## INTRODUCTION

A significant number of acute injuries within the sporting population are associated with the hamstring muscles (Mason *et al*, 2012). They are most prevalent in sports involving rapid acceleration and sprinting such as soccer (Hoskins and Pollard, 2005a). Ekstrand *et al* (2011) found almost one third of all injuries in professional soccer are muscle related and 37% of these affect the hamstring region. Globally, hamstring injuries in professional soccer account for between 11% and 15.9% of all muscle injuries (Dadebo *et al*, 2004; Woods *et al*, 2004; Arnason *et al*, 2008).

A clinical review of British soccer hamstring injuries found a total of 13,116 days and 2,029 matches were missed, an average of 90 days and 15 matches for each of the 91 clubs included per season (Woods *et al*, 2004). Petersen *et al* (2010) reported a mean of 3.4 hamstring injuries per season, and a mean of 21.5 days missed per injury in the Danish professional league. Hamstring injuries are therefore, associated with prolonged absence from competition ranging from a few days to weeks, producing a substantial economic impact through missed training time, match unavailability and lost player payments (Ekstrand *et al*, 2013; Hallen and Ekstrand , 2014; Moen *et al*, 2014; Bahr *et al*, 2015).

Numerous risk factors have been proposed for the incidence and occurrence of hamstring pathology. Frickleton and Pizzari (2013) meta-analysis concluded age, injury and increased quadriceps torque are associated with hamstring injury. Other risk factors including H:H ratio, peak torque, extensibility and proprioception require further investigation. Equivocal evidence is available for the role of decreased hamstring extensibility (Witvrouw *et al*, 2003; Arnason *et al*, 2008; Clark, 2008; Freckleton and Pizzari, 2013). However, Witvrouw *et al* (2003) found decreased hamstring extensibility was associated with hamstring injury in Belgian soccer players ($p=0.02$). Importantly, a significant difference between hamstring extensibility in injured and non-injured athletes exists (Worrell *et al*, 1991; Bradley and Portas, 2007; Henderson *et al*, 2010)**.** Level 2 evidence suggests that hamstring

extensibility deficit is associated with return to play time and increased extensibility significantly reduces lower extremity overuse injuries (Hartig and Henderson, 1999; Witvrouw *et al*, 2003; Dadebo *et a,l* 2004; Malliaropoulos *et al*, 2010). Despite the role of hamstring extensibility being ambiguous amongst research, clinically, restoration of hamstring extensibility is considered an important part of return to play criteria post hamstring injury in professional soccer teams (Delvaux et al, 2013).

Authors (Watson 1995; Verrall *et al*, 2001; Watson 2001; Hoskins and Pollard 2005b; Mason *et al*, 2012) have suggested lumbar spine, sacroiliac and pelvic orientation/control are areas clinicians must assess and treat as part of a holistic approach to hamstring management. This is due to the anatomical and functional relationship between the regions. Range of motion deficits can be addressed with manual therapy to normalize extensibility limitations, due to the evidence of static stretching to increase tissue extensibility in soccer players, remaining unclear (Hoskins and Pollard, 2005b; Arnason *et al*, 2008; Sherry *et al*, 2015).

Szlezak *et al* (2011) investigated the effect of unilateral zygapophyseal lumbar mobilisations on the posterior neurodynamic chain. Multi-level mobilisations increased neurodynamics of the posterior lower limb in the immediate term, compared to stretching and control groups ($p < 0.001$). Grade III zygapophyseal mobilisations (large amplitude into resistance) at L4/5 have been shown to induce sympathetic nervous system changes in the lower limb (Perry and Green, 2008). Shanker Ganesh *et al* (2014) reported consistent results whilst replicating Szelzak *et al* (2011) study with a 24-hour follow-up. However, only the neurally biased SLR was used by Szelzak *et al* (2011) and Shanker Ganesh *et al* (2014) as outcome measures, in a non-sporting population, therefore the effect of the intervention on muscle biased tests and elite sports people is unknown.

A lack of evidence is available to determine the effect of lumbar mobilisations on both the neural and muscle components of the hamstring complex. Whilst studies have been conducted in the general population, the potential to affect hamstring extensibility components in elite athletes and specifically soccer, where the practice is common, has yet to be addressed. This study aimed to address this by investigating the effect of L4/5 lumbar

zygapophyseal mobilisations on hamstring tissue extensibility biased to both the neural and muscle components. We also investigated the potential of lumbar mobilisations to increase tissue extensibility in elite soccer to allow comparisons to previously researched non-elite populations.

