al. 2016). Typically, RTP testing include uniplanar and multiplanar functional assessments. By using dynamic functional assessments and increasing task difficulty, persistent deficits in neuromuscular control and the stretch shortening cycle be observed. Following a lower limb injury, players alter their jumping strategy to display the same force dissipation at the point of RTP compared to pre-injury. Specifically, larger loading rates are reported in an anterior cruciate ligament reconstructed (ACLR) limb compared to the uninjured limb (Pfeiffer et al. 2018). Landing strategy and load tolerance has also been found to change following lower limb injury. During Hewett and colleagues (2005) prospective study, they found athletes who went onto sustain an ACLR had 20% larger vertical ground reaction forces during landing compared to players who did not sustain an injury. This suggests that rehabilitation does not successfully target such deficits to the neuromuscular system or adequately retrain the system, failing to restore sufficient muscle recruitment and activation capacities (Buckthorpe et al. 2017). Although a large body of research exists investigating the affected lower limb injuries, typically this assessment is at the point of RTP (Paterno et al. 2013; King et al. 2019; Daniels et al. 2020), resulting in limited knowledge of the longitudinal changes following a lower limb injury across rehabilitation phases. The aim of this study was to characterise the kinetic and kinematic profile of rugby union players' jumping strategy during the middle and late phase rehabilitation following lower limb injury.

METHODS: Participants and phases of rehabilitation: Nine players from a professional rugby union team (height 1.80±0.06 m; mass 96.1±13.2 kg; age 25±3 years) provided written, voluntary, informed consent to participate. Uniplanar and multiplanar functional assessments

were used across middle and late phases of rehabilitation, respectively. Pre-injury baseline measurements were taken as part of a larger 2019-2020 preseason screening. The initiation of the middle phase was when players were medically cleared to perform intersegmental control and linear movement mechanics and ended at the initiation of the late phase which consisted of players being medically cleared for multidirectional movements, the end of the late phase was at the point players RTP. Players were tested at the initiation and end of each rehabilitation phase (middle and late). Participants were given time to familiarise themselves with the movements before testing commenced. For the middle and late sessions only the injured limb was measured. Players sustained a range of injuries, 50% were ligament, 30% muscle and 10% tendon and bone respectively. The mean duration of the middle and late phases were 10±5 weeks and 6±2 weeks respectively.
Data collection: Drop jump and hurdle hop were measured using PASCO single axis force platforms (PS-2141; 1000 Hz). The middle phase assessed three successful trials of a unilateral drop jump from 20 cm per trial, with a 30 s rest period interspersed between trials. Players were instructed to stand upright with their hands on their hips, and place their non-weight bearing limb behind them. During the late phase, players completed a lateral hurdle hop assessment. Players were required to hop unilaterally over a 15 cm hurdle and immediately hop back to their initial starting position. When testing the right leg players were instructed to stand on their right foot to the left of the hurdle (on the left force plate), with the first hop being in a rightwards direction over the hurdle, and then hop back in a leftwards direction back to the original stating position. Three trials were measured with a 1-minute rest period between trials. The variables of interest were Initial peak landing force, ground contact time, net impulse, Instantaneous loading rate, flight time and second peak landing force. Instantaneous loading rate was calculated by assessing the peak difference in differentiation of force between any two successive points with respect to time.
Data analysis: All data were processed using a customised written MATLAB script (Matlab R2019b). A 4^{th} order, recursive low pass Butterworth filter with a cut-off frequency 25 Hz. All statistical analysis was conducted using SPSS (v.27.0) and significance was set at $p < 0.05$. Normality of the residuals was assessed with the Shapiro-Wilk test. Simple, last category contrast analysis were used to assess the difference between testing session. For non-parametric data, Wilcoxon tests were run separately (baseline to the end session and the initial to the end session). Cohen's d effect size (ES) were used to determine the magnitude of significant differences (d 0.2-0.49 small; d > 0.5-0.79 medium; d > 0.8 large; Cohen 2013).

RESULTS: All discrete variables were similar between the middle phase baseline and end session comparison (Table 1). The late phase identified a number of differences between testing sessions, with a longer ground contact time (F(1) 7.64, p 0.03, η2 0.56), smaller landing net impulse (F(1) 7.95, p 0.01, η2 0.69) (Table 1). For comparisons between the initial and the end middle rehabilitation phase a larger second peak landing force (F(1) 11.97, p 0.01, η2 0.60) and flight time (p <0.05) were found. A smaller ground contact time was found during the end session (F(1) 38.04, p <0.001, η2 0.83). For the late phase a larger peak take-off force (F(1) 33.07, p <0.001, η2 0.85), smaller landing net impulse (F(1)17.00, p 0.01, η2 0.74), smaller initial peak landing force (F(1) 8.95, p 0.02, η2 0.60) and second peak landing force (F (1) 17.54, p 0.01, η2 0.75) was observed (Table 1).

