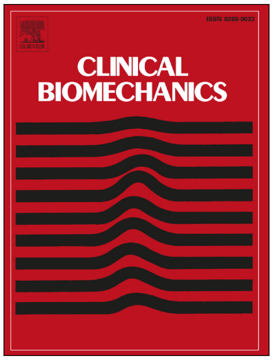

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NEUROMUSCULAR CHANGES IN FOOTBALL PLAYERS WITH PREVIOUS HAMSTRING INJURY

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Abstract

Background: Impact of prior injury on myoelectrical activity of the hamstrings during isokinetic eccentric contractions has received increased literature attention. This cross-sectional study aimed to assess neuromuscular adaptations, namely proprioception, core stability, muscle strength, extensibility and activity, in football players with history of hamstring strain injury. *Methods:* Seventeen players, 10 with history of hamstring injury and 7 without prior injury underwent isokinetic strength testing, eccentric knee extension at 30 and 120 º/s. Myoelectrical activity of bicep femoris and medial hamstrings was calculated at 30, 50 and 100ms after onset of contraction. Functional tests included core stability, muscle strength, and knee proprioception tests. *Finding:* Differences were observed between Hamstring Group injured and uninjured and Control Group dominant limbs in the bicep femoris activity at almost all times in both velocities ($p<0.05$). Joint position sense error was higher in the injured side compared to uninjured and control dominant limb; additionally there were also differences between injured and uninjured limb in the triple-hop test. *Interpretation:* Previously injured side showed deficits in bicep femoris myoelectrical activity after onset of contraction during eccentric testing, proprioceptive deficits, and functional asymmetry.

Key Words: sports injuries, electromyography, proprioception, maladaptation

1- Introduction

Hamstring strain injuries (HSI) are the most common type of muscle injury in football, with a high rate of re-injury, resulting in considerable loss to the athlete and organizations (Opar et al., 2012; Orchard et al., 2013). Although there is a wide variety of literature around HSI risk factors rehabilitation strategies, injury and re-injury rates over the years suggest that our current knowledge about HSI prevention remains incomplete (Opar et al., 2012).

Primary injury is still the main risk factor for HSI recurrence (Arnason et al., 2004). Maladaptation after first episode has been shown to affect variables such as eccentric muscle strength, activation patterns and horizontal force development in running actions (Croisier et al., 2002; Opar et al., 2012; 2013; Sole et al., 2011). Research in this field has shown that subjects with history of HSI have significant reductions in electromyographic muscle activity ratios, and pelvic and lower limb movement pattern asymmetries during high-speed running (Chumanov et al., 2012). Diminished biceps femoris (BF) long head activation may have an important role in HSIs recurrence, because lower levels of myoelectrical activity may limit the adaptive response to rehabilitation programs, and may induce several maladaptation (Brukner, 2015), including chronic eccentric hamstring weakness (Fyfe et al., 2013; Lee et al., 2009), selective hamstring atrophy (Silder et al., 2008) and shifts in torque joint-angle relationship (Brockett et al., 2004; Brukner, 2015; Fyfe et al., 2013).

Studies have shown eccentric weakness post-HSI to be long-lasting, even in athletes who have fully returned to competition (Lee et al., 2009); like football players who returned to play after rehabilitation having lower high-speed running performance, when compared to uninjured athletes (Brukner, 2015; Mendiguchia et al., 2014). Moreover, Opar and colleagues showed that athletes with unilateral HSI history displayed less improvement in eccentric hamstring strength during preseason not only in the injured limb, but also in the contralateral limb, when compared to uninjured players, which reinforces the idea that the neuromuscular inhibition after unilateral HSI may be mediated by central mechanisms (Opar et al., 2015). The purpose of the present study is to analyse the influence of previous HSI in several isolated domains of neuromuscular adaptations, namely hamstring myoelectrical activity during eccentric contractions, core stability, muscle strength, and knee proprioception in football players.