## METHODOLOGY

Participants

A convenience sample from the target population recruited current male soccer players employed at a Premier League Club, between July 2012 and June 2013, aged between eighteen and twenty-two. Table 1 displays the sample descriptions.

Table 1 – Description statistics for intervention and control groups

| | **Intervention Group** | **Control Group** |
|---|---|---|
| | **Mean ± SD** | **Mean ± SD** |
| Age (years) | 17.9 ± 1.0 | 18.3 ± 1.4 |
| Height (cm) | 179.8 ± 6.2 | 176.6 ± 6.7 |
| Body Mass (kg) | 75.6 ± 6.4 | 72.7 ± 5.0 |

Due to the elite sample required, players at the Premier League Soccer Club were contacted directly to participate in the study. The athletes were included if they were current professional soccer players without current pathology preventing participation in soccer training and match-play. Participants were excluded if they reported current symptomatic low back pain, hamstring or hip pathology, diagnosed with neurological disorders or presented with neurological symptoms. Previous lumbar surgery, and those with any contraindications to spinal mobilisation were also excluded (Maitland *et al*, 2005; Ridehalgh *et al*, 2005). To replicate clinical practice participants were not excluded based on their current hamstring extensibility or previous hamstring injury. Participants gave

informed consent and all study procedures were conducted according to Sheffield Hallam's ethics committee, which granted approval for the study.

Procedures

A pre-test/post-test parallel design measured change in both the intervention and control group. Players were randomised to one of two groups; intervention and control. A physiotherapist, blinded to the study verified athletes met the inclusion criteria, and performed the randomisation process using Microsoft Excel 2010 (Microsoft Corp, Redmond, Washington).The order of the two outcome measures, the straight leg raise (SLR) (Figure 1) and passive knee extension test (PKE) (Figure 2), were counterbalanced to prevent the order of assessment adversely influencing measurements. Measurements of the SLR and PKE were taken at initial assessment. The study took place within the professional clubs medical treatment room on a non-training day.

Pre-Conditioning

Range of motion during assessment tests can be influenced by repeated assessment (Dixon and Keating, 2000). A pilot study of three players identified five SLR and four PKE were required to counteract the fluctuations and gain consistent measurements. Therefore following this preconditioning protocol the final test was recorded as the pre-intervention measurement. Preconditioning tissue in this way allows stiffness to be stabilised and repeatable data obtained (Lee and Munn, 2000). The pilot study identified a 9-minute period was required for the clinician to explain, identify and perform lumbar mobilisations.

Measurement Protocol

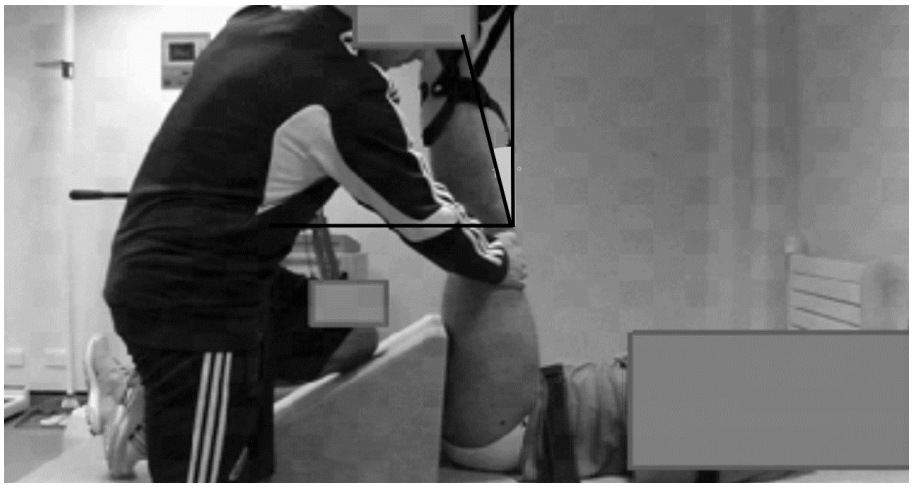
Test leg was determined by dominant/kicking foot, with 80% (20/25) right foot dominant. The SLR, was utilised as a reliable (ICC 0.95-0.96) neural biased assessment tool (Butler, 2000; Alonso *et al*, 2009; Rancour *et al*, 2009; Alyala *et al*, 2010; Ayala and Sainz de Baranada, 2010) . During the SLR, the ankle was held in zero degrees dorsiflexion by an ankle brace, ensuring a fixed position preventing fluctuations in neural sensitization (Boyd *et al*, 2009; Boyd *et al*, 2010). The participant's knee was placed in manual extension, determined by the examiner as end range resistance. The anterior pelvis and non-dominant leg were secured to the plinth via mobilisation

belts. The test leg was raised increasing hip flexion while the ankle and knee were maintained in neutral, with the clinician preventing hip rotation during the test (Figure 1). Participants were instructed to verbally notify the examiner when they felt "mild discomfort", a method found to be reliable (ICC 0.96) (Portney and Watkins, 2009; Feland *et al*, 2010). An inclinometer, a valid and reliable measure (ICC 0.95-0.99) of the SLR for intra-session analysis, was placed on the mid-tibia anteriorly recording measurement (Boyd, 2012).

