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Escola Superior de Saúde da Universidade de Aveiro

CARLOS MORGADO AREIA

ADAPTAÇÕES NEUROMUSCULARES EM FUTEBOLISTAS COM HISTÓRIA DE LESÃO DOS ISQUIOTIBIAIS

NEUROMUSCULAR ADAPTATIONS IN FOOTBALL ATHLETES WITH PRIOR HISTORY OF HAMSTRING STRAIN INJURY

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Fisioterapia, realizada sob a orientação científica do Professor Doutor Fernando Ribeiro, Professor Adjunto da Escola Superior de Saúde da Universidade de Aveiro e sob co-orientação do Professor Doutor José Oliveira, Professor Associado com Agregação da Faculdade de Desporto da Universidade do Porto

Dedico a presente dissertação à minha família e à minha namorada pelo apoio incondicional.

O júri

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Palavras-chave Lesão Isquiotibiais, futebolistas, adaptações neuromusculares

Sumário

Enquadramento: As lesões dos isquiotibiais são bastante comuns numa grande variedade de desportos que envolvem corrida, resultando num grande período de abstinência desportiva e competitiva. Uma das consequências mais problemáticas desta lesão é a sua alta taxa de recorrência que, embora tenha sido alvo de bastantes estudos, não tem diminuído nas últimas décadas. Estudos recentes encontraram também várias maladaptações em atletas com história desta lesão, provavelmente devido a inibição neuromuscular, sendo proposto que estas adaptações pós-lesão possam contribuir como factores de risco no ciclo de lesão-recorrência, e para a elevada taxa desta. Pelo que recentemente estudos sugerem considerar a interacção destas adaptações e factores de risco, de modo a aprofundar o nosso conhecimento dos mecanismos desta complexa lesão.

Objectivo: Determinar, analisar e correlacionar adaptações neuromusculares em futebolistas amadores com história de lesão dos isquiotibiais em comparação com atletas sem história de lesões, em condições semelhantes.

Metodologia: Todos os participantes foram sujeitos a testes isocinéticos em modo concêntrico (60 e 240º.sec) e excêntricos (30 e 120º.seg^{-1}) em ambos os membros, com análise do pico de torque, ângulo de pico de torque e rácio convencional isquiotibial:quadriceps (H:Q), também foi medida a actividade mioeléctrica do Bicípite Femoral (BF) e dos isquiotibiais mediais (MH) durante a avaliação isocinética excêntrica em ambas as velocidades e a percentagem de activação muscular foi calculada a 30, 50 e 100ms após início da contracção. Além destes, foram medidos e correlacionados os testes de extensão do joelho activa e passiva, teste de sensação de posição do joelho (JPS), triple-hop distance (THD) e testes de estabilidade do core (endurance dos flexores e extensores, side bridge para o lado direito e esquerdo).

Resultados: Dezassete jogadores participaram neste estudo: 10 atletas com história de lesão dos isquiotibiais (HG) e 7 atletas sem história de lesões graves (CG). Foram encontradas diferenças significativas entre o lado lesado e não lesado do HG na actividade mioeléctrica do BF em quase todos os tempos em ambas as velocidades, e entre o lado lesado do HG e lado não dominante do CG aos 100ms durante o teste excêntrico á velocidade de 120º.seg^{-1} ($p<.05$). Não foram encontradas diferenças significativas na actividade dos MH. Quanto ao teste proprioceptivo foram encontradas diferenças no HG entre o membro lesado e não lesado no JPS quando a posição inicial era a extensão completa do joelho ($p=.027$). Não foram encontradas alterações nos outros testes. No entanto houve correlação significativa entre a actividade mioeléctrica do BF aos 100ms a 120º.seg^{-1} e os resultados do JPS com a 90º de flexão do joelho (r-.372; p=0.031) como posição inicial, assim como entre o rácio H:Q no teste isocinético concêntrico a 240graus.sec e o score to THD (r=-345.; p=.045).

Conclusão: Neste estudo foram encontradas diferenças significativas que suporta literatura anterior no que toda a existência de adaptações neuromusculares e inibição do BF após lesão dos isquiotibiais. Além disso, no nosso conhecimento, este foi o primeiro estudo a encontrar correlação significativa entre estas adaptações, pelo que pode abrir uma porta a novas perspectivas e estudos futuros.

Keywords Hamstring Strain Injury, Neuromuscular adaptations, Football players

Abstract

Background: Hamstring strain injuries (HSI) are one of the most common injuries in a wide variety of running-sports, resulting in a considerable loss of competition and training time. One of the most problematic consequences regarding HSI is the recurrence rate and its non-decrease over the past decades, despite increasing evidence. Recent studies also found several maladaptations post-HSI probably due to neuromuscular inhibition and it has been proposed that these adaptations post-injury may contribute as risk factors for the injury-reinjury cycle and high recurrence rates. Furthermore it has been recently proposed not to disregard the inter-relationship between these adaptations and risk-factors post-injury in order to better understand the mechanisms of this complex injury.

Objective: To determine, analyze and correlate neuromuscular adaptations in amateur football players with prior history of HSI per comparison to uninjured athletes in similar conditions.

Methodology: Every participant was subjected to isokinetic concentric (60 and 240deg.sec) and eccentric (30 and 120deg.sec^{-1}) testing, and peak torque, angle of peak torque and hamstrings to quadriceps (H:Q) conventional ratios were measured, myoelectrical activity of Bicep Femoris (BF) and Medial Hamstrings (MH) were also measured during isokinetic eccentric testing at both velocities and muscle activation percentages were calculated at 30, 50 and 100ms after onset of contraction. Furthermore active and passive knee extension, knee joint position sense (JPS) test, triple-hop distance (THD) test and core stability (flexors and extensors endurance, right and left side bridge test) were used and correlated.

Results: Seventeen players have participated in this study: 10 athletes with prior history of HSI, composing the Hamstring injury group (HG) and 7 athletes without prior severe injuries as control group (CG). We found statistical significant differences between HG injured and uninjured sides in the BF myoelectrical activity at almost all times in both velocities and between HG injured and CG non-dominant sides at 100ms in eccentric 120deg.sec^{-1} velocity ($p<.05$). We found no differences in MH activity. Regarding proprioception we found differences between the HG injured and uninjured sides ($p=.027$). We found no differences in the rest of used tests. However, significant correlation between myoelectrical activation at 100ms in 120deg.sec^{-1} testing and JPS with initial position at 90º ($r-.372$; $p=0.031$) was found, as well as between isokinetic H:Q ratio at 240deg.sec and THD score ($r=-.345$; $p=.045$).

Conclusion: We found significant differences that support previous research regarding neuromuscular adaptations and BF inhibition post-HSI. Moreover, to our knowledge, this was the first study that found correlation between these adaptations, and may open a door to new perspectives and future studies.

Abbreviations and/or acronyms

HSI- Hamstring strain injury

BF- Bicep Femoris

BFLh- Bicep Femoris Long Head

BFSh- Bicep Femoris Short Head

BMI- Body Mass Index

CG- Control Group

EMG- Electromyography

H:Q- Hamstrings to Quadriceps ratio

HG- Hamstring injury Group

IIR- Infinite Impulse Response filter

JPS- Joint Position Sense test

MH- Medial Hamstrings

RTD- Rate of Torque Development

RTP- Return To Play

SAPO- Software Para Avaliação Postural (software for postural analysis)

SD- Standard Deviation

sEMG- Surface Electromyography

SENIAM- Surface Electromyography for the Non-Invasive Assessment of Muscle

SM- Semimembranosus

ST- Semitendinosus

THD- Triple-Hop Distance

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Introduction and Purpose

Muscle strain injuries are a problem for most running based sports, and affects both amateur, recreational, professional and elite athletes [1–3]. Hamstring strain injuries (HSIs) are the most common and prevalent type of muscle strain injury, resulting in a considerable loss of competition and training time, performance decline and resources and substantial financial costs to clubs and organizations [1–4]. The financial costs of HSIs have been previously observed in some studies, and has been suggested to have cost in excess of £74.4 million in English football premier league among all its participating clubs during 1999-2000 season [5] and $AUS1.5 million in Australian football league during 2009 season[4].

