CHARACTERISING LONGITUDINAL ALTERATIONS IN POSTURAL CONTROL FOLLOWING LOWER LIMB INJURY IN PROFESSIONAL RUGBY UNION PLAYERS

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Assessment of player's postural control following a lower limb injury is of interest to sports science and medicine practitioners due to its fundamental role in daily tasks and sporting activities. The purpose of this study was to measure the longitudinal changes in rugby union player's postural control throughout return to play (RTP) following lower limb injury. Rehabilitation was divided into three phases – acute, middle and late. 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. Static unilateral postural control was measured in the acute phase using a PASCO dual axis force platform (PS-2142). Dynamic postural control was measured using single axis PASCO force platforms (PS-2141) with the middle phase being assessed by unilateral drop jump and the late phase a unilateral lateral hurdle hop. During the acute phase, no improvement were observed between the initial testing session and end testing session, nor any differences between the end of the acute rehabilitation phase and pre-injury baseline. Whereas for the middle and late phase improvements were observed between the initial and end testing session, with smaller magnitudes of dynamic postural control adjustment (DPCA; p <0.05). However, when comparing the end testing session of the middle and late phase of RTP to pre-injury baseline deficits were reported in the ability to restore postural control to pre-injury levels, with larger magnitudes of DPCA (p <0.05). Therefore, greater focus in players' RTP programmes needs to be given to the dynamic postural control players have on landing.

KEYWORDS: return to play, rehabilitation, static postural control, dynamic postural control

INTRODUCTION: Lower limb injuries have been found to occur at a high frequency in team sports (Fuller et al. 2017). Following an injury, structural damage occurs at the injured site, but there are also often deficits in the player's neuromuscular function (Paterno et al. 2010). Postural control can be categorised from static and dynamic functional assessments (Jonsson et al. 2004; Wikstrom et al. 2012), allowing investigation of alterations to players sensorimotor control throughout the course of their rehabilitation until return to play (RTP). Investigations into static postural control typically evaluate unilateral stance, with trials lasting between 20 and 30 s. However, Jonsson and colleagues (2004) identified dynamic and static phases as two distinct components during a unilateral static postural control assessment. The initiation of a trial represents the dynamic phase and characterises the rapid adjustments required to execute the task. The proposed dynamic phase may therefore predispose a player to increased injury risk due to high forces imposed on the lower extremity and an inability for the postural orientation and stability to withstand the variability of these forces. Dynamic postural control has been identified to be a risk factor for sustaining a subsequent injury when RTP (Paterno et al. 2010). Dynamic postural control is typically measured through dynamic postural stability index (DPSI), quantifying how well one can maintain control in transition from dynamic to static state and can be considered to better represent the functional demands of multiplanar sports than solely assessing on static postural control (Wikstrom et al. 2005). DPSI has been proposed to reflect player's ability to decelerate their centre of mass (COM) upon landing, with an association being found between jump height and limb stiffness (Huurnink et al. 2019). Furthermore, DPSI is thought to reflect the peak vertical force that individuals also have to dissipate upon landing (Huurnink et al. 2019). Worse DPSI scores have been found at the point of RTP following a range of lower limb injuries when assessed through uniplanar and multiplanar assessments when compared to controls and injured limbs (Wikstrom et al. 2012; Heinert et al. 2018). To date, no study has longitudinally assessed postural control across the entire rehabilitation period through to RTP. Therefore, the aim of this study was to characterise the longitudinal alterations to postural control throughout rehabilitation following lower limb injury in professional rugby union players.

METHODS: Participants and rehabilitation phases: 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. Players sustained a range of injuries, 50% were ligament, 30% muscle and 10% tendon and bone respectively. Three rehabilitation phases were categorised as, acute, middle and late. The acute phase initial session was categorised from players being medically clear to weight bear and ended at the start of the middle phase which was assessed through intersegmental control and linear movement mechanics. Finally, the late phase consisted of players being medically cleared for multidirectional movements, the end of the late phase was at the point players RTP. Pre-injury baseline measurements were taken as part of a larger 2019-2020 preseason screening. Players were tested at the initiation and end of each rehabilitation phase. The mean duration of the acute, middle and late phases were 7±4 weeks, 10±5 weeks, 6±2 weeks respectively.