Figure 1 – SLR Testing Procedure

The PKE test was reported as a reliable method (ICC 0.91-0.98) for measuring muscle hamstring tissue extensibility (Gajdosik, 1991; Bandy and Irion, 1994; Bandy *et al*, 1997; Hartig and Henderson, 1999; Ford and McChesney, 2007; Feland *et al*, 2010; Atamaz *et al*, 2011). A purpose made wooden wedge provided the testing clinician with a right angled surface to ensure the hip was held at 90 degrees. The ankle was maintained in plantigrade by an ankle brace. The knee was passively extended to 'mild discomfort' determined by the participant. An inclinometer was held to the subject's tibial crest at the distal end of the tibial tuberosity (Johnson *et al*, 2014). Full knee extension was considered zero degrees, and therefore measurements were taken from this reference point and calculated as a negative value. The pelvis and non-dominant leg was secured to the bed as per the SLR (Figure 2).

Figure 2 – The PKE Testing Position



Two experienced musculoskeletal clinicians with postgraduate qualifications were involved in the assessment and recording process and were both blinded to group allocation. Testing clinicians were also blinded to the studies aims and were simply instructed on how to perform the outcome measures and measurements. One clinician measured the appropriate angles throughout with the other clinician manually performing the assessment tests. The measuring clinician did not inform either the primary researcher or second tester to the results between each intervention and retesting.

Participants allocated to the intervention group were taken into a separate room and received lumbar mobilisations of the unilateral zygapophyseal L4/5 joint to the ipsilateral side as the dominant limb. Louis (1981) reported the lumbar neural convergence point was anatomically adjacent to L4/5 and together with the nerve root innervation of the hamstrings (L5), provided the clinical rationale for mobilising this segment. Grade III posterior-anterior (PA) mobilisations were applied to the intervention group for one minute, three times, at the L4/L5 vertebral level to reflect common clinical application and previous studies (Maitland *et al*, 2005; Stamos-Papastamos *et al*, 2011). The level was determined by a passive physiological intervertebral movement (Maitland*et al*, 2005). Lumbar mobilisations to the L4/5 region were performed by a separate experienced clinician blinded to the pre measurements.

The control group, following pre-measurement, lay in prone on a plinth in a separate room for the 9-minute interval determined by the pilot study. Post intervention and control SLR/PKE were re-assessed once and measurements taken.

Statistical Analysis

Data are presented as the mean ± standard deviation (SD). Prior to analysis all outcome measures were log transformed and then back transformed to obtain the percent difference, with uncertainty of the estimates expressed as 90% confidence intervals (CI), between the post and pre-tests. This is the appropriate method for quantifying changes in athletic performance (Hopkins *et al,* 2009). We used mixed effects linear modeling (SPSS v.21, Armonk, NY: IBM Corp) to analyse the intervention effect as this method allows for and quantifies (as a SD) individual differences in response to the intervention. An analysis of covariance (ANCOVA) method was adopted to compare the two groups, with the pre-test score and test order as covariates. Effects were then evaluated for clinical significance by pre-specifying 0.2 between-subject SDs as the smallest worthwhile effect (Hopkins *et al,* 2009). Inference was subsequently based on the disposition of the confidence interval for the mean percentage difference to the smallest worthwhile effect; the probability (percentage chances) that the true population difference between trials was substantially beneficial, harmful (>0.2 SDs) or trivial was calculated as per the magnitude-based inference approach (Batterham and Hopkins, 2006). These percentage chances were qualified via probabilistic terms and assigned using the following scale: 25–75%, possibly; 75–95%, likely; 95–99.5%, very likely; >99.5%, most likely (Hopkins, 2007; Hopkins *et al*, 2009). Magnitude-based inferences were then categorised as clinical given that interventions can be potentially harmful as well as beneficial. The default probabilities for declaring an effect clinically beneficial are <0.5% (most unlikely) for harmful and >25% (possibly) for benefit; a clinically unclear effect is therefore possibly beneficial (>25%) with an unacceptable risk of harm (>0.5%) (Hopkins *et al*, 2009).