There are two proposed types of acute HSIs, one occurring during high speed running and mainly involving bicep femoris long head and the second during movements leading to wide-ranging muscle stretching (high kicking, sagittal split, tackling) that often involve the proximal tendon of semimembranosus [6–8]. The bicep femoris long head is the most commonly injured component [3,9]. Historically, acute muscle strains are classified as grade I, II and III based on the amount of fibers disrupted. A grade I strain is characterized by overstretching with microscopic damaged, without perceptible fiber disruption. Grade II strain is a macroscopic partial muscle tear while a grade III strain is a complete disruption of the muscle or tendon (grade 3 injuries are quite rare) [10]. Average time loss of training and competition in European professional football are 17±10 days for grade I, 22±11 days for grade II, and 73±60 days for grade III [11], but the majority of HSI in football (97%) are classified as grade I and II [12].

One of the most problematic consequences of HSIs that remains unresolved is the high rate of reinjury, being the primary injury the principal risk factor for recurrence [13], and whereas this injury-reinjury cycle is acknowledge by literature, little is known about the role of maladaptations in HSIs, and how can it influence and sabotage rehabilitation programs, as well as their role after return to play. In the last years, research has been focusing its attention on neural maladaptations post-HSI and associate them with injury recurrence [14]. Although there is increasing evidence in HSI prevention and rehabilitation strategies, the injury and reinjury high rates over the years suggest that our current knowledge around HSI remains incomplete [4].

A recent study, in general agreement to previous ones [15–17], found that their participants with history of HSI demonstrated significant reductions in electromiographic muscle activity ratios, and pelvic and lower limb movement patterns asymmetries during high-speed running when compared with the uninjured member, including anterior tilt, hip flexion and medial knee rotation on the injured side; these biomechanical adaptations are likely to place the bicep femoris long head under increased strain compared to the semitendinosus and semimembranosus, known as the medial hamstrings. The asymmetries occurred during the immediate precontact late swing phase of running, which is the time identified in literature as most riskful for the bicep femoris long head injury [15–17]. Another recent study[18] also found that during prone hip extension football players with HSI history had significant differences in medial hamstrings and gluteus maximus myoelectrical activity when compared to uninjured ones; with a decrease of medial hamstrings activity and an gluteus maximus activity increase, overacting as a medial hamstrings synergist in order to substitute and compensate their decreased activity.

Decrease and deficits of the bicep femoris long head activation may have an important role in HSIs incidence and recurrence, because lower levels of myoelectrical activity may limit and sabotage the adaptative response to rehabilitation programs, and may induce several maladaptations [19], including chronic eccentric hamstring weakness [4,20,21], selective hamstring atrophy [22] and shifts in torque joint-angle relationship [19,21,23].

Terminal swing-phase of gait cycle requires high force eccentric contractions, and as such high rates of torque development (Δtorque/Δtime) and early contractile pulse (the area under the time-vs-torque curve) during eccentric contractions are very important because the limited time for deceleration (100ms average) [14,24] prevents the development of maximal torque [14]. Therefore, considering post HSIs impulse decrease, it is expected hamstrings increased effort in the terminal swing phase to reduce the leg frontal movement due to weak deceleration during the initial swing; and the decrease of deceleration force production right after initial contraction may augment necessary muscle work when hamstrings are more lengthened (especially the bicep femoris long head); this can induce an anticipated muscle fatigue and increase the probability of tension induced muscular failure; furthermore it may also increase the likelihood of muscle overlengthening due to the decline of myoelectrical activity and hamstrings torque production inability in response to concurrent eccentric forces, increasing reinjury risk by exceeding muscle mechanical limit or gathering muscle microscopic damage [14]. Regarding this, a recent study using functional magnetic resonance imaging evaluated the magnitude and distribution of the metabolic changes within the hamstring muscles after intense eccentric hamstring exercise, and concluded that the injury group had a lower exercise capacity, suggesting that HSIs in football are associated with compensatory and asymmetrical neuromuscular activation and recruitment patterns in heavy eccentric actions, leading hamstrings to a more severe and premature fatigue. During running, the bicep femoris, semimembranosus and semitendinosus work together as synergists, however during heavy eccentric loading in athletes with prior HSI the semitendinosus has a predominant function and elicits the highest metabolic muscle activity, and hamstrings show compensatory and less isolated activation patterns when compared to uninjured athletes, and this may predispose football athletes to a higher reinjury risk [25].

Increased mechanical strain arise near the proximal bicep femoris myotendinous junction during lengthening contractions, and subjects with HSI history presented significantly greater muscle strain, when compared to the contralateral limb, suggesting that residual scar tissue at the site of the prior musculotendon injury may negatively affect local tissue mechanics and contribute to reinjury risk during active lengthening contractions [26]. Interestingly, latest research suggest that early stages of rehabilitation after HSI avoid excessive muscle stretch, because it may exacerbate scar formation [27], and as a consequence the long head of hamstrings may develop significant atrophy, showing a reduction in in-series sarcomeres if the strain is severe (grade II/III) [21]. There is a wide variety of literature over the past few decades regarding HSIs and re-injury risk factors and its prevention, therefore it is crucial to correlate various risk factors in a new conceptual analytical model for HSI, focusing the inter-relationship between them, allowing correlation and regression analysis, for instance between core stability, muscle flexibility, strength and architecture, among others [28]. It is important not to exclude the interaction between multiple risk factors in order better understanding of HSI and reinjury mechanisms [29].

Considering all the above, the **purpose** of the present study was to determine, analyze and correlate neuromuscular adaptations in amateur football players with prior history of HSI and uninjured athletes in similar conditions, by measuring isokinetic concentric and eccentric strength, angular peak torque, muscle myoelectrical activity during early eccentric contractions, core stability, flexibility, proprioception and functional performance.

Review of Literature

1- Epidemiology

Hamstring Strain Injury (HSI) is the most common injury in a wide variety of sports, for instance a) football 12-14% of all injuries incidence [3,30,31]; b) Australian Football, 13-15% incidence [2,32]; c) Rugby, 15% incidence [1,33]; d) American Football, 12% incidence [34] and e) Track and field, 26% incidence [35].

This injury has a reported prevalence of 37% of all muscle injuries, accounting for 12% of all sport injuries [36]. In a sport team, it is expected to occur 5 to 6 hamstrings strains per season, and in English and Australian football, authors found that HSI resulted in 90 days stoppage of practice and 15 to 21 matches missed on average [2,3]. High recurrence rates are also one of the most problematic issues of HSI, because recurrence HSI injuries normally result in an increased sports nonparticipation period than the initial injury [30]. These muscles have an higher and prolonged recurrence injury risk than other muscles [2]. In a variety of sports the recurrence rates ranges from 12% to 41% [3,37,38]. The recurrence is more common when the injury involves the bicep femoris [39].

2- Risk Factors

2.1- Non-modifiable risk factors

According to literature, we can identify as non-modifiable risk factor athletes age, ethnicity and history of HSI. The age has been identified by several authors as a independent risk factor [2,40–42], with increased odds of suffering an HSI if athletes are older than 23 [3]. There are some hypothesized age-related changes that can increase risk of HSI, such as increased bodyweight and reduced flexibility, as well as decreased strength and muscle mass in older athletes [42,43] or L5/S1 nerve entrapment, among other suggested explanations for age-related HSI risk [4]. Regarding ethnicity role in HSI risk, one study found that black football players have more HSI risk when compared to caucasian athletes, one possible explanation suggested by this study is the anterior pelvic tilt commonly seen in black origin athletes that might predispose them to this injury [3]. Finally, within the non-modifiable risk factors, the previous history of HSI has been the most documented risk of injury [41,43]. Whether recent or old, prior HSI has been suggested to induce several maladaptations in the hamstrings muscles, that will be discussed further in this study, and considerably contribute to reinjury rate and likelihood, being HSI one of the most recurrent and long-lasting injuries in sports [4].

2.2 – Modifiable risk factors

2.2.1- Strength imbalances

Evidence supports that muscle weakness may predispose the muscle to a strain injury, as stronger muscles provide more strain protection [4]. Regarding hamstrings, it has been demonstrated that its strength decline occurs mostly during eccentric forces; being the strength imbalances minimal or inexistent during concentric efforts [20,44,45]. Strength asymmetries between limbs may predispose the weaker hamstring to higher risk of injury [46], varying its asymmetry degree from 8% to 15%, depending on the sport practiced, to increase HSI risk [2,44]. One recent systematic review with meta-analysis also concluded that although hamstrings peak torque may not be a risk factor for HSI, however an increase in quadriceps peak torque can be a predisposal factor [47].

