CAN A SINGLE LEG SQUAT SCREEN PROVIDE AN INSIGHT INTO NEUROMUSCULAR CONTROL DURING A SINGLE LEG DROP LANDING AND A RUNNING CUT

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This study examined relationships between three dimensional (3D) pelvis, hip and knee biomechanical measures in a bodyweight single leg squat and those same measures in a drop landing and a pre-planned 75° cutting manoeuvre. 40 field sports players with chronic athletic groin pain were recruited. There were no significant ($p > 0.05$) correlations between hip and pelvis measures in the SLS and the equivalent measures in either the drop landing or cut. This suggests that a SLS screen may not be a valid test to identify those with abnormal hip and pelvis control in aggravating activities like landing and cutting. There were, however, significant correlations ($p < 0.05$) between knee measures in the SLS and drop landing which may be relevant to knee injury screening.

KEYWORDS: athletic groin pain, functional screening, correlation

INTRODUCTION: Abnormal lower limb mechanics during functional movements have been implicated in the aetiology of several injuries including chronic athletic groin pain (Falvey et al. 2009) and anterior cruciate knee ligament injury (Myer et al. 2005). The examination of lower extremity movement quality (neuromuscular control) during functional tasks is thus frequently used to screen for potential injury risk and to assess rehabilitation progress following injury (Dingenen et al. 2013). The current authors, for example, use a SLS screen to assess rehabilitation status in athletic groin pain patients.

The single leg squat (SLS) is a common functional test used in the assessment of neuromuscular control (Chmielewski et al. 2007). In spite of this there is still much debate regarding its effectiveness. While several authors suggest that the SLS may be useful in screening for injury risk (Chmielewski et al. 2007; Graci et al. 2012), others have questioned its validity and the lack of evidence based research supporting its use (Aikens et al. 2013; DiMattia et al. 2005). From an ecological validity perspective, a major criticism of the SLS is that it does not involve the same speed or dynamic loading characteristics of normal sporting actions that are implicated in the aetiology of injury (Ageburg et al. 2010), such as cutting (Falvey et al. 2009) and landing (Myer et al. 2005). It therefore remains unclear whether a SLS movement screen can provide an insight into relevant deficiencies during more dynamic activities.

The aim of the current study is to examine the relationships between 3D biomechanical measures (at the pelvis, hip and knee) in a SLS and those same measures in a single leg drop landing and cutting manoeuvre. In addition a comparison of ground reaction forces and movement speeds between the three tests will also be undertaken.

METHODS: Forty (n = 40) male recreational field sports players diagnosed with chronic athletic groin pain were recruited from patients at the Sports Surgery Clinic, Dublin, Ireland (mean ± *SD*: age, 27.8 ± 6.3 years; height, 180.2 ± 6.1 cm; mass, 83.1 ± 10.7 kg; time with groin pain, 53.8 ± 70.2 weeks). The majority of participants played Gaelic football (60%),

hurling (18%), soccer (10%) and rugby (8%). A SLS screen is currently used with these patients to assess rehabilitation status. Participants provided written informed consent as required by the Sports Surgery Clinic's Ethics Committee.
Testing involved three trials of a SLS, a single leg drop landing (30 cm) and a running cut (75°). For the running cut, participants ran as fast as possible toward a marker placed on the floor, made a single complete foot contact in a 40X60cm area in front of the marker (the force plate), and performed an approximate 75° cut before running maximally to the finish. The cutting direction was pre-planned whereby participants knew the direction in which they were cutting before completing the task. An eight camera 3D motion analysis system (Vicon - Bonita B10, UK), synchronized with two 40 x 60 cm force platforms (AMTI – BP400600, USA), was used to collect kinematic and kinetic data. Reflective markers were placed at bony landmarks according to Plug in Gait marker locations (Vicon, UK). Both marker and force data were filtered using a fourth order Butterworth filter with a cut-off frequency of 15 Hz. Standard inverse dynamics techniques (Winter 2005) were employed to calculate segmental and joint mechanics.
Trials on the symptomatic side were selected for further analysis. Three dimensional hip, knee and pelvis angles (range of motion) were examined as measures of neuromuscular control. In addition, maximum moments at the hip and knee were also analysed. Moments were normalised to body mass (kg). The mean of each participant's three trials were used in the analyses.
Pearson product moment correlations were calculated for a given measure in the SLS and this same measure in either the drop landing or cut. A significance level of $\alpha < 0.01$ was adopted for this analysis; a more stringent α value was used due to the number of relationships being examined. To compare the loading and movement characteristics of each test, differences in ground reaction forces and time to peak knee flexion were examined using a repeated measures ANOVA with bonferroni post-hoc analysis. A significance level of $\alpha < 0.05$ was adopted for this analysis.

