Does Prior Hamstring Strain Injury Affect Hamstring Muscle Activation Patterns in Amateur Football Players? A Feasibility Study

Ahmed Ahmed
Queen Mary University of London, Mile End Road, Bethnal Green, London, E1 4NS, U.K.

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Abstract: Hamstring stains are very common injuries among athletes. Re-injury rate for hamstring strains is high and factors effecting hamstring re-injury is a research topic of interest. The aim of this study was to determine if there is a relationship between prior hamstring strain injury and medial:lateral (M:L) hamstring activation ratio in amateur football players during normal gait. Six male amateur football players with a history of unilateral hamstring strain injury volunteered for participation in this study. EMG data from the semitendinosus and biceps femoris muscles was recorded across a full gait cycle. The results of this preliminary, feasibility study show no significant difference between mean M:L hamstring activation ratios in previously injured hamstrings (Mean (M)=2.54, Standard Deviation (SD)=1.56) and uninjured contralateral hamstrings (M=3.06, SD=2.86) across the full gait cycle; $t(10) = 0.73$, $p>0.05$. Mean M:L activation ratios during 'Stance phase' show no significant difference between case and control hamstrings; $t(10)=0.88$, $p>0.05$. During 'Swing phase' there is no significant difference in mean M:L activation ratios between previously injured and uninjured hamstrings; $t(10)=0.61$, $p>0.05$.

1 INTRODUCTION

Acute hamstring strains are the most common form of injury in professional soccer players, making up 12% of all injuries (Ekstrand et al., 2009). Biomechanical analysis of running suggests that the injury occurs during terminal swing phase of the gait cycle (Chumanov et al., 2007). The hamstrings must change from contracting eccentrically to decelerate knee extension, to contracting concentrically acting as an active hip extensor (Thelen et al., 2005). This rapid change from eccentric to concentric contraction is when the muscle is most vulnerable to injury (Verrall et al., 2001). The impact on the individual and the resultant time-off is variable and often prolonged due to issues surrounding rehabilitation and recovery. Moreover, the recurrence rate of injuries is very high, with re-injury occurring in up to 63% of hamstring strains (Brukner et al., 2013). Since these types of injuries are so common and difficult to prevent, hamstrings strains have proven to be a prominent area of research.

Numerous studies have investigated the relationship between the ratio of hamstring to quadricep activation and how they relate to injury occurrence. A systematic review by Opar et al. investigated a potential relationship between prior hamstring strain injuries and increased risk of future anterior cruciate ligament tear (Opar et al., 2014). One study included in this review looked at the functional deficits caused by previous hamstring strains. They found that 'athletes with a history of hamstring strain injury displayed lower hamstrings:quadriceps strength ratio in the previously injured limb when compared to the uninjured limb.

In 2015, Ardern et al. investigated hamstring strength imbalances in professional soccer players in Australia (Ardern et al., 2015). Hamstring strength tests were performed on 42 players, 24% of which were discovered to have hamstring strength imbalances. One of the major findings was that the strength imbalances were almost invariably found in the stance leg of athletes. In this paper the researchers were only assessing the prevalence of hamstring strength imbalances, whereas further studies go on to explore this topic in more depth, considering aetiology and sequelae of strength imbalances.

Bourne et al. aimed to determine if eccentric knee flexor strength imbalance is a risk factor for hamstring strain injuries in rugby union (Bourne et al., 2015). In this prospective cohort study 178 rugby players had strength tests performed at the start of the playing season with the primary outcome measure of

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prospective hamstring strain injuries. The results of their study showed that a between-limb imbalance in eccentric knee flexor strength of ≥20% increased the risk of a hamstring strain 3.4-fold (95% CI, 1.5 -7.6; $p = 0.003$). This provides evidence to support the rational that strength imbalances should be corrected, particularly in those with previous hamstring strains to prevent future injury.

A study by Sole et al. investigated EMG activity of thigh muscles in people with a recent hamstring injury during a weight bearing exercise (Sole et al., 2011). They found that EMG onsets of the hamstrings were significantly earlier in those with a previous hamstring injury when compared with a control group. These results indicate that hamstring strains can effect muscle activation patterns post injury.

The insight gained from a review of the literature provided the bases for developing a research question and in choosing methodology. It has already been shown that prior hamstring strain injury can result in strength imbalances. This is true when comparing ipsilateral, injured and contralateral, uninjured sides, as well as when comparing quadriceps to hamstring strength ratios on ipsilateral injured side (Opar et al., 2014; Ardern et al., 2015). Moreover, studies have shown that an imbalance of strength in antagonistic muscles of the thigh increased the risk of hamstring strain injury (Bourne et al., 2015). However, to our knowledge changes in activation ratios of the synergistic hamstring muscle group, post-injury has not been investigated.