DISCUSSION: The aim of this study was to characterise the kinetic and kinematic profile of the jumping strategy of rugby union players during the middle and late phase of rehabilitation following lower limb injury. A main finding of this study was the opposing direction of restoration in kinetic jumping profile strategy used during the initial session between the middle and late phase of rehabilitation. Examination of the initial and the end session of rehabilitation phases also observed opposite magnitudes of change in ground contact time and net impulse, with improvements in the ability to reduce the second peak landing force.
In the middle rehabilitation phase ground contact time decreased from the initial to the end time point with no change to net impulse, therefore vertical force must have increased. For the late rehabilitation phase similar ground contact times were evident between the initial to end,

yet net impulse reduced, meaning second peak landing force must have also reduced. It is postulated that these changes occur due to the varied kinetic strategies adopted. This may suggest a more efficient lateral jumping strategy, with lower vertical impulses being generated in favour of generating greater horizontal impulses. However, this requires confirmation through examining horizontal force-time histories during rehabilitation. Landing vertical impulse has previously been identified to give an overall representation of the function of the injured limb whilst also being associated with mean knee extension moment and total knee work during a cutting functional assessment (Dai et al. 2014).

Table 1 Mean ± standard deviation of middle phase (unilateral drop jump) and late phase (hurdle hop) of rehabilitation. Effect size and relative change between testing session comparison.

		Testing session			Baseline – End		Initial – End	
		Baseline	Initial	End	ES	RC %	ES	RC %
Initial peak landing force (BW)	Drop jump	2.55±0.24	2.10±0.7	2.47±0.74	0.15	3.90	0.50	22.18
	Hurdle hop	2.33±0.44	<u>3.10±0.61</u>	2.52±0.38	0.46	12.73	1.14	17.19
Ground contact time (s)	Drop jump	0.35±0.08	<u>0.42±0.06</u>	0.32±0.02	0.59	6.72	2.48	23.58
	Hurdle hop	<u>0.35±0.10</u>	0.27±0.04	0.28±0.04	1.11	19.62	0.22	3.81
Net impulse (BW·s)	Drop jump	0.59±0.09	0.44±0.16	0.52±0.14	0.61	10.84	0.51	27.52
	Hurdle hop	<u>0.49±0.13</u>	<u>0.43±0.06</u>	0.31±0.07	0.58	4.99	1.81	42.77
Instantaneous loading rate (BW·s^{-1})	Drop jump	57.45±13.95	49.29±13.09	52.66±24.62	0.24	10.54	0.17	17.01
	Hurdle hop	405.35±88.83	460.34±200.48	565.01±157.41	1.25	43.94	0.58	36.94
Flight time (s)	Drop jump	0.33±0.05	<u>0.22±0.07</u>	0.33±0.05	0.08	1.31	1.79	58.45
	Hurdle hop	0.24±0.04	0.24±0.03	0.24±0.03	0.02	1.41	0.05	0.41
Second peak landing force (BW)	Drop jump	1.78±0.25	<u>1.19±0.49</u>	1.86±0.80	0.14	6.07	1.01	55.03
	Hurdle hop	1.95±0.17	<u>2.81±0.34</u>	2.21±0.45	0.77	14.70	1.51	21.28

Abbreviations: RC: Relative change, ES: Effect size. Dashed underline: significant difference between baseline and the end session (*p<0.05*), <u>solid underline</u>: significant comparison between the initial and end session ($p < 0.05$)

Although the positive trend of the initial landing was observed for the end of the late rehabilitation phase in the current study, this occurred independently of any improvement in loading rate. The reduction in ground reaction force suggests that players have a greater ability to dissipate vertical landing force. Furthermore, the similar magnitudes between baseline and end of the rehabilitation phases suggests that players have restored their ability to dissipate mechanical forces following injury during the middle and late phase of rehabilitation. This contradicts previous findings, however these comparisons are typically examined between participants uninjured limb (Paterno et al. 2010; Miles et al. 2019; Gore et al. 2020). This study found a 9-fold greater instantaneous loading rate in the late rehabilitation phase compared to the middle phase when comparing the hurdle hop and drop jump respectively, despite similar peak landing forces. These findings could signify that the force is being applied to the body at a greater rate during lateral movement as opposed to a vertical movement, that has previously been associated with greater risk of injury (Hewett et al. 2005; Van Der Worp et al. 2016). The reduction in peak landing force and vertical impulse may indicate a more effective lateral jumping strategy being employed, that minimises both passive impact and active generation of vertical forces (Hewett et al. 2005; Paterno et al. 2007). Collectively the findings suggest a change in force, hence the use of players varied kinetic jumping strategies.

CONCLUSION: The investigation of the biomechanical profile of rugby union players during the middle and late phase of rehabilitation demonstrate a change in kinetic jumping strategy to attain the same performance magnitudes. The findings further suggest the need to utilise both uniplanar and multiplanar functional assessments in RTP testing.

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