RESULTS: Table 1 details the results of the correlation analysis which examined relationships between biomechanical measures in the SLS and equivalent measures in the single leg drop landing and running cut. Of the nine range-of-motion measures examined, there were two significant ($p < 0.05$) correlations between the SLS and drop landing (knee adduction/abduction and knee internal/external rotation range of motion) but none between the SLS and the running cut. Of the six peak moment measures examined, there were three significant ($p < 0.05$) correlations between the SLS and drop landing (knee moments in all three planes), but none between the SLS and the cut.
The drop landing displayed significantly greater vertical ground reaction forces than the cut which in turn had greater vertical forces than the SLS (Table 2). In contrast, forces in the medial/lateral and anterior/posterior directions were greater in the cut in comparison to the other movements. In addition time to peak knee flexion was shortest in the cut followed by the drop landing and then the SLS.

Table 1. Correlations between biomechanical measures in the single leg squat and in the drop landing and running cut

Joint		Magnitudes			Correlations	
		SLS Mean ± SD	Drop Land Mean ± SD	Cut Mean ± SD	Drop Land r (p)	Cut r (p)
Knee ROM (°)	Flex/ext	64.1 ± 12.9	49.1 ± 8.9	42.9 ± 13.5	0.43 (0.07)	-0.06 (0.79)
	Ab/add	9.8 ± 5.5	7.9 ± 4.9	13.1 ± 5.3	0.61 (< 0.01)*	0.03 (0.91)
	Int/ext	16.0 ± 5.5	19.0 ± 4.8	18.4 ± 6.4	0.62 (< 0.01)*	0.42 (0.07)
Hip ROM (°)	Flex/ext	56.3 ± 11.4	23.5 ± 8.2	42.6 ± 11.1	0.26 (0.24)	0.03 (0.90)
	Ab/add	12.3 ± 4.2	15.6 ± 5.3	12.3 ± 4.7	0.15 (0.49)	-0.21 (0.34)
	Int/ext	8.5 ± 3.8	10.0 ± 4.8	22.9 ± 8.3	0.43 (0.05)	0.11 (0.64)
Pelvis ROM (°)	Flex/ext	13.8 ± 4.8	5.2 ± 3.0	12.0 ± 3.9	-0.03 (0.88)	-0.11 (0.64)
	Ab/add	9.9 ± 4.2	10.1 ± 3.6	10.1 ± 3.8	0.17 (0.44)	-0.18 (0.41)
	Int/ext	8.5 ± 3.4	7.0 ± 3.7	18.4 ± 6.1	-0.07 (0.75)	0.03 (0.91)
Knee peak moment (N·m/kg)	Flex/ext	12.9 ± 2.6	28.5 ± 5.8	23.9 ± 5.2	0.55 (0.01)*	0.27 (0.23)
	Ab/add	12.3 ± 2.6	22.6 ± 5.2	11.6 ± 4.9	0.62 (< 0.01)*	0.28 (0.22)
	Int/ext	1.1 ± 0.5	2.7 ± 1.0	2.1 ± 0.8	0.69 (< 0.01)*	0.16 (0.47)
Hip peak moment (N·m/kg)	Flex/ext	14.3 ± 2.9	21.7 ± 12.1	26.0 ± 7.5	-0.08 (0.74)	0.03 (0.90)
	Ab/add	7.5 ± 1.3	17.9 ± 5.2	14.3 ± 4.8	0.32 (0.15)	-0.10 (0.65)
	Int/ext	5.3 ± 1.4	6.6 ± 1.6	5.7 ± 1.9	0.06 (0.78)	0.17 (0.44)

*Significant correlation ($p < 0.01$)

Table 2. Comparison of peak ground reaction force and time to peak knee flexion

Factor	Plane	SLS Mean ± SD	Landing Mean ± SD	Cut Mean ± SD	Summary
Peak force ($N.kg^{-1}$)	Vertical	10.9 ± 0.7	34.2 ± 3.7 †	17.5 ± 3.4 † ¥	L>C>S
	Ant/Post	0.2 ± 0.1	4.0 ± 0.5 †	10.6 ± 2.3 † ¥	C>L>S
	Med/Lat	0.2 ± 0.1	1.9 ± 0.5 †	2.7 ± 1.1 † ¥	C>L>S
Time to peak knee flexion (ms)	Sag	153 ± 80	26 ± 12 †	10 ± 3 † ¥	S>L>C

† Significantly different compared with SLS ($p < 0.05$)
¥ Significantly different compared with the landing ($p < 0.05$)

DISCUSSION: There were no significant correlations between any biomechanical measure in the SLS and the running cut. These findings suggest that the single leg squat test cannot provide an insight into neuromuscular control while cutting. This is of relevance as poor neuromuscular control of the pelvis, hip and lower extremity during commonly aggravating sporting actions like cutting are considered key factors in the development of chronic athletic groin pain (Falvey et al. 2009). The usefulness of undertaking a SLS screen to assess individuals with this injury (or other injuries associated with cutting actions) therefore appears questionable.