## RESULTS

The baseline outcome measures, along with effect statistics and inferences for the within- and between-treatment comparisons are presented in Table 2. After controlling for baseline imbalances and test order, the application of lumbar mobilisations had a very likely small beneficial effect on SLR test and a possibly small beneficial effect on the PKE test.

**Table 2 Outcome measures at baseline with effect statistics and inferences for within- and between-group comparisons**

| | Mobilisation group | | Control group | | (Mobilisation veruscontrol) | |
|---|---|---|---|---|---|---|
| | Baseline values (mean ± SD) | Adjusted change score (% mean; 90% CI) | Baseline values (mean ± SD) | Adjusted change score (% mean; 90% CI) | Difference between groups (% mean; 90% CI) | Qualitative inference |
| ***Measures*** | | | | | | |
| SLR | 75.9 ± 8.7 | 4.3; 2.5 to 6.2 | 79.5 ± 10.6 | -1.9; -3.6 to 0.0 | 6.3; 3.6 to 9.0 | Small +ve*** |
| PKE | -21.6 ± -8.7 | -22.8; -32.0 to 12.5 | -21.1 ± 10.4 | 1.4; -11.1 to 15.6 | -23.9; -36.6 to -8.7 | Small +ve** |

SD = standard deviation. CI = confidence interval. +ve = positive effect on mobilisation group when compared to controls.

SLR = Straight Leg Raise. PKE = Passive Knee Extension

*25-75%, possibly; **75-95%, likely; ***95-97.5% Very Likely

## DISCUSSION

Hamstring injuries within elite soccer are responsible for the greatest time lost to competition due to muscle injury (Ekstrand *et al,* 2011). The exact causes of hamstring strain injury remain unknown, though it is widely acknowledged, that hamstring injury risk is multifactorial in nature. Age, previous injury, eccentric strength and fascicle orientation are all considered notable risk factors (Prior et al, 2009; Opar et al, 2012; Timmins et al, 2014; Brunker, 2015). Extensibility is linked to hamstring injury in soccer players and is considered an important part of athlete conditioning and injury prevention (Witvrouw *et al,* 2003; Dadebo *et al,* 2004, Nelson and Bandy, 2005; Bradley and Portas, 2007; Clark, 2008; Henderson et al, 2009). This study demonstrates a *very likely small beneficial* effect with improvement of hamstring extensibility with the neurally biased SLR test. The intervention also produced a *likely small beneficial* effect on the muscle biased PKE test. L4/5 mobilisations increased hamstring extensibility of both the neural and muscle components of the hamstring complex in the immediate term of young male soccer players when compared to a control. These results suggest practitioners working in an elite soccer environment can influence hamstring extensibility through specific lumbar mobilisations, however the mechanisms responsible for these changes are not addressed.

The effects observed in this study may be due to change in the biomechanical or neurophysiological properties of the nervous tissue as a result of the mobilisations to the L4/5 zygapophyseal joint (Shacklock, 2005). Numerous hypothesises have been described to explain increases in muscle extensibility. Saranga *et al* (2003) observed an increase in an upper limb neural test with cervical mobilisations. The authors suggested the recorded change may be due to the mobilisation influencing the mechanical interface thus increasing neural

tissue movement. A further explanation may be related to participants altered perception through the 'sensory theory' (Weppler and Magnusson, 2010). Numerous authors, (Halbertsma and Goeken, 1994; Halberstma *et al*, 1996; Magnusson *et al*, 1996; Nelson and Bandy, 2004) through hamstring muscle group studies, have all suggested increases in extensibility are due to the phenomenon of stretch tolerance. Increases in neural extensibility may also be due to decreasing neuromeningeal sensitivity. Mobilisation without thrust can attenuate alpha motoneuronal excitability leading to short-term inhibitory effects on the motor system (Dishman and Bulbulian, 2000). Perry and Green (2008) reported side-specific peripheral sympathetic nervous change in the lower limb from L4/5 zygapophyseal mobilisations. They concluded neurophysiological and anatomical inter-relationships in the lumbar region exist and modulation can be achieved with mobilisation.