2- Material and Methods

2.1- Participants

Ten players with previous HSI (HG) and ten control players from the same club/position without history of HSI accepted to participate (CG). From the latter, data from three players was not used due to technical difficulties with the data collection on those days, leaving the CG with 7 players. A snowball sampling method intended to voluntarily recruit amateur level male football players, who sustained HSI or reinjury between 6 to 24 months prior to recruitment, competing in the Portuguese District Football Association Leagues. The inclusion criteria were age between 18 and 35 years old, training frequency ≥ 3 times per week, sustained a grade ≥ 2 HSI (Pollock et al., 2014) that restrained them from training and competition for at least 4 weeks (confirmed by club's physiotherapist/sports medicine clinician assessment and with ultrasonography/magnetic resonance imaging scan). Players were excluded in the presence of moderate or severe lower limb injuries 3 months prior to the study. Injury severity was categorised based on the number of days from the date of injury to full return to team training or matches: slight (0 days); minimal (1–3 days); mild (4–7 days); moderate (8–28 days); severe (>28 days); career ending (Fuller et al., 2006). All participants provided informed written consent.

Ethical approval was guaranteed by the Ethics Committee of the Faculty of Sports, University of Porto and all procedures were conducted according to the Declaration of Helsinki.

2.2- Procedures

Knee flexors/extensors isokinetic strength procedures (Biodex System 3, Shirley, New York) were performed as described elsewhere (Sole et al., 2011), including concentric quadriceps and hamstrings exertions at 60°/s and 240º/s and eccentric hamstrings exertions at 30°/s and 120º/s. Bicep Femoris (BF) and Medial Hamstrings (MH) myoelectrical activity at rest and during eccentric testing was recorded and sampled at 1000 Hz using a wireless system (BTS FREEEMG 300, BTS Bioengineering, Milan, Italy), according to the SENIAM guidelines (Hermens et al., 2000). Each participant was seated on a custom pillow, placed on top of the dynamometer seat, which had two holes at the level of the posterior mid-thigh in order to minimise movement artifacts from the surface electromyography (sEMG) electrodes on the seat during isokinetic assessment (Sole et al., 2011). Isokinetic testing was video-recorded (at 50 frames per second) for analysis and synchronisation of isokinetic tests and sEMG data, to ensure correct timestamping. In brief, raw sEMG signals were filtered with a FIR band-pass (10-500 Hz), full wave rectified, and root-mean square derived (AcqKnowledge 3.9.0, Biopac System, Goleta, CA, USA); in each eccentric test, every muscle activation onset was pre-determined to each contraction (Opar et al., 2013); onset and offset of muscle activity was determined by using a 10% threshold of the maximum amplitude of the muscle contraction and visually confirmed by synchronised video recording at the selected time-frame, myoelectrical activation was measured from 30, 50 and 100 milliseconds after onset of muscle activity (Opar et al., 2012). In each contraction, maximal peak activation of BF and MH was recorded and percentage of the activation at 30, 50 and 100 milliseconds was calculated.

Regarding proprioception, the active knee joint position sense test was performed in the ipsilateral limb, in open kinetic chain, and with active re-positioning of passively determined position (Salgado et al., 2015). Prior to assessment two pairs of markers representing the axis of the thigh (apex of the greater trochanter; the iliotibial tract) and leg (the iliotibial tract, level with the posterior crease of the knee when flexed to 80°; the head of the fibula) were fixed with tape to the skin. Joint position sense was assessed in knee flexion (starting position was full extension) movement with the participant blindfolded and seated on a physiotherapy treatment table with legs hanging freely but without contacting the floor. Then, participants performed three attempts to reproduce one target angle (between 40° and 60° of knee flexion) (Salgado et al., 2015). Joint positions were recorded with a video camera positioned 3 meters away from the participant. Knee angles of target and repositioned joint positions were determined by computer analysis of the videotaped images of the knee joint using the Posture Assessment Software (SAPO) (Ferreira et al., 2010). The absolute angular error was calculated as the absolute difference between the test position and the position reproduced by the participant (Salgado et al., 2015).

Flexibility was assessed through the use of active and passive knee extension tests (Neto et al., 2014). For this purpose, we used the same four markers used to assess joint position sense and derived the joint angle with the SAPO software as described (Torres et al., 2016).

Core stability was assessed with three different tests: the extensors endurance test (Latimer et al., 1999), the flexors endurance test, and the side bridge test (McGill et al., 1999). Lower limb power was assessed using the triple hop test. Participants were allowed one to three practice trials before the completion of the three test trials. Mean time or distance of the three trials was recorded (respectively for core stability and triple hop test) and used for analysis (Hamilton et al., 2008). With the exception of the core stability tests, all the assessments were performed in both limbs of the HG and in the dominant limb (defined as the limb used to kick a ball) of the CG.