Studies indicate that an eccentric hamstrings to quadriceps force low ratio (functional H:Q ratio) predispose athletes to a higher risk of HSI [44,48]. Croisier et al. (2008) studied 462 football players with hamstrings strength deficits, between limb asymmetries or low H:Q ratio and demonstrated that they were more predisposed to HSI. In the Croisier's study, the number of athletes with concentric strength alteration was very low, being the majority of functional H:Q ratio differences during eccentric force [44]. Comparing hamstring to opposite hamstring ratio, is has been suggested that eccentric asymmetries were predictive of HSI in football players [47]. Hamstring eccentric torque comparisons are described in literature, comparing injured with non-injured members, and individuals with and without HSI history; revealing significant deficits in hamstrings with previous injury history [20,44,49,50]. This predominant eccentric weakness is suggestive of neuromuscular inhibition, which is the only known mechanism that could explain this selective muscle weakness [21]. Regarding this and because the late swing phase during sprinting is responsible for most HSI injuries [16,51–53], it has been demonstrated that during this phase the muscle is simultaneously lengthening rapidly while performing an high level of eccentric force, to decelerate the lower limb for the foot strike [16]. This can be a possible explanation why both peak musculotendon length and electromiographic activation of the bicep femoris long head are synchronous during late swing phase, exposing this muscle to high tensile force in response to eccentric loading, possibly contributing to HSI occurrence during high-speed running [54].

2.2.2- Reduced Flexibility

There is some controversy around flexibility role as a HSI risk factor, as there are authors who defend that lower prolonged flexibility increase HSI risk [27,55,56], while some prospective studies did not find any association between hamstring flexibility and HSI incidence [13,42]. Additionally one study reported an association between diminished hip flexors flexibility and HSI risk [42], also other studies demonstrated that contralateral psoas muscle had great influence in the hamstring leg [53] and its peak elongation of the stance limb is synchronous with the peak elongation of the hamstring on the swing leg in running [57]. Furthermore, it has been also demonstrated the negative effects of a football match in hip flexibility [58].

2.2.3- Fatigue

Normal muscles absorb more energy than fatigued or with activation deficits muscles, therefore weak hamstrings may absorb insufficient energy during the terminal swing phase of running [17,59]; and a fatigued muscle has increased likelihood of suffering a strain injury because of its incapacity in resist the overlengthening muscle during this running phase [4]. Hamstrings fatigue may lead to increased knee extension during the late swing phase, which will predispose the muscle to an higher strain [51,60]. One recent study was also focused in understanding the bicep femoris myoelectrical activity alterations during an eccentric hamstrings contraction after repeated sprint running in recreational athletes [61] because: (i) running displacement sports (such as European and American football) require concurrent and high-speed sprints during matches; and (ii) previous studies conducted in European football teams, found that prolonged intermittent running may have a negative impact in eccentric hamstrings strength [62,63], and predispose the bicep femoris long head to a strain injury [44,48], as has been previously studied and showed that there is a tendency of suffering an HSI in the end of each half in football [3] and in rugby [64]. Regarding this Timmins and colleagues evaluated isokinetic eccentric strength before and after repeated running, and found that the decline in eccentric strength may be explained by the decline of bicep femoris myoelectrical muscle activation in consecutive sprinting [61]. Also Marshall and colaborators evaluated 8 athletes, during a simulated soccer match with 90 minutes duration, every 15 minutes of each half and found centrally mediated reductions in rate of torque development and maximal torque, and this decline specially occurred in the end of each half, in association with the simultaneous decrease of bicep femoris maximal activity. Furthermore, rate of torque development decline occurred only 15 minutes after the beginning of the 1st half and further decrease was found until the end of the 2nd half [65].

<u>2.2.4- Musculotendon architecture</u>

Muscle tendon architecture may be a factor in development of HSI as authors have suggested that the aponeurosis morphology of the bicep femoris long head may have a significant role in muscle stretch distributions [66]. A recent study also found that individual musculotendon dimensions also contribute to strain likelihood, as larger muscles and confined proximal aponeurosis increase the injury risk, by increasing peak local tissue strain; which might explain the athletes interindividual differences in susceptibility to HSI when exposed to same conditions [67]. Hamstrings architecture variation may be one of the factors involved in HSI and reinjury. Indeed the bicep femoris long head has shorter fascicles and bigger muscle area compared to its short head [68] and this explains why the long head is more susceptible to injury, because longer fascicles allows greater stretching of the muscle, avoiding eccentric overlengthening [23,69]. Additionally, it is during the terminal swing phase of running that peak elongation occurs and that this muscle is required to exert most eccentric force, predisposing it to injury [16,51,53,70,71]. Many authors defend that muscle strain injuries are associated with high-force eccentric contractions, where the muscle lengthening demands exceed its mechanical limits [6,8,13,20,53,70].

Hamstring strain injuries are typically a result of simultaneous hip flexion and knee extension [10], more frequently during running and sprinting [3,8,64], but also during other actions such as kicking or tackling [3,7,8,37,64]. Because hamstrings are a biarticular muscle, it allows significant muscle lengthening during simultaneous hip flexion and knee extension, as observed during running; which may predispose hamstrings to a strain injury, by exceeding muscle mechanical limits [16] or microscopical damage [23]. Most of running-related HSI affect the bicep femoris long head, because this muscle reaches longer lengths than the semitendinosus and semimembranosus during terminal swing phase of running [51].

2.2.5- Core stability

In recent studies, HSI has been associated with core stability [53,59,72,73]. One study found that athletes who performed a core stability program had significantly less hamstring reinjuries compared to conventional stretching and strength rehabilitation [74]. Also a study shown reduced hamstrings stiffness after lumbopelvic stability exercises [75]. Nevertheless association between core stability and HSI risk requires further investigation [28].

2.2.6- Other risk factors described in literature

There are more HSI risk factors described in literature, however there are very few studies supporting these. One is lumbar disorders, as there are studies that found increased activity and decreased flexibility in the hamstrings of individuals with low back pain, that can increase tension and result in muscle damage; on the other hand studies found a significant increase in lumbar lordosis in athletes with HSI [29]. Other is neural tension, which is proposed as a possible risk factor for HSI recurrence, because branches of the sciatic can create increased neural tension and local damage to hamstring muscles [76]. Furthermore, another possible risk factor is the muscle fiber composition as evidence hypothesized that since the hamstrings have relatively high percentage of type I fibers (slow), may be prone to HSI [29,77,78].

3- Hamstring Strain Injury recurrence and return to play

3.1- Return to play

After HSI, there are a number of factors suggested as indicators of return to play; as for instance, the distance of injury to ischial tuberosity. Several studies suggest that a longer time to return to play is correlated with a closer distance to ischial tuberosity [8,79,80]. Also, a recent review evaluated the relationship between the size of HSI on magnetic resonance imaging and the time to return to play, concluding that there was no strong evidence that supports professionals decision for return to play prediction or risk of reinjury based on magnetic resonance imaging [80], despite its excessive reliance in decision to return to play prognosis in a sports and teams settings, sometimes conditioning athletes rehabilitation times [81].

Even after rehabilitation and returned to play, football players returning from a recent HSI, when compared to uninjured athletes, had lower high-speed running performance [19,82]. Additionally, other study also found that some of the included football players with HSI history, had one or more isokinetic deficit of more than 10% after clinical discharge and return to sport practice, despite the correlation between isokinetic deficits and the increase of recurrence risk remains inconclusive in literature [83].

3.2- Hamstring Strain Injury recurrence

This injury, in addition to high rates of incidence, also exhibits very high rates of recurrence [1–3,12,33,64] in all the aforementioned sports a) football, 16% reinjury rate [30]; b) Australian Football, 27% [2]; c) Rugby, 21% [64] and d) American Football, 32% [4]. There is increasing evidence that supports that hamstrings eccentric weakness may be a factor for high recurrence rates of HSI [20,49,83–86]. However, other studies found no correlation, assuming that the primary risk factor for recurrence is the history of prior HSI [18,23,45,87].