This study was the first to examine the effects of lumbar mobilisation on both neural and muscle components of the hamstring region. The study developed the work of Szlezak *et al* (2011) who found multi-level facet mobilisation increased neurodynamics of the posterior lower limb tested via the SLR. This study's sample differs to Szlezak's work, which used a large age range and a non-elite sports population. The *very likely small beneficial* effect found in this study may have further and larger benefits in athletes with original shorter hamstring range. Szlezak *et al* (2011) study mobilised each segment (T12-S1) for a 30 second period, three times. A differing treatment dosage of one minute, three repetitions (L4/5) was used in this study. Despite both studies observing improvement in hamstring extensibility following the application of lumbar mobilisations, the influence of different treatment doses to increase hamstring extensibility is not currently known. Shankar Ganesh *et al* (2014) replicated Szlezaks *et al* (2011) study reporting consistent results. A 24-hour follow-up also identified that improvements in hamstring extensibility had been maintained. The authors

acknowledge the lack of follow-up in the current study minimises potential comparisons to Shanker Ganesh et al (2014) work. This area of research is required to understand any potential short and medium term effects lumbar mobilisation may have on hamstring extensibility.

The current study findings support the potential of the neural system to influence hamstring extensibility. Recently researchers have investigated the effect of neurodynamic sliding on hamstring extensibility reporting superior results to muscle stretching (Castellote-Caballero *et al*, 2014). The study suggested that isolated neurodynamic intervention provided a greater immediate increase in the SLR range of motion compared to a static stretching and control group. Despite the large sample, only participants with a SLR below 80 degrees, were included. Potentially these individuals with shortened hamstring tissue may be favorable to increased length post intervention compared to a population with greater initial hamstring length. The participants, in the current study, were not excluded based on current hamstring range replicating clinical practice. Participants were not grouped in relation to previous hamstring injury, severity and time lost to competition and therefore the impact of these factors on the study's results are unknown. However, all participants were currently injury free and actively involved in club training and matches.

Castellote-Caballero *et al* (2013) also previously investigated the effects of a neurodynamic sliding technique on hamstring flexibility in male soccer players. This pilot study found a nerve sliding exercise increased the immediate extensibility of the hamstring muscle group. Similar results from work by Mendez-Sanchez *et al* (2010) in soccer players, provide evidence to support the theories that hamstring extensibility can be influenced by neural mechanics in this population. The exact mechanism for this increase is unknown, however Perry and Green *et al* (2008), have observed the ability for L4/5 zygapophyseal mobilisations to result in side-specific peripheral sympathetic nervous system changes.

Gold standard management of hamstring pathology rehabilitation is yet to be universally accepted but the restoration of intrinsic risk factors including extensibility, movement patterns and biomechanics are generally considered as an important part of any rehabilitation programme (Goldman and Jones, 2010). A multifactorial approach to hamstring injury prevention and treatment is essential for high quality clinical outcomes. Brukner *et al* (2013) incorporated lumbar mobilisations into a seven-point management plan of an elite soccer player with recurrent hamstring pathology. The authors concluded their work, together with previous evidence (Szlezak *et al*, 2011; Perry and Green *et al*, 2008), suggests beneficial effects of lumbar mobilisations on posterior chain mechanics. However, to understand the exact mechanics further research is required.

With the current evidence it is postulated by the authors that lumbar mobilisations have the potential to form one aspect of hamstring management. It is acknowledged that the mechanisms of hamstring injury are multifactorial and therefore a range of interventions are required to reduce hamstring injury incidence, injury duration and improve return-to-play time. The results of this study offer practitioners an alternative way to manage the extensibility of the hamstring complex in injury prevention or pre-performance scenarios.

This study investigated only the immediate effects of the mobilisations. Due to a lack of longer-term follow-up it is unclear as to how long any change in extensibility would remain. To support clinical practice, further studies assessing the effect of lumbar mobilisations on hamstring extensibility, in the short and medium term are required. This study was conducted on asymptomatic participants and therefore it is unknown whether lumbar mobilisations have the ability to influence the extensibility of the hamstring complex in participants with

hamstring pathology. The dosage, levels and frequency of the intervention requires future research to establish the potential of lumbar mobilisations to be part of rehabilitation and injury prevention programmes.

## CONCLUSION

The results of this study support those of previous authors displaying an improvement in hamstring extensibility with lumbar mobilisations. A multi-factorial approach to hamstring injury prevention and treatment is fundamental to improve clinical outcomes; however, L4/L5 zygapophyseal mobilisations have the ability to have a beneficial effect on hamstring extensibility. Future research should consider investigating the longer term effects of lumbar mobilisations on the hamstring extensibility of both healthy and symptomatic individuals. Research conducted on symptomatic individuals will inform clinicians if lumbar mobilisations have the potential to decrease rehabilitation time and facilitate return to play by facilitating the restoration of hamstring extensibility.

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