2.3- Data Analysis

Data was analysed using IBM SPSS statistics 21.0 (IBM Corporation, Chicago, IL, USA). Normality of data distribution was assessed with the Shapiro-Wilk test and analysis of histograms. The data were normally distributed. Descriptive statistics were used to calculate the mean and standard deviation. Comparisons between HG and the dominant limb of the CG were made using two-tailed independent samples t-tests. Two-tailed paired t-tests were performed to compare the mean differences between previously injured and uninjured limbs of the HG. The effect size (ES) was calculated using Cohen d coefficient; ES of 0.2, 0.5 and 0.8 were considered to correspond to small, medium and large differences, respectively. The level of significance was set as $p < 0.05$.

3- Results

No significant differences were observed between groups for age and body mass (Table 1). The HG and CG were composed by 3/2 defensive, 3/2 midfield and 4/3 offensive players. The HG reported a mean post-HSI rehabilitation time of 4.5±1.6 weeks.

Regarding muscle strength (Table 2), no significant changes were found between HG previous injured and non-injured limb, as well as between both limbs of the HG and CG dominant limb. Also, no differences were found in angle of peak torque within HG and between groups at 30º/s and 120 º/s (Table 2). The BF myoelectrical activity was significantly lower in the HG injured limb compared to the HG uninjured limb at both 30º/s and 120º/s eccentric velocities and at 30ms (ES=1.680 and ES=2.847, respectively), 50ms (ES=1.774 and ES=3.188, respectively), and 100ms (ES=2.276 and ES=2.011, respectively) after onset of muscle activity; the BF activity was also significantly lower in the HG injured limb per comparison to the dominant limb of the CG at 30º/s at all assessment times (30ms, ES=1.388; 50ms, ES=1.003; 100ms, ES=1.408), and at 50ms after onset of muscle activity at 120º/s (ES=1.429) (please see Table 2). No differences were observed in medial hamstrings activation at the 3 assessment times (Table 2).

Regarding proprioception, knee joint position sense was significantly worse (i.e., higher absolute angular error) in the HG injured limb when compared to the uninjured leg (ES=1.570) and the CG (ES=1.980) (Table 3). The performance in the triple hop test was significantly better in the uninjured limb of the HG per comparison to the injured limb (ES=2.656) (Table 3). No significant differences were observed in flexibility, and core stability (Table 3).

4- Discussion

Our main findings showed a significant decrease in BF myoelectrical activity during eccentric testing, proprioceptive deficits, as well as functional asymmetry in the HSI limb. Our results are in accordance with previous evidence (Higashihara et al., 2014; Schuermans et al., 2014; Sole et al., 2012), as we observed a significant decrease in injured BF myoelectrical activity during eccentric efforts, but not in the MH. Lower sEMG values indicate BF inability in minimising risk of hamstrings overlengthening, and this early weakness may be responsible for the increased hamstrings work in the late swing phase of running (Fyfe et al., 2013; Higashihara et al., 2014; Opar et al., 2012; Schuermans et al., 2014). Moreover, this reduced activation has been hypothesised to be the responsible for the BF post-HSI atrophy (Silder et al., 2008) and increased recurrence risk associated with early exercise-induced muscle fatigue of the BF (Opar et al., 2012). This selective muscle activation is hypothesised in literature by chronic pain-driven maladaptations and neurophysiological inhibitory mechanisms (Fyfe et al., 2013), which are believed to be more frequently activated during eccentric efforts (Lunnen et al., 1981; Opar et al., 2013; Sole et al., 2011). Decrease of BF myoelectrical activity may limit hypertrophy, even when using eccentric training (Fyfe et al., 2013). This is a possible explanation to our sEMG results, as all HG participants had fully returned to play for at least 6 months and still presented a significant decline in the BF activity during eccentric contraction, which might be due to persistent atrophy (Silder et al., 2008).

Research has given relative importance to the role of neuro-inhibitory mechanisms behind post-HSI maladaptations and our results seem to strengthen previous findings (Opar et al., 2012; Sole et al., 2011). Our sEMG evaluation of HG injured side also resulted in lesser myoelectrical BF activity after early onset of eccentric contractions, presenting several differences to HG uninjured side at both eccentric velocities, ranging from 5% to 12%. This can have several implications in HSI re-injury risk due to muscle inability to produce early eccentric force and decelerate the hip during running, positioning the BF long head at longer muscle length and increasing its work during terminal swing phase, prematurely fatiguing and increasing the likelihood to exceed its mechanical limits and re-injure (Opar et al., 2012; 2014; Silder et al., 2010; Sole et al., 2011).