4- Neuromuscular inhibition

Previous HSI has been shown to be a nonmodifiable risk factor for reinjury, however there are several functional deficits post HSI identified in literature. One study [88] gathered recent evidence and reported that these neuromuscular adaptations include lower knee flexor eccentric strength (10%-24%) [23,45], lower voluntary myoelectrical activity during knee flexors maximal eccentric contraction (18%-20%) [14,49,85], lower knee flexor eccentric rate of torque development (39%-40%) [14], lower voluntary myoelectrical activity during early eccentric contraction (19%-25%) [14], and lower functional H:Q ratio (19%) [45].

Previously injured hamstrings also generate their peak torque at shorter muscle lengths when compared to their contralateral limb and uninjured individuals during knee flexor eccentric isokinetic dynamometry testing [23,89]. This higher optimal angular peak torque observed on the injured member results in increasing work of these muscles, predisposing them to greater microscopic damage and anticipated fatigue as consequence of the powerful active lengthening during sprinting [23,89]. After accumulation of such skeletal muscle damage after consecutive trainings involving high-speed running, there are studies proposing that this may result in macroscopic muscle strain [20,23,89].

Studies suggest eccentric weakness post-HSI to be long-lasting (from months to years), even athletes have fully returned to competition [20,90]. Interestingly Opar et al. (2015) in their recent study demonstrated that athletes with unilateral HSI history displayed less improvement in eccentric hamstring strength during the Australian football preseason not only in the injured limb but also in the contralateral uninjured one, when compared to control uninjured players. Reinforcing the neuromuscular inhibition after unilateral HSI may be mediated by central mechanisms, and these can affect both injured and uninjured limb [91]. Not only eccentric weakness, but also altered angular peak torque has been demonstrated to persist months to years after HSI [20,23], exhibiting optimal peak torque at shorter muscle lengths in the previously injured knee flexors [23,92]. Furthermore Opar et al. (2012) have previously studied the influence of prior HSI in the rate of torque development and contractile impulse, and found lower values on the injured limb, when compared with the contralateral member. Simultaneously they have found reduced myoelectrical activity was only restricted to the previously injured bicep femoris long head muscle, and not medial hamstrings [14]. Furthermore, the intention to perform an eccentric action has been shown to provoke greater movement-related cortical potential when compared to concentric movements, suggesting that the modulation of motor activity depends on contraction type [93].

Additionally, Sole et al. (2011) showed that previous injured hamstrings were less activated during maximal eccentric actions at longer muscle lengths when compared to uninjured athletes [85]. Again one possible explanation for this reduced ability to activate previously injured hamstrings may be the neural defense mechanism response and sustained neuromuscular inhibition, limiting muscle adaptation to its optimal state [21], resulting in reduced activation during eccentric actions at longer muscle lengths limiting muscle hypertrophy during eccentric actions [15,21,85,87]. Hamstring recovery may be impaired by the limited exposure to eccentric stimulus in longer muscle lengths during rehabilitation due to chronic pain-driven neuromuscular inhibition on the lengthened muscle [21].

Other neuromuscular adaptations have been reported. For instance one study [53] highlighted the potential influence of lumbopelvic musculature on bicep femoris strain. Chumanov et collaborators[53] found a relative increase in ipsilateral gluteus maximus and external oblique muscle activity, accompanied with a decrease of bicep femoris activity; the investigators hypothesized that this activity can be “protective” towards reducing bicep femoris strain during terminal swing phase in running as well as contralateral rectus femoris and ipsilateral erector spinae muscular activity increase was also noted [53]. These alterations in muscle activity can be a maladaptive process, a failure to adapt to the bicep femoris specific dysfunction or post-injury neuromuscular inhibition [21].

Methodology

1- Participants

Seventeen amateur level male football players volunteered to participate in the study. Recruitment occurred through verbal advertisement and research posts. All participants play on a synthetic based field. To be included in the study, participants had to be senior team player, with age between 18-35 years old and training frequency more than 3 times per week. To be included in the hamstring injury group (HG), players had to have sustained at least one grade I or II HSI within the past 2 seasons (season 2013/2014 and 2014/2015). As inclusion criteria participants had to confirm the HSI through ultrasonography or medical report, or if not possible to report hamstring strain injury as sudden onset of non-traumatic posterior thigh pain during a training or match that prevented them from returning to play at least 4 weeks and needed intervention from a healthcare professional, and when this was the case, the injury severity was confirmed with the Physiotherapist or Sports Medicine Doctor responsible for the athlete at the time injury occurred. Hamstring injury group exclusion criteria were: not fully recovered from the HSI for more than 6 months, any other serious injury to his lower limbs (for instance, anterior cruciate ligament or meniscal tear), being on medications. To constitute the control group, football players from the same teams without a history of hamstrings or any other severe lumbopelvic, hip, thigh and knee injuries were recruited; when a player from the same team was not available, another player in a team with same competition level and resources was recruited.

Limb dominance was defined as the preferred kicking leg. Each subject completed all data collection in one session. The participants were familiarized with the experimental protocol and apparatus. The assessment was conducted 48 hours after a game or practice, to avoid the effects of intense exercise on the outcomes. All participants provided written informed consent, and all procedures were conducted according to the Declaration of Helsinki.

2- Procedures

The participants reported to the laboratory once for assessment of muscle concentric and eccentric strength, bilateral muscle activity of hamstrings (medial hamstrings and biceps femoris) during maximal eccentric contractions, proprioception, flexibility, core stability and functional performance.

Before the data collection, all participants were informed about the study procedures and thereafter were asked to sign the written informed consent (annex 1). Afterwards, participants completed a questionnaire, with anthropometric, demographic, sport-related (athlete field position; type of field, type of field surface) and injury related questions (time that he had primary and recurrent injuries, how much time was he absent from competition, time of rehabilitation, injury mechanism and rehabilitation time), among others (Annex 2 for Hamstring group, Annex 3 for Control Group). Height and weight were measured using a standard scale and stadiometer (Seca 285, Seca, Birmingham, United Kingdom).

2.1 - Assessment of muscle strength and electromiographic activity

The assessment of knee muscles strength was performed on both limbs on a Biodex 3 dynamometer (Biodex Medical Systems, Shirley, New York). Athletes were 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 minimize movement artifacts from the surface electromyography (sEMG) electrodes on the seat during isokinetic assessment. The hips were flexed at 85º from neutral with the lateral epicondyle of the femur aligned with the dynamometer fulcrum, then the tested leg was attached to the lever of the dynamometer with a Velcro strap and padded restraints were fastened across the hips and trunk, as well as the mid-thigh of the tested leg to isolate movement to the knee joint. Range of motion was set at 0º to 90º of knee flexion (0º=full extension; 90º=start position).

Before the protocol, the participants performed a warm-up consisting 5 min of cycling in a mechanically braked cycle ergometer with a fixed load of 50 watts, and also performed submaximal contractions of the knee extensors and flexors and one maximal contraction at the test speed on the isokinetic dynamometer in order to familiarize with the isokinetic device.

Isokinetic testing protocol consisted in four tests for each limb (Table 1) in order to assess concentric and eccentric muscle strength at different velocities. The order of tests and limb testing was randomized through participants. Maximum effort was requested with verbal stimulus to participant in every test. Each test was interspersed with 30 seconds rest period. Participants were also instructed to remain relaxed before each set to allow a stable baseline measurement of muscle activity. To confirm muscle activity, athletes were asked to voluntarily bend their knee and push their heel back, towards their gluteus as quickly as possible when given the signal to contract.

Table 1 – Bilateral Isokinetic Dynamometry Testing Protocol

Test	Speed	Sets	Repetitions
Concentric knee extensors/flexors	60 deg.s^{-1}	2 (1st set warm-up)	3
Concentric knee extensors/flexors	240 deg.s^{-1}	2 (1st set warm-up)	5
Eccentric knee flexors	30 deg.s^{-1}	2 (1st set warm-up)	3
Eccentric knee flexors	120 deg.s^{-1}	2 (1st set warm-up)	4

Myoelectrical activity as measured during the isokinetic eccentric contractions via sEMG from bicep femoris and medial hamstrings through the use an EMG system (BTS FREEEMG 300, BTS Bioengineering, Milan, Italy) and disposable circular silver surface electrodes (Covidien Kendall, Minneapolis, USA) with a diameter of 24 mm. Before the electrodes application the athletes skin was prepared by shaving the area, cleaning and rubbing it with alcohol; and, it was given a 5-min rest time to reduce skin impedance. The electrodes were placed on the posterior thigh halfway between the tibial epicondyles and the ischial tuberosity, according to Surface Electromyography for the Non-Invasive Assessment of Muscle (SENIAM) guidelines [94]. Muscle bellies were identified by palpation during isometric knee flexion, and correct placement was confirmed by observing sEMG activity in the computer during internal and external rotation of the flexed knee. All isokinetic test repetitions were video-recorded for analysis and synchronization of isokinetic testing and electromiographic data.