Our study will focus on amateur football players with previous hamstring strain injuries. The aim of our study is to assess the medial:lateral hamstring activation ratio in amateur football players during on-ground walking.

The primary objective is to identify if there is an association between previous hamstring strain injury and altered hamstring activation patterns when comparing medial and lateral hamstrings. We hypothesise that a prior hamstring strain injury results in altered medial:lateral activation ratio when compared to the contralateral uninjured side. It is hoped that a better understanding of how a hamstring strain injury affects muscle activation and the different hamstring groups may lead to lower injuries and recurrence rates.

2 METHODS

2.1 Sample Size

This study was designed as a feasibility study, with the aim of determining whether further testing may be applicable, if a relationship between prior hamstring strain injury and medial:lateral (M:L) hamstring activation ratio is observed. As such a relatively small sample size was used; including only 6 study participants.

2.2 Inclusion & Exclusion Criteria

Criteria were chosen with the aim of limiting confounding factors and generating a homogenous sample group. Six, male, amateur level football players, aged 22 with a history of a unilateral hamstring strain injury sustained within the previous 24 months were included. Participants were excluded if they had: a current symptomatic hamstring strain injury, a history of bilateral hamstring strains or a history of cardiovascular disease.

2.3 Participant Characteristics

Six amateur football players (from St Bartholomew and The Royal London 1st XI football team) volunteered for this study. Players trained once per week, playing in competitive matches in an amateur level league twice per week. All participants were 22 year old males with a mean height of 178.7cm ± 3.2cm and an average body mass of 72.35kg ±9.8kg. All recruited individuals had a history of a unilateral hamstring strain injury within the previous 24 months. Hamstring strains were self-reported and defined as an acute onset posterior hamstring pain that occurred during sprinting and resulted in time off sport. All participants provided written consent prior to participating in the study. Ethical approval was given by the Queen Mary Committee of Research Ethics. were chosen with the aim of limiting confounding factors and generating a homogenous sample group. Six, male, amateur level football players, aged 22 with a history of a unilateral hamstring strain injury sustained within the previous 24 months were included. Participants were excluded if they had: a current symptomatic hamstring strain injury, a history of bilateral hamstring strains or a history of cardiovascular disease.

Table 1: Baseline Characteristics of Study Participants.

Characteristic	Mean (±SD)	Minimum	Maximum
Age	22	22	22
Body Mass (kg)	72.35 (±9.8)	60.7	87.6
Height (cm)	178.73 (±3.17)	173.5	183.0
BMI	22.62 (±2.81)	18.7	26.9

2.4 Instrumentation

Surface Electromyography (EMG) data were collected with DELSYS Trigno Lab Wireless Surface 16 EMG system (16 channel) (DELSYS INC, Massachusetts, USA). The sampling rate was 2000Hz. Wireless EMG electrodes were applied over the semitendinosus muscle at the mid-point of the ischial tuberosity and the medial epicondyle of the tibia. Electrodes for the biceps femoris muscle were applied at the mid-point of ischial tuberosity and lateral epicondyle of the tibia. Electrodes for the rectus femoris muscle were applied at the mid-point of the anterior superior iliac spine and the superior patella. Electrodes were attached using self-adhesive tape and placement was based on the recommendations of SENIAM (“The Seniam Project”, 2020). Raw EMG data was then transferred to MATLAB (v2009a, Mathworks, Natwick, MA, USA) where it was filtered rectified and smoothed.

The data from motion analysis was used to determine ‘Heel Strike ’and ‘Toe Off ’stages of the gait cycle enabling distinction of the stance and swing phases of the cycle. This was achieved by mapping the vertical height of the heel markers and the 5th metatarsal markers. Kinematics were measured using a CodaMotion system (Charnwood Dynamics Ltd., Leicestershire, United Kingdom). Four CX1 Series Codamotion 3d Scanners were used to capture the markers placed on the study subject. Clusters consisting of four active markers were used on the lower limbs to minimise marker movement. The sampling rate was 200Hz. The software used for measurement and analysis was ODIN Codamotion 3D Modelling & Control Software (v1.05).

2.5 Protocol

Upon arriving at the Human Performance Laboratory, participants were briefed on proceedings after which informed consent was given. For each participant weight, height and age were recorded prior to data collection. After these baseline measurements, EMG electrodes were placed onto the relevant muscles. The medial hamstring EMG data was recorded from the semitendinosus muscle. The lateral hamstring EMG data was recorded from the biceps femoris muscle. The recordings from the previously injured leg will be compared to the uninjured leg of the individual as a control. Motion analysis markers were placed around the subjects pelvis and feet with marker clusters placed on the lateral aspect of the thighs and shanks. Once all EMGs and markers were placed, anatomical landmarks were digitised using a CLSTR-PTR-02 pointer. The anatomical landmarks digitised included: lateral femoral epicondyle, lateral malleolus, medial femoral epicondyle and medial malleolus (bilaterally).