Previous studies found eccentric weakness in the injured limb per comparison to the uninjured and reported isokinetic deficits in 67% of their participants with HSI history (Tol et al., 2014); although our results are in contrast with these findings, they are in agreement with previous studies that have also found no significant differences in isokinetic muscle strength (Brockett et al., 2004; Silder et al., 2010; Sole et al., 2011).

Moreover the lack of differences in eccentric angle of peak torque within and between groups combined with the BF activation deficit found in this study suggests that there may be some muscle compensations, such as the ipsilateral gluteus maximus and/or external oblique (Daly et al., 2015). A decrease of bicep femoris myoelectrical activity may contribute to the sabotage of rehabilitation programs (Fyfe et al., 2013), due to its inability to quickly produce torque at early onset of eccentric contractions and when the muscle is more lengthened, during late rehabilitation, because of its neuromuscular inhibition, the bicep femoris hypertrophy is limited, even when using eccentric training, known as a great stimuli for muscle growth (Fyfe et al., 2013). This is a possible explanation to our EMG results, as all HG participants have fully returned to play for at least 6 months and still present a significant decline in the bicep femoris activity in eccentric loadings, probably due to its persistent atrophy (Silder et al., 2008).

The proprioceptive deficits observed in the injured limb should not be minimised, as they may impact motor control in sporting activities, such as running, due to an inaccurate perception of joint positioning (Allen et al., 2010). A high knee joint position sense error may lead to the perception that the hamstrings are working on a normal range of motion and muscle length when in reality repeated over lengthening is occurring (Allen et al., 2010).

The present study has some limitations. Isokinetic eccentric testing was limited to 30º/s and 120º/s, which do not reproduce all the hamstrings functional efforts during running (Opar et al., 2012). The generalisability of the results may be limited, as the study encompasses a small number of amateur players. During joint position sense testing players were in a seated position; prone evaluation should be considered to increase gravitational effort, consequently increasing hamstring eccentric effort during the repositioning phase. Further studies are encouraged to understand the role of proprioceptive training in HSI prevention and rehabilitation (Freckleton and Pizzari, 2013), to explore whether proprioceptive examination should be included in rehabilitation progression and return to play criteria.

5- Conclusion

A significant decrease in the injured BF myoelectrical activity after onset of contraction during eccentric testing, proprioceptive deficits and functional asymmetry were observed in the HSI limb. Physical therapists, physical trainers, and sports medicine doctors should take into consideration the changes in BF activity when designing rehabilitation and strengthening programs as well as when considering return to play clearance.

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Table 1. Characteristics of the participants [mean (SD)]

Variable	**Hamstring injury group**	**Control group**	**P value**
Age (years)	24.40 (3.41)	23.86 (3.44)	0.752
Height (meters)	1.79 (0.06)	1.78 (0.08)	0.772
Weight (kilograms)	78.02 (4.66)	73.60 (6.73)	0.129
Body Mass Index (kg/m^2)	24.36 (1.23)	23.24 (1.87)	0.156

Table 2. Isokinetic and Electromiographic tests in Control (CG) and Hamstring Injury group (HG) [mean (SD)]