Biodex isokinetic dynamometer torque and angle position data were transferred to computer and peak torque was defined as the mean of all repetitions in each velocity and limb. Peak torque and respective angle were stored for further analysis. Surface EMG was recorded and synchronized with the isokinetic testing; a videotape was recorded to synchronize the isokinetic eccentric contractions and the sEMG recordings manually. EMG muscle activity was recorded during the eccentric tests with surface electrodes and sampled at 1000 Hz using a wireless EMG system. Data were analyzed with AcqKnowledge, version 3.9.0 (Biopac System, Goleta, CA, USA). The raw EMG signals were digitally filtered with a IIR band-pass (20-500 Hz) filter, full wave rectified, and the root-mean square of the signal was derived. In each eccentric test, every muscle activation onset was pre-determined to each contraction [49]. Onset and offset of muscle activity was determined by using a 10% threshold of the maximum amplitude of the muscle contractions selected for analysis and visually confirmed by synchronized video recording at the selected time-frame [60]. Similarly to Opar et al. (2013), myoelectrical activation was measured in all the eccentric tests repetitions, from onset of contraction until 30, 50 and 100 milliseconds of the contraction [14]. In each contraction, maximal peak activation of bicep femoris and medial hamstrings was noted and percentage of the 30, 50 and 100 milliseconds activation value was calculated for both muscles.

2.2- Assessment of proprioception

The knee joint position sense test was performed on athlete's lower members in an open kinetic chain and with active positioning of a previously determined passive position. The participants had to be wearing shorts. The technique was performed in the ipsilateral limb and without visual input. Prior to the test, four reflective markers were placed with red-color tape in the a) great trochanter, b) illiotibial tract, at the knee posterior crease level (with 80º knee flexion), c) peroneus head, d) lateral malleoli prominence. Each pair of markers (a-b, c-d) represented the axis of the thigh and the leg.

To record participants positioning, it was used video recording for later analysis. The camera was aligned with the knee subject to test, and then manually focusing on the field of view (sagittal plane). To evaluate the knee joint position sense, participants were seated in a treatment bed with their lower limbs without touching the floor, and were blindfolded in order to remove visual input. Furthermore every test was made individually in a quiet place to avoid external stimuli [95].

We analyzed two joint positions between 40º and 60º of knee flexion; for one position the movement was from flexion to extension (initial position in 90º knee flexion), and for the other was from extension to flexion (initial position was complete knee extension, 0º). The examiner slowly (at approximately 10º/second) moved the testing leg from initial position to a knee angle between 40º and 60º flexion, and asked the athlete to maintain this position for 5 seconds to memorize it. After the participant was instructed to actively return to initial position and immediately place the knee to previously passive placed position, reporting "target" to the examiner and hold that position for 5 seconds, and on the command "return", the subject returned to initial position and repeated the repositioning twice. This test was repeated 3 times for each limb and it was then performed again, being the initial position full knee extension (0º). After data gathering knee angles were determined by computer analysis of the videotaped images of the knee joint using a computer software (SAPO- Software para Avaliação Postural) [96]. Knee joint position sense is reported as the absolute angular error, defined as the absolute difference between test position and the position reproduced by the athlete, which represents accuracy without directional bias [95]. This absolute difference was taken by the mean of 5 frames (one in each second of the participant active hold positioning) analysis of each position.

2.3- *Assessment of flexibility*

Flexibility was assessed through two tests: active and passive knee extension.

To assess active knee extension, the athlete was laying supine in the testing surface. The tested leg was then positioned at 90º hip flexion and contralateral leg fully extended and in neutral rotation positioned by a second examiner; with the foot in neutral position and the knee in 90º flexion. In this position and without any prior warm up, the participant was instructed to extend the knee until strong resistance and hold this position for 3 seconds, allowing evaluation. The result corresponds to the range of motion in degrees, starting in the initial position (knee at 90º flexion, corresponding to 0º goniometer). After evaluation, the tested member was positioned in a neutral rest position for 60 seconds, and then proceeding to a second evaluation. After second testing, contralateral member was tested [97]. The video recording procedures and the same software (SAPO) were used to withdraw the test degrees and best of the two measures for each test was noted.

The protocol for assessing passive knee extension was similar to the aforementioned with the difference that the examiner extended the knee until it reached maximum hamstrings stretching tolerated by the participant. This is a protocol adapted from [98], switching the goniometer with video analysis by the use of the referred software.

2.4- *Assessment of lumbopelvic stability*

Lumbopelvic stability was assessed with three different tests: the extensors endurance test, the flexors endurance test, and the side bridge test.

The extensors endurance test is a test modified from the Biering-Sorensen test [99], which has been shown as a consistent and reliable measure of back extensor muscle endurance. Participants laid prone with the lower body fixed to the test bed (positioned approximately 25 centimeters above the floor) at the ankles, knees, hips and the upper body extended over the edge of the bed (aligning anterior superior iliac spines with the border of the bed). They were then instructed to rest their trunk on the floor before test.

When it started, upper limbs cross at chest level with both hands in the opposite shoulders and the upper body was lift from the floor until it was horizontally aligned with this. The participants were then instructed to maintain this horizontal position for as longer as possible. The endurance time was manually and video recorded in seconds, since the time the participant achieved horizontal positioning until the moment the upper body touched the ground [100].

During flexors endurance test, participants were seated on the physiotherapy test bed and supported their upper body against the bed support positioned in a 60º angle from the remaining bed. Both knees and hips were flexed to 90º and arms folded across the chest and both hands placed on the opposite shoulders, and toes placed under toes straps. Athletes were then asked to maintain this position while the support was pulled back approximately 10cm to begin the test. The endurance time was manually and video recorded in seconds which ended when participants upper body felt below the 60º [100].

The side bridge test consisted of athletes laying on an exercise mat, on one side with legs fully extended. The top foot was positioned in front of the lower foot for support and participants were instructed to support themselves lifting their hips of the mat and to maintain a straight aligned position over their body, supported only on one elbow and their feet for as long as possible. The uninvolved arm was held across the chest with hand on the opposite shoulder. The endurance time was manually and video recorded in seconds from the time they straighten their hip from the mat until the hips touched the exercise mat again [100].

During all endurance tests (only one repetition for each test, with 5 minutes interval between test), subjects were reminded to maintain the positions for as long as possible and only the participant and the examiner were present in the testing room. Athletes were not provided with any clues to their scores until the conclusion of all the endurance testing protocol.

2.5- Assessment of functional performance of lower limb

In the triple hop test, it was fixed tape straps on the ground, perpendicular to the starting line, with 1-meter distance. Athletes then stood on the testing leg, with the tip of the hallux on the starting line. They were then instructed to perform 3 consecutive maximal hops forward on the same limb. Arm swinging was allowed. The examiner measured the distance hopped from the starting line to the point where the heel struck the ground on the last (3rd) hop. All athletes were allowed one to 3 practice trials (self-selected) on each leg and then completed 3 test trials. Practice trials were provided to allow athletes to familiarize with the triple hop test protocol but were limited to 3 practice tests on each leg to avoid the effects of fatigue. A test trial was repeated if the participant was unable to complete a triple hop without losing balance and/or contacting the ground with the opposite leg. Mean distance of the 3 trials was recorded in centimeters and used for analysis. Athletes were using self-selected footwear [101].

3- *Statistical Analysis*

Data was analyzed using IBM SPSS statistics 21.0 (IBM Corporation, Chicago, IL, USA). The normality of data distribution was tested with the Shapiro-Wilk test and analysis of histograms. For group comparison (age, height, weight, flexors endurance, extensors endurance, right and left side bridge) independent samples t-test were used. For comparisons of dependent variables between injured, uninjured (HG), dominant and non-dominant (CG) limbs we used an analysis of variance (one-way ANOVA) test; post hoc comparisons were made using Bonferroni tests. For between group comparisons in core stability and H:Q ratio between groups, independent T-tests were used. To test the association between muscle strength, muscle activity, proprioception, flexibility, functional performance and lumbopelvic stability, Pearson correlation coefficient was used. $P \leq 0.05$ was considered indicative of statistical significance.