Data collection: Unilateral static postural control was measured using PASCO dual axis force platform (PS-2142; 1000 Hz) whereas unilateral drop jump and lateral hurdle hop was measured using PASCO single axis force platforms (PS-2141; 1000 Hz). The acute phase involved assessment of player's unilateral static postural control which were tested under the following two conditions: eyes-open and eyes-closed. A total of 3 x 20 s trials were collected interspersed with 30 s rest periods for each condition. Eyes-open conditions were assessed first, followed by eyes-closed on player's injured limb only. Players were informed that if they should come out of this starting position, they should regain it as soon as possible as the trial would not be stopped. For both conditions, they were verbally instructed when the trial had stopped and to resume a relaxed position. Dynamic postural control was assessed during the middle phase by a unilateral drop jump from 20 cm, three successful trials, with a 30 s rest period interspersed between trials. Finally, the late phase assessed a unilateral lateral hurdle hop. Players were required to hop unilaterally over a 15 cm hurdle and immediately hop back to their initial starting position. Three trials were measured each being interspersed with a 1-minute rest period. Dynamic postural control was measured during the final landing of the two dynamic assessments.

Data analysis: All data were processed using a customised written MATLAB script (Matlab R2019b). A 4th order, recursive low pass Butterworth filter with a cut-off frequency of 34 Hz for unilateral static postural control and 25 Hz for drop jump and hurdle hop was applied. Unilateral static postural control was measured through sway path (m) (Winter 1995; Prieto et al. 1996). The first 5 s of the trial was analysed to assess the dynamic phase of the postural control assessment. As a result of only assessing vertical force, an adjusted DPSI calculation was used with dynamic postural control being referred to as dynamic postural control adjustment (DPCA). $DPCA = \sqrt{(\sum bodyweight - landing\ force)^2 \div landing\ impact}$. Simple, last category contrast analysis were used to assess the difference in postural control 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 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). All statistical analysis was performed using SPSS (v.27.0), significance was set at *p* <0.05.

RESULTS: The acute phase found no difference between pre-injury baseline and end session, and initial to end session for eyes open and eyes closed conditions (Table 1). The middle and late phases showed similar changes in DPCA. Improvements (reductions) were evident during rehabilitation (drop jump: $F(1)$ 10.10, p 0.01, η^2 0.56; ES 1.0; hurdle hop: $F(1)$ 32.47, p <0.001, η^2 0.84; ES 0.94; Table 1) , but these improvements did not lead to pre-injury baseline DPCA being restored at the end of rehabilitation (Drop jump: $F(1)$ 55.92, p <0.001, η^2 0.88; ES 2.7; Hurdle hop: $F(1)$ 7.68, p 0.03, η^2 0.561; ES 1.7).

Table 1 Mean ± standard deviation of sway path (m) and DPCA.

		Testing session		
		Baseline	Initial	End
Sway path (m)	Eyes open	0.22±0.03	0.24±0.05	0.23±0.06
	Eyes closed	0.44±0.07	0.39±0.09	0.41±0.11
Drop jump DPCA		9.23±2.28	20.35±3.70	16.83±3.29
Hurdle hop DPCA		8.73±3.57	25.45±16.02	14.53±3.38

Dashed underline: significant difference between pre-injury baseline and the end session (p <0.05), solid underline: significant comparison between the initial and end session (p <0.05)

DISCUSSION: The aim of this study was to characterise the longitudinal alterations to postural control throughout rehabilitation following lower limb injury in professional rugby union players. Improvements were found in all measures of postural control between initial and end of each rehabilitation phase. However, across the phases overall there were still deficits compared to pre-injury (baseline) levels of postural control.
The acute phase found similar magnitudes of sway path during the dynamic phase between for both eyes open and eyes closed conditions between all session comparisons. The similarity across all testing sessions suggests players still exhibit the same static postural control, implying that there are no acute changes in player's postural control. The middle and late phases demonstrate smaller DPCA, indicated that there have been improvements across the rehabilitation sessions in a player's ability to control the deceleration of the COM upon landing (Huurnink et al. 2019). Given the improvements across rehabilitation sessions, findings suggest that players have effectively improved their ability to tolerate and dissipate kinetic energy on landing. Despite rehabilitation across the middle and late phases improving the ability to decelerate the COM during functional assessments, it was not able to restore player's back to their healthy baseline. This is further supported by the findings of the middle and late phase of rehabilitation, as DPCA did not return to pre-injury baseline at the end of the last two phases. These findings advocate landing to be a complex action, requiring both dynamic resistance from structures to withstand the force and simultaneously, enable rapid deceleration of the COM. Empirical findings suggest that control of functional assessments was not adequately addressed before rehabilitation was progressed. The abnormal landing mechanisms in this current study suggest persistent deficits to neurosensory characteristics through an inability to control and stabilise on landing, as a result of the inability to absorb and dissipate kinetic energy during impact (Heinert et al. 2018). Moreover, this could also infer that there is an altered tone of the multi-linked lower limb segment across all phases. Therefore, although rehabilitation during the middle and late phase improved the ability to decelerate the COM following reactive rebound functional assessments, it was not able to restore players back to their healthy baseline. This supports previous research which has observed deficits in functional assessments at the point of RTP, meaning control of landing linear movements was not adequately addressed before rehabilitation was progressed (Decker et al. 2002; Paterno et al. 2007; King et al. 2019; Miles et al. 2019; Gore et al. 2020).