	HG injured limb	**HG uninjured limb**	**P value (injured vs. uninjured)**	**CG dominant limb**	**P value (CG vs. injured)**	**P value (CG vs. uninjured)**
Isokinetic strength						
Quadriceps						
Concentric at 60º/s (Nm)	215.4 (35.1)	214.1 (49.5)	0.904	203.7 (48.7)	0.574	0.675
Concentric at 240º/s (Nm)	123.4 (29.2)	123.3 (31.5)	0.986	124.1 (22.7)	0.956	0.952
Hamstrings						
Concentric at 60º/s (Nm)	129.0 (17.7)	131.7 (22.0)	0.541	124.9 (19.3)	0.657	0.516
Concentric at 240º/s (Nm)	83.9 (24.7)	82.9 (18.5)	0.761	84.8 (17.3)	0.936	0.833
Eccentric at 30º/s	202.7 (51.7)	217.7 (46.1)	0.272	184.8 (29.0)	0423	0.118
Eccentric at 120º/s	195.9 (51.7)	213.7 (53.4)	0.206	196.2 (49.1)	0.990	0.505
H/Q Conventional Ratio at 60º/s	0.61 (0.12)	0.64 (0.14)	0.447	0.54 (0.10)	0.176	0.120
H/Q Conventional Ratio at 240º/s	0.68 (0.13)	0.68 (0.11)	0.845	0.70 (0.17)	0.806	0.877
H/Q functional ratio‡	1.74 (0.61)	1.83 (0.48)	0.577	1.51 (0.28)	0.379	0.140
Angle of peak torque during eccentric exertions						
Eccentric at 30º/s	15.8 (10.6)	11.7 (8.1)	0.381	20.1 (12.9)	0.468	0.129
Eccentric at 120º/s	23.4 (13.2)	14.6 (11.9)	0.084	19.9 (9.5)	0.555	0.353
Electromiographic activity during eccentric exertions						
Biceps Femoris at 30º/s						
30ms (%)	10.0 (4.1)	15.6 (5.3)	**0.029**	17.6 (7.0)	**0.013**	0.497
50ms (%)	13.2 (4.4)	23.4 (11.4)	**0.023**	18.2 (5.7)	0.060	0.285
100ms (%)	16.9 (6.8)	27.0 (7.2)	**0.007**	27.7 (8.7)	**0.012**	0.865
Biceps Femoris at 120º/s						
30ms (%)	14.3 (5.0)	21.4 (5.3)	**0.002**	17.6 (7.0)	0.276	0.224
50ms (%)	16.9 (4.4)	27.4 (7.0)	**0.001**	24.4 (6.3)	**0.011**	0.372
100ms (%)	22.5 (9.5)	34.7 (6.6)	**0.013**	31.0 (6.8)	0.063	0.275
Medial Hamstrings at 30º/s						
30ms (%)	20.2 (10.2)	16.7 (7.5)	0.434	17.4 (6.7)	0.526	0.847
50ms (%)	22.7 (7.5)	23.1 (12.7)	0.903	18.5 (12.2)	0.398	0.466

100ms (%)	29.8 (10.7)	25.0 (11.3)	0.113	21.9 (10.0)	0.146	0.564
Medial Hamstrings at 120º/s						
30ms (%)	24.1 (10.8)	22.5 (7.7)	0.700	16.37 (9.2)	0.147	0.156
50ms (%)	24.9 (12.4)	27.0 (10.8)	0.683	25.2 (7.6)	0.955	0.703
100ms (%)	32.0 (11.5)	31.7 (10.8)	0.963	27.5 (11.7)	0.450	0.456

‡ eccentric peak torque of the hamstrings at 30º/s / concentric peak torque of the quadriceps at 240º/s.

Table 3 - Core stability, flexibility, triple hop test and joint position sense in Control (CG) and Hamstring Injury group (HG) [mean (SD)]

Variable	Hamstring injury group	Control group	P value (HG vs. CG)
Flexors Endurance (s)	216.7 (68.8)	226.7 (62.7)	0.782
Extensors Endurance (s)	109.6 (20.0)	106.0 (30.3)	0.771
Side Bridge Right (s)	68.7 (15.5)	69.9 (24.6)	0.852
Side Bridge Left (s)	66.1 (13.0)	69.7 (30.8)	0.743

	HG injured limb	HG uninjured limb	P value (injured vs. uninjured)	CG dominant limb	P value (CG vs. injured)	P value (CG vs. uninjured)
Passive Knee Extension (º)	5.9 (4.7)	5.2 (4.2)	0.483	4.7 (2.5)	0.533	0.761
Active Knee Extension (º)	8.6 (4.5)	7.4 (4.2)	0.195	8.9 (5.6)	0.899	0.538
Triple Hop Test (cm)	568.3 (23.9)	579.0 (20.6)	**0.003**	565.9 (34.5)	0.865	0.340
Joint position sense (º)	4.6 (2.0)	1.9 (1.1)	**0.038**	1.8 (1.7)	**0.014**	0.844

NEUROMUSCULAR CHANGES IN FOOTBALL PLAYERS WITH PREVIOUS HAMSTRING INJURY

Conflict of Interest

I affirm that I have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript. There are no conflicts of interest of any kind.

Neuromuscular changes in football players with previous hamstring injury - Highlights

Highlights

- Players with this injury may show decreased biceps femoris myoelectrical activity
- It tends to occur during eccentric contraction, despite showing no eccentric weakness
- This occurs even after a successful rehabilitation and return to play
- Players may also show proprioceptive deficits at the knee joint