Results

1- Participants characteristics

Twenty players have volunteered and been included in the study. However, three of the ten participants in the control group were excluded from analysis due to EMG software technical problems or due to athlete unavailability to attend isokinetic evaluation, being the final sample included for analysis 17 football players included: 10 athletes with HSI history (HG) and 7 control athletes (CG) (Figure 1).

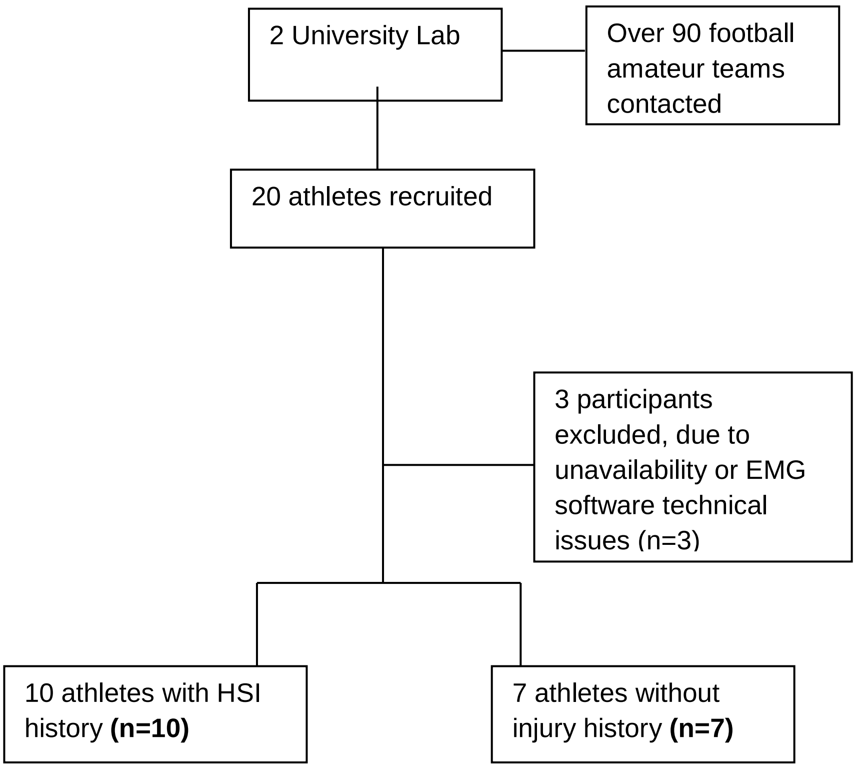

Figure 1 – Flow Chart describing Football players recruitment and inclusion for analysis

No significant differences were observed between groups for age (Hamstring Group: 24.40 ± 3.41 years; Control Group: 23.86 ± 3.44 years), height (HG: 1.79 ± 0.06 meters; CG: 1.78 ± 0.08 meters) and weight (HG: 78.02 ± 4.66 kilograms; CG: 73.6 ± 6.73 kilograms) (Table 2). Inside Hamstring injury group, athletes have returned to play after last injury for a 12 months median average (ranged between 6 and 16 months), after an average rehabilitation and time away from competitions after HSI of 4.5 weeks (ranging from 3 to 8 weeks). Only 3 of the 10 included participants in HG group had reported hamstring reinjury (being for 2 athletes the second injury and for one the third injury, all in the same limb). All injuries occurred during high-speed running and only one of the athletes had reported eccentric strength conditioning as part of his rehabilitation program. Regarding player positions, inside the HG group we had 3 defensive, 3 midfield and 4 offensive players; and in the CG we had 2 defensive, 2 midfield and 3 offensive players.

Table 2- Samples characteristics

Variable	HG (n=10)	CG (n=7)	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
BMI	24.36 ± 1.23	23.24 ± 1.87	0.156

Legend: BMI- Body Mass Index, CG- Control Group, HG- Hamstrings Group. Values are expressed in mean ± SD

2- Isokinetic Strength and eccentric peak torque angle

The isokinetic concentric and eccentric peak torque and the comparisons between groups and limbs can be observed in table 3. We found differences between groups in hamstrings concentric peak torque at 60deg.sec as seen on table 3, however post hoc analysis found no statistical significant differences ($p>0.05$). Furthermore we found no significant differences between groups regarding eccentric hamstrings strength and the rest of concentric quadriceps and hamstrings strength between HG injured and uninjured side when compared between them and with CG dominant and non-dominant side ($p>0.05$).

Table 3 - Peak Torque (mean ± SD) at different velocities in Control (CG) and Hamstring Injury group (HG)

Variable	HG injured side	HG uninjured side	CG non-dominant side	CG dominant side	P value*
Quadriceps peak torque at concentric 60deg.s^{-1}	215.35 ± 35.11	214.07 ± 49.46	193.4 ± 44.58	203.71 ± 48.69	0.735
Hamstrings peak torque at concentric 60deg.s^{-1}	128.98 ± 19.71	131.74 ± 21.96	112.80 ± 19.72	106.37 ± 16.05	0.031
Quadriceps peak torque at concentric 240deg.s^{-1}	123.39 ± 29.24	123.28 ± 31.51	124.47 ± 25.48	124.13 ± 22.73	0.998
Hamstrings peak torque at concentric 240deg.s^{-1}	83.91 ± 24.74	82.90 ± 18.45	74.81 ± 16.80	84.80 ± 17.34	0.767
Hamstrings peak torque at eccentric 30 deg.sec^{-1}	202.7 ± 51.67	217.65 ± 46.14	177.93 ± 25.48	184.81 ± 28.98	0.220
Hamstrings peak torque at eccentric 120 deg.sec^{-1}	195.91 ± 51.68	213.65 ± 53.35	190.14 ± 31.36	196.23 ± 49.13	0.753

* P value for one-way Anova

In H:Q ratio comparison between legs no statistical significance was also found between all limb comparisons, in concentric at 60deg.s^{-1} ($p=0.422$) and 240deg.s^{-1} ($p=0.901$), as seen on Figure 2.

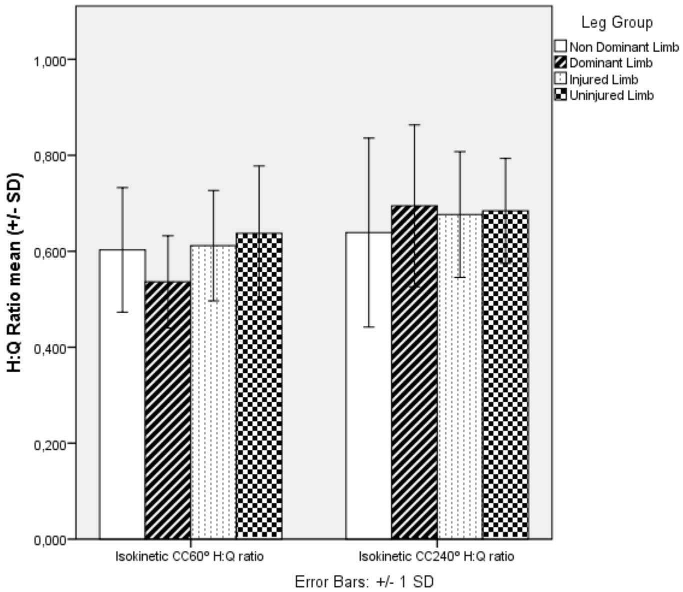

Figure 2- H:Q ratio during isokinetic concentric testing at 60deg.s⁻¹ and 240deg.s⁻¹ velocity for Hamstring Injury Group (HG) and Control Group (CG) sides

Regarding the angle of peak torque during eccentric testing, no statistical significance was also found at 30deg.sec⁻¹ (p=0.433) and 240deg.sec⁻¹ (p=0.243) (Figure 3).