Similar to the running cut results, there were no significant correlations between hip and pelvis measures in the SLS in comparison to the single leg drop landing. This suggests that a SLS screen may not be a valid test to identify individuals with abnormal hip and pelvis control in dynamic activities such as unilateral landing. In contrast to the hip and pelvis findings, there were several correlations between the SLS and the single leg drop landing for knee related factors. Knee flexion/extension and internal/external rotation range of motion in the SLS, as well as peak knee moments, were all significantly related to these same measures in the drop landing (r range = 0.55 - 0.61). It appears therefore, that the SLS can provide an insight into neuromuscular control of the knee in single leg landings. This is of relevance as single leg landing activities are, at least in part, implicated in knee injuries such as anterior cruciate knee ligament injury (Kristianslund & Krosshaug, 2013). Unlike our findings, Kristianslund and Krosshaug (2013) found that knee abductor/adductor moments were not related between the SLS and a bi-lateral drop landing (r = 0.14). It would appear that the degree to which a SLS screening test can account for neuromuscular control in a landing activity depends on whether that landing activity is uni- or bi-lateral.

Findings presented in table 2 clearly illustrate that the SLS and the drop landing involve whole-body loading primarily in the sagittal plane (Table 2). In contrast, the cut displayed considerable forces in all three movement planes. These findings may partly explain why the SLS was able to provide an insight into some biomechanical factors in the drop landing but not in the running cut. As the movement in question moved from the predominantly sagittal plane activity of a drop landing to the tri-planar plant and pivot of the running cut, the number of significant correlations with the SLS diminished. These findings support the notion that clinicians must ensure that the screening tests they use should be as specific as possible to the injury mechanism they are examining (Ageburg et al. 2010).

CONCLUSION: Our findings suggest that a SLS movement screen cannot provide a meaningful insight into neuromuscular control during a running cut manoeuvre. In addition, the SLS could not provide an insight into neuromuscular control at the hip or pelvis during a single leg drop landing. Together, these findings do not support the use of a SLS in assessing abnormal hip and pelvis biomechanics during such dynamic sporting actions. This is of particular relevance to the assessment of athletic groin pain as poor neuromuscular control of the hip and pelvis during aggravating activities such as uni-lateral landing and cutting may be associated with the development of this injury. Additional findings do suggest that a SLS may provide an insight into neuromuscular control at the knee while performing a single leg landing. This may be significant as poor control in a single leg landing is a common mechanism of knee injury.

REFERENCES:

Ageberg, E., Bennell, E., Hunt, M., Simic, M., Roos, E. & Creaby, M. Validity and inter-rater reliability of medio-lateral knee motion observed during a single-limb mini squat. (2010). *BMC Musculoskeletal Disorders*, 11, 265.

Akins, J.,Longo, P., Bertoni, M., Clark, N., Sell, T., Galanti, G. & Lephart, S. (2013). Postural stability and isokinetic strength do not predict knee valgus angle during single-leg drop-landing or single-leg squat in elite male rugby union players. *Isokinetics and Exercise Science,* 21, 37-46.

Chmielewski TL, Hodges MJ, Horodyski M, Bishop MD, Conrad BP, Tillman SM. (2007). Investigation of clinical agreement in evaluating movement quality during unilateral lower extremity functional tasks: a comparison of 2 rating methods. *The Journal of Orthopaedic and Sports Physical Therapy*, 37, 122-9.

DiMattia, M., Livengood, A., Uhl, T., Mattacola, C., & Malone, T. (2005). What are the validity of the single-leg-squat test and its relationship to hip-abduction strength? *Journal of Sports Rehabilitation*, 14, 108-123.

Dingenen B, Malfait B, Vanrenterghem J, Verschueren SM, Staes FF. (2013). The reliability and validity of the measurement of lateral trunk motion in two-dimensional video analysis during unipodal functional screening tests in elite female athletes. *Physical Therapy in Sport*, epub ahead of print.

Falvey, E., Franklyn-Miller, A. & McCrory, P. (2009). The Groin Triangle: A clinical patho-anatomical approach to the diagnosis of chronic groin pain in athletes. *British Journal of Sports Medicine*, 43, 213-20.

Graci V, Van Dillen LR, Salsich GB. (2012). Gender differences in trunk, pelvis and lower limb kinematics during a single leg squat. *Gait Posture,* 36, 461-6.

Kristianslund, E., Krosshaug, T. (2013). Comparison of drop jumps and sport-specific sidestep cutting: implications for anterior cruciate ligament injury risk screening. *American Journal of Sports Medicine,* 41, 684-8.

Myer, G., Ford, K., Palumbo, J., & Hewett T. Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. (2005). *Journal of Strength and Conditioning Research*, 19, 51-60.

Acknowledgement

This study has emanated from research supported in part by a research grant from Science Foundation Ireland (SFI) under Grant Number SFI/12/RC/2289.