Figures 1 and 2 below are images of a study participant post instrumentation setup. They illustrate the cluster markers on the lateral aspect of the thighs and shanks bilaterally, and EMG surface electrodes on the posterior aspect of the thigh.

Figure 1: Study Participant, Post-Instrumentation (Anterior View).

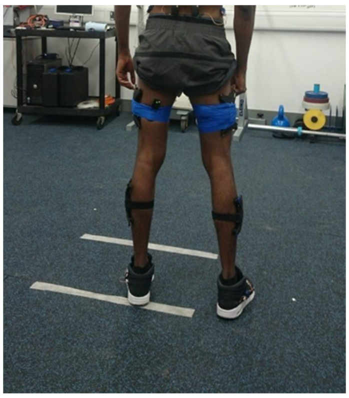

Figure 2: Study Participant, Post-Instrumentation (Posterior View).

With instrumentation setup complete, participants were then allowed to familiarise themselves with the experimental protocol. Participants walked for a distance of 3 meters without footwear at a self selected speed to ensure a full gait cycle was completed. Participants were asked to place their hands on the alternate shoulder as they walked to avoid obstruction of marker visibility. This was repeated 3 times before data collection trials began. For data collection trials subjects were again asked to walk for 3 metres at a comfortable speed. This was repeated until two acceptable trials were obtained. Criteria for adequate trials was marker visibility >80% in all markers across a full gait cycle. EMG data was only analysed from the first full gait cycle completed during the 3 meter walk with start point and end point of the gait cycle defined as right foot 'heel strike 'and left foot 'toe off 'respectively.

2.6 Statistical Analysis

Data was extracted using Matlab version 9.0 (Mathworks, Inc. Massachusetts, USA). Raw EMG data was initially processed by application of a notch filter at 50Hz to remove electrical noise. The signal was then rectified and smoothed with a 4th order FIR low-pass filter with a cut off frequency of 10Hz to produce a 'linear envelope 'with mean RMS values calculated. This technique has been used numerous times in previous studies (Arendt-Nielsen et al., 1991; Neumann et al., 1996; Ng et al., 1997). EMG data were taken from the same muscles, on the same day with subjects acting as their own controls and comparisons between individuals being made in-terms of activation ratios. As such, EMG normalisation was not thought to be necessary (Soderberg et al., 2000).

The mean root mean square (RMS) for the processed EMG signals were then calculated for the stance phase, the swing phase and the complete gait cycle. Medial:lateral hamstring activations ratio was defined as the ratio of non-normalised, mean RMS of EMG wave amplitude between the biceps femoris and semitendinosus muscles, taken at various stages of the gait cycle. The primary outcome measure was mean medial:lateral hamstring activation ratio during the complete gait cycle. Secondary outcome measures were medial:lateral ratios during the 'Stance 'and 'Swing 'phase. Comparisons were made between the previously injured legs and control legs under these three parameters. Student's independent two-sided t-test was then carried out to compare data from previously injured and previously uninjured (control) legs. Statistical analysis was performed using SPSS version 17.0 (SPSS Inc, Chicago, IL). Statistical significance was set at $p < 0.05$.

3 RESULTS

The inter-subject variation in M:L activity ratios was relatively high ranging from ratios of 0.66 during swing phase of the gait cycle to 10.3 in the stance phase. During the full gait cycle mean hamstring M:L activation ratios of participants showed very little discrepancy between previously injured and control hamstrings, the latter having a lower ratio on average (-0.24 ±2.79). Table 2 illustrates the mean M:L activity ratios across the gait cycle. Figure 3 graphically represents M:L activation ratios across the full gait cycle.

Table 2: Mean M:L Hamstring Activation Ratios (±SD) Across One Complete Gait Cycle.

	Injured Side	Uninjured (Control) Side
Stance Phase	2.52 (1.17)	22
Swing Phase	3.10 (2.23)	60.7
Full Gait Cycle	2.54 (1.56)	173.5

Students independent two-sided t test revealed that there is no significant difference between mean M:L hamstring activation ratios in hamstrings with prior strain injuries and previously uninjured hamstrings across a full gait cycle; $t(10)=0.73$, $p>0.05$. There was no significant difference found between previously injured and control hamstrings during the stance phase of the gait cycle. $t(10)=0.88$, $p>0.05$. Moreover, there was no significant difference found between previously injured and control hamstrings during the swing phase of the gait cycle; $t(10)=0.61$, $p>0.05$.