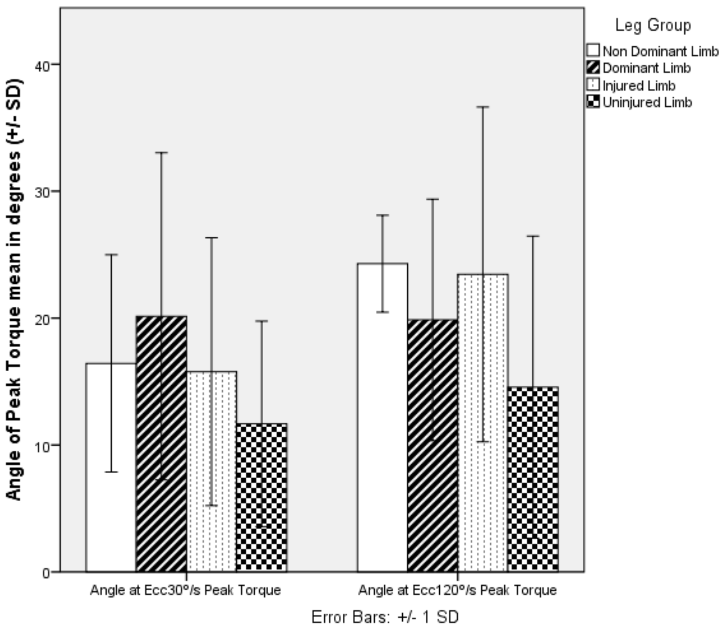

Figure 3- Angle of peak torque during isokinetic eccentric testing at 30deg.s⁻¹ and 120deg.s⁻¹ velocity for Hamstring Injury Group (HG) and Control Group (CG) sides

3- *Electromiographic muscle activity*

Values for EMG activity, in percentage of maximal activation, during isokinetic eccentric testing at 30deg.s^{-1} can be found in table 4 and testing at 240deg.s^{-1} in table 5.

Statistical significant differences groups/limbs were found between bicep femoris activity at 30ms (p=0.042) and 50ms (p=0.032), no differences were found at 100ms. *Post hoc* comparisons revealed that during eccentric at 30deg.s^{-1} there is a significant higher activation of the uninjured in comparison to the injured at 30ms (p=0.05) and 50ms (p=0.028). No significant differences were observed in medial hamstrings activation at the 3 assessment times (p>0.05) (table 4).

Table 4 - Electromiographic activity percentage during isokinetic eccentric testing at 30deg.s^{-1}

Variable	HG injured side	HG uninjured side	CG non-dominant side	CG dominant side	P value
BF activation during Eccentric at 30deg.s^{-1} - 30ms (%)	10.04 ± 4.06*	15.57 ± 5.26	11.37 ± 3.87	14.04 ± 3.88	0.042~~444~~
BF activation during Eccentric at 30deg.s^{-1} - 50ms (%)	13.17 ± 4.42*	23.36 ± 11.37	15.58 ± 4.82	18.16 ± 5.71	0.032~~142~~
BF activation during Eccentric at 30deg.s^{-1} - 100ms (%)	16.92 ± 6.84	27.03 ± 7.24	24.93 ± 10.28	27.70 ± 8.65	0.027
MH activation during Eccentric at 30deg.s^{-1} - 30ms (%)	20.21 ± 10.16	16.66 ± 7.47	15.35 ± 8.98	17.35 ± 6.66	0.673
MH activation during Eccentric at 30deg.s^{-1} - 50ms (%)	22.65 ± 7.48	23.12 ± 12.71	16.38 ± 7.63	18.50 ± 12.21	0.496
MH activation during Eccentric at 30deg.s^{-1} - 100ms (%)	29.75 ± 10.68	25.01 ± 11.31	24.93 ± 16.66	21.88 ± 9.97	0.608

Legend: BF, Bicep Femoris; CG, Control Group; HG, Hamstring injury group; MH, Medial Hamstrings. Values are expressed in mean ± SD

* significantly different from uninjured side, p<0.05

Statistical significant differences were observed in bicep femoris sEMG activity between groups/limbs at 30ms (p=0.025), 50ms (p=0.001) and 100ms (p=0.01). *Post hoc* comparisons revealed that there was statistical difference between HG injured leg and the uninjured leg at 30ms (p=0.04), 50ms (p=0.002) and 100ms (p=0.012). Furthermore, at 100ms there were also significant differences between HG injured leg and CG non-dominant (p=0.05), but not with the dominant limb. There were no significant differences between groups and limbs regarding medial hamstrings sEMG activity (table 5).

Table 5 - Electromiographic activity during isokinetic eccentric testing at 120deg.s^{-1}

Variable	HG injured side	HG uninjured side	CG non-dominant side	CG dominant side	P value
BF activation during Eccentric at 120deg.s^{-1} - 30ms (%)	14.34 ± 5.02*	21.39 ± 5.25	14.34 ± 4.25	17.63 ± 7.02	0.025
BF activation during Eccentric at 120deg.s^{-1} - 50ms (%)	16.93 ± 4.41*	27.42 ± 6.95	19.05 ± 4.84	24.38 ± 6.30	0.001
BF activation during Eccentric at 120deg.s^{-1} - 100ms (%)	22.50 ± 9.53*#	34.69 ± 6.58	33.71 ± 8.71	30.97 ± 6.81	0.010
MH activation during Eccentric at 120deg.s^{-1} - 30ms (%)	24.06 ± 10.83	22.50 ± 7.71	15.96 ± 5.02	16.37 ± 9.18	0.149
MH activation during Eccentric at 120deg.s^{-1} - 50ms (%)	24.87 ± 12.37	27.03 ± 10.79	17.58 ± 8.57	25.18 ± 7.59	0.313
MH activation during Eccentric at 120deg.s^{-1} - 100ms (%)	31.95 ± 11.53	31.71 ± 10.75	21.76 ± 7.48	27.52 ± 11.66	0.210

Legend: BF, Bicep Femoris; CG, Control Group; HG, Hamstring injury group; MH, Medial Hamstrings. Values are expressed in mean ± SD
* significantly different from uninjured side, p<0.05; # significantly different from CG non-dominant side, p<0.05;

4- Proprioception

When the starting position was 90º knee flexion we found no significant differences between groups / limbs (p>0.05) (Table 6). However, we found significant differences between groups in the joint position sense when the starting position was full knee extension as the initial position (p=0.027), more concretely differences between the HG injured side when compared to the uninjured leg (p=0.023).

Table 6 - Mean absolute error values for both groups

Variable	HG injured side	HG uninjured side	CG non-dominant side	CG dominant side	P value
Absolute Error (initial position = 90°)	4.73 ± 2.78º	2.96 ± 1.10º	2.71 ± 2.26º	2.11 ± 1.31º	0.058
Absolute Error (initial position = 0°)	4.60 ± 2.01º	1.94 ± 1.08º	2.81 ± 1.65º	2.64 ± 2.73º	0.027

Legend: Hamstring injury group; MH, Medial Hamstrings. Values are expressed in mean ± SD

5- Core stability, flexibility and functional performance

No significant differences between groups / limbs were observed in flexibility (active and passive knee extension), triple-hop test, core stability (flexors and extensors endurance, left and right side bridge tests) (table 7).

Table 7 - Core Stability, flexibility and functional performance values

Variable	Hamstring injury group		Control group		P value
Flexors Endurance (s)	216.7 ± 68.76		231.29 ± 58.33		0.681
Extensors Endurance (s)	109.6 ± 19.95		106.43 ± 29.88		0.796
Side Bridge Right (s)	68.70 ± 15.49		70.29 ± 22.61		0.865
Side Bridge Left (s)	66.10 ± 13.02		73.86 ± 27.99		0.452
	HG injured side	**HG uninjured side**	**CG non-dominant side**	**CG dominant side**	
Passive Knee Extension (º)	5.91 ± 4.67	5.22 ± 4.18	5.42 ± 4.15	4.67 ± 2.52	0.939
Active Knee Extension (º)	8.55 ± 4.48	7.38 ± 4.19	8.12 ± 5.90	8.864 ± 5.55	0.928
Triple Hop Test (cm)	568.30 ± 23.94	579.00 ± 20.60	560.43 ± 38.97	565.86 ± 34.54	0.603

6- Correlations

EMG activity and proprioception

We found a correlation between bicep femoris activation at 100ms during eccentric contractions at 120deg.s^{-1} and joint position sense with using 90° flexion (r-.372; p=0.031) as initial position.