CONCLUSION: Dynamic postural control improvements were identified during the middle and late rehabilitation phase. However, these improvements did not return to baseline, with altered kinetics throughout each rehabilitation phase including at the point of RTP. The findings of this study suggest that rehabilitation may not effectively return player's pre-injury movement strategy to control their COM. Practitioners are advised to focus on player's aberrant kinetics to control their COM during dynamic functional assessments.

REFERENCES

Decker, M.J., Torry, M.R., Noonan, T.J., Riviere, A. and Sterett, W.I. 2002. Landing adaptations after ACL reconstruction. *Medicine and Science in Sports and Exercise* 34(9), pp. 1408–1413. doi: 10.1097/00005768-200209000-00002.

Fuller, C.W., Taylor, A., Kemp, S.P.T. and Raftery, M. 2017. Rugby World Cup 2015: World Rugby injury surveillance study. *British Journal of Sports Medicine* 51(1), pp. 51–57.

Gore, S.J., Franklyn-Miller, A., Richter, C., King, E., Falvey, E.C. and Moran, K. 2020. The effects of rehabilitation on the biomechanics of patients with athletic groin pain. *Journal of Biomechanics* 99, p. 109474.

Heinert, B., Willett, K. and Kernozek, T.W. 2018. Influence of Anterior Cruciate Ligament Reconstruction on Dynamic Postural Control. *International Journal of Sports Physical Therapy* 13(3), pp. 432–440.

Huurnink, A., Fransz, D.P., Kingma, I., de Boode, V.A. and Dieën, J.H. va. 2019. The assessment of single-leg drop jump landing performance by means of ground reaction forces: A methodological study. *Gait and Posture* 73, pp. 80–85.

Jonsson, E., Seiger, Å. and Hirschfeld, H. 2004. One-leg stance in healthy young and elderly adults: A measure of postural steadiness? *Clinical Biomechanics* 19(7), pp. 688–694.

King, E., Richter, C., Franklyn-Miller, A., Wadey, R., Moran, R. and Strike, S. 2019. Back to Normal Symmetry? Biomechanical Variables Remain More Asymmetrical Than Normal During Jump and Change-of-Direction Testing 9 Months After Anterior Cruciate Ligament Reconstruction. *The American Journal of Sports Medicine* 47(5), pp. 1175–1185.

Miles, J.J., King, E., Falvey, É.C. and Daniels, K.A.J. 2019. Patellar and hamstring autografts are associated with different jump task loading asymmetries after ACL reconstruction. *Scandinavian Journal of Medicine and Science in Sports* 29(8), pp. 1212–1222.

Paterno, M.V., Ford, K.R., Myer, G.D., Heyl, R. and Hewett, T.E. 2007. Limb asymmetries in landing and jumping 2 years following anterior cruciate ligament reconstruction. *Clinical Journal of Sport Medicine* 17(4), pp. 258–262.

Paterno, M.V., Schmitt, L.C., Ford, K.R., Rauh, M.J., Myer, G.D., Huang, B. and Hewett, T.E. 2010. Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport. *American Journal of Sports Medicine* 38(10), pp. 1968–1978.

Prieto, T.E., Myklebust, J.B., Hoffmann, R.G., Lovett, E.G., Myklebust, B.M., Member, S. and Myklebust, B.M. 1996. Measures of postural steadiness: Differences between healthy young and elderly adults. *IEEE Transactions on Biomedical Engineering* 43(9), pp. 956–966.

Wikstrom, E.A., Tillman, M.D., Chmielewski, T.L., Cauraugh, J.H., Naugle, K.E. and Borsa, P.A. 2012. Discriminating between copers and people with chronic ankle instability. *Journal of Athletic Training* 47(2), pp. 136–142.

Wikstrom, E.A., Tillman, M.D., Smith, A.N. and Borsa, P.A. 2005. A new force-plate technology measure of dynamic postural stability: The dynamic postural stability index. *Journal of Athletic Training* 40(4), pp. 305–309.

Winter, D.A. 1995. Human balance and posture standing and walking control during. *Gait and Posture* 3(2), pp. 193–214.

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