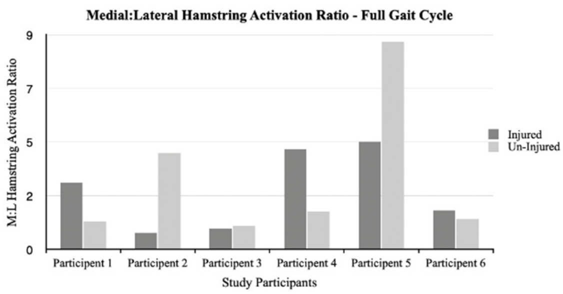

Figure 3: Comparing M:L activation ratios of injured hamstrings vs. controls across a full gait cycle.

4 DISCUSSION

4.1 Main Findings

The main finding of our study was that there is no significant difference in hamstring medial:lateral activation ratios in previously injured hamstrings compared to non-injured hamstrings. These results disprove the original research hypothesis. It is difficult to state whether these results are in keeping with similar studies as the number of papers investigating individual hamstring muscle activation patterns post-injury are very limited. However, a study by Sole et al. compared EMG activity of gluteal and thigh muscles of sportspeople with a recent injury with uninjured controls during a weight-bearing task (Sole et al, 2011). They found that the EMG onsets of biceps femoris and medial hamstrings were significant earlier for the injured group compared to the control group. Although this study focussed on EMG onset rather than mean EMG activity, their results suggest alterations in neuromuscular control of hamstrings post-injury. Following this, it could be postulated that injury alters the M:L activity ratios of hamstrings, which contradicts the findings from our study.

Emami et al. conducted a study investigating EMG activity pattern of the lumbo-pelvic muscles during prone hip extension in athletes with and without hamstring strain injury (Emami et al., 2014). Rather than calculating activity ratios, EMG data was processed and normalised with muscle activity being expressed as percentage of maximal voluntary electrical activity (MVE). Their results showed that there were significant differences in EMG activity of the gluteus maximus and the medial hamstring between the injured group and the control group. However, no significant difference was found in activity of the lateral hamstring between the two groups. This would suggest that a previous hamstring injury will alter the medial:lateral hamstring activation ratio. This again is not in keeping with the results of our study.

4.2 Limitations

One of the major limitations to this study was the small sample size. Adequate sample sizes ensure high statical power in null hypothesis testing (Liu et al., 2013). Access to the target population of male amateur football players with a unilateral hamstring strain injury occurring in the past 2 years was limited within the time frame that this study was conducted. Future work on this topic should be carried out on a larger scale to further assess the link between hamstring strain and muscle activation patterns.

Another limitation to this study was the self-reported nature of the injuries. Gabbe et al. investigated the validity of self reported sports injury histories. (Gabbe et al., 2003). Their results showed that at 12 months post-injury 80% of participants were able to accurately recall the body regions injured, but not the exact diagnosis, with only 61% of participants able to recall the exact body region and diagnosis of injury sustained. Participants of this study were included if they had sustained a hamstring strain any time in the past 24 months. As such details on the injury including severity, and exact location had a decreased validity due to probable recall bias.

The inclusion criteria specified only male subjects could be recruited. This criterion was chosen because of the different neuromuscular control strategies and movement patterns in women including lower hamstring muscle activation (Malinzak et al., 2001). As such, a limitation to this study is that the findings are not transferable and can not be applied to females.

Furthermore, EMG data collected in our study was not normalised. Normalisation was not necessary for this study and non-normalised signals allowed us to answer the research question. However this is a weakness to our study as it limits comparability of our results to similar studies using normalised EMG signals.

4.3 Future Work

Future studies could investigate how strain injuries of the different hamstring components lead to different physiological response of the hamstrings. It has previously been suggested that following hamstring strain the biceps femoris compensates for the lack of endurance capacity of the semitendinosus, increasing the re-injury risk (Schuermans et al., 2014).

Furthermore, Opar et al. recently showed that previously strained hamstrings show less improvement in eccentric strength following a training programme when compared to uninjured hamstrings (Opar et al., 2014). However, it is not clear whether this is the cause of or the result of the injury. This is another aspect of this topic that has potential to be investigated in the future. Fully understanding the biomechanics and neuromuscular response following hamstring strain injury is necessary before prevention and rehabilitation techniques can be improved. The potential benefits of research in this area to lower rehabilitation time and re-injury rates, resulting in less time-off sport.

4.4 Conclusion

To conclude, previous hamstring strain injuries do not result in a significantly different medial:lateral hamstring activation ratio when compared with uninjured hamstrings. This is true for both ‘Stance phase ’and “Swing phase ’of gait cycle as well as across the entire gait cycle. However, due to various limitations of this study, further research on this topic is needed to comprehensively establish the association between between previous hamstring injury and medial:lateral hamstring activation ratios.

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