Isokinetic Strength and Triple Hop Test

We found statistical significant correlation between Isokinetic H:Q ratio at concentric 240deg.s^{-1} and triple-hop scores (r=-.345; p=0.045).

Discussion

It is crucial not to ignore risk-factors inter-relationship in order to better understand the complexity of hamstring strain injury-reinjury cycle [28,29]. Based on this premise, this study was designed to analyze several possible neuromuscular adaptations in amateur football players with HSI history and compare with healthy athletes. Furthermore we tried to correlate findings and explore their relationship. To our knowledge this was the first study exploring the interactions between isokinetic concentric and eccentric peak torque, eccentric angular peak torque, electromiographic activity of bicep femoris and medial hamstrings after 30, 50 and 100milliseconds after onset of eccentric contraction at low and high velocities, knee joint position sense, active and passive knee extension, triple-hop functional performance test, trunk flexors and extensors endurance tests and bilateral side-bridges.

The present study found differences in the bicep femoris electromiographic activity in almost all times during eccentric testing at 30deg.s^{-1} (significant differences between HG injured and uninjured side at 30 and 50ms) and 120deg.s^{-1} (significant differences between HG injured and uninjured leg at 30, 50 and 100ms, and between HG injured side and CG non-dominant limb at 100ms), we also found significant differences regarding proprioception, in the knee joint position sense test using 0° (full extension) as initial position (significant differences between HG injured and uninjured sides). There were no statistical significant differences in the rest of evaluated variables (isokinetic concentric and eccentric peak torque, conventional H:Q ratios, angle of peak torque during eccentric testing, active and passive knee extension, flexors and extensors endurance, right and left side bridges test and triple-hop distance test. However we found significant correlation between bicep femoris myoelectrical activity at 100ms during 120deg.sec^{-1} with the knee joint position sense test at 90º flexion as initial position; we also found correlation between isokinetic H:Q conventional ratio and the triple-hop distance test score.

Hamstring strain injury is the most prevalent muscle injury in running-based sports, frequently occurring during high-speed running [3,4,8,16,17,29,33,47,61,64,87], being the bicep femoris long head the principal injured muscle in running-related HSIs [6–8,14,49]. During the past few years there has been increasing attention around HSIs, and more and better studies regarding its prevention, treatment and rehabilitation, risk factors for injury and reinjury, return to play criteria, among many other components associated with this complex injury [4,19,21,29,102]. Hamstring strain injury incidence and recurrence rates have not lowered in the last years [4,27,31,36,64,89,103], and there are several post-HSI maladaptations documented in current literature, for instance peak torque angle [92], rate of torque development and impulse [14], bicep femoris electromiographic decrease not only in the beginning of isokinetic eccentric strength[14,85], but also in the end, when the bicep femoris was more lengthened during eccentric contractions, as well as medial hamstrings [85]. It has been hypothesized that these alterations may be due to centrally mediated mechanisms resulting in maladaptations of the injured muscles, and the role of pain-driven neuro-inhibition sabotaging athletes rehabilitation, and as a consequence prolonged maladaptations months to years after return to play [19,21].

Isokinetic strength testing has been widely used in literature not only for screening of strength asymmetries as a risk factor for HSI and other strain injuries [20,44,45], but also for study differences in isokinetic strength post-HSI [49,83,87]; in this study we found no significant differences in peak torque, H:Q ratio and angle of peak torque between HG injured and uninjured leg or with CG dominant and non-dominant leg at both concentric or eccentric tests at low and high velocities. Our results are contrasting with previous studies reporting post-HSI isokinetic deficits [20,49,83,104,105]. One recent study has reported isokinetic deficits in 67% of their participants with HSI history [83]. Similarly, Lee et al. (2009) found eccentric weakness in the injured limb per comparison to uninjured limb. Nonetheless, our results are consistent with some studies that have also found no significant differences in isokinetic strength [23,85,87,106]. Sole et al. (2011) in their study found no differences between peak torque in all contractions when comparing HG injured and uninjured sides to CG bilateral average; however in eccentric testing the HG injured limb torque was statistically significant lower when the muscle was most lengthened (approximately between 25º and 5º). Silder et al. (2010) also found no between sides differences, however they only included concentric strength evaluation in their testing protocol. Our finding discrepancy from literature may be because we used the maximum peak torque and not the average peak torque value as Opar et al. (2013), or in the HG group we included both grade I and grade II HSI and Opar and colleagues in their study only evaluated athletes that suffered a grade II injury [49], similar to Lee et al. (2009) that only included athletes with grade II or minimal grade III HSI history.

Furthermore, likewise Silder et al. (2010) we found no bilateral or group differences in H:Q concentric ratio at both velocities; interestingly H:Q conventional or/and functional ratios (conventional is the concentric hamstring to concentric quadriceps ratio; the functional ratio is eccentric hamstring to concentric quadriceps ratio) causes controversy in current literature, as some authors defend this measure as a risk factor for HSI incidence [4,12,44], and consequently recurrence. Similarly, we found no differences in eccentric angle of peak torque within and between groups. Interestingly the angular peak torque is another isokinetic variable that is creating controversy among HSI related literature, which has become popular as an outcome measure post-HSI rehabilitation, recurrence prevention and return to play measure, disregarding its limited supporting literature [52,92,107]. One recent study critically analyzed the use of peak of torque angle in predicting HSI injury and/or reinjury and as a measure of return to play and concluded that this measure has yet to be more studied and developed to become a reliable outcome, nevertheless we should not disregard joint-torque angle when dealing with HSI, despite the use of this measure alone is unreliable [92].

Regarding electromiographic muscle activity, there has been literature supporting that muscle activation is feed forwarded mediated by the central nervous system (CNS) before the movement initiation, including approximately the first 100ms following movement initiation [86]. Running-related HSIs have been shown commonly affect the bicep femoris long head due to instantaneous exposure to elevated tensile force in the terminal swing phase of running, time when bicep femoris long peak activity synchronous with peak musculotendon length [54]. In our HG all participants had history of at least one running-related HSI and we have reported similar finds as Opar et al. (2012)[14], that to our knowledge was the only previous study to ours evaluating hamstrings electromiographic activity during eccentric isokinetic testing at 30, 50 and 100ms after contraction onset. In their study they found significant differences in the HG injured vs uninjured leg in 100ms at both velocities. Our findings were similar, however we have found HG significant side differences at almost all times in both velocities. Probably due to the use of percentages instead of normalized integrated EMG values or selected sample differences (sport, general characteristics, among others). Similarly to Opar and colleagues study we found no statistical significant alterations in medial hamstrings myoelectrical activity in all times and tests [14]. This study hopefully gives more relevance to bicep femoris early eccentric lower myoelectrical activity consequences for reinjury risk and clinical practice, as lower EMG values indicate bicep femoris inability in minimizing risk of hamstrings overlengthening, and this early eccentric weakness may be responsible for the increased hamstrings work in the late swing phase of running as reported in previous studies [14,21,25,54]. Studies have also reported that this early bicep femoris EMG limited activation associated with decreased activation also when the muscle is in a more lengthened position [14,85,86]. Opar et al. (2012) suggests that this may increase recurrence risk associated with early induced muscle fatigue of the bicep femoris, which is the main knee flexor at longer lengths, and since there is not effective muscle activation, the bicep femoris allows its overlengthening [14]. Moreover this lack of activation has been hypothesized to be the responsible for the bicep femoris post-HSI atrophy [22]. This selective muscle activation explanation is hypothesized in literature by chronic pain-driven maladaptations and neurophysiological inhibitory mechanisms [21,108], which are believed to be more frequently activated during eccentric efforts [49,85,109].

Active and passive knee extension test have been shown to have a good intertester reliability [110] and some authors used these tests as a clinical grading prognosis in HSI, as there is correlation between test score and the actual duration of recovery after hamstring strain. Additionally, the range of motion deficit measured with active knee extension test was significantly correlated with rehabilitation time [55,98,111]. However, poor hamstring flexibility assessed by these tests have been shown not to influence the risk of HSI [13,110,112]. In Reurink et al.[98] study, the researchers found that hamstring flexibility was reduced in the injured limb and was limited by pain and discomfort, being measures taken within 5 days of hamstring injury occurrence [98]. Maybe because our study was conducted when athletes have returned to play by at least 6 months, we found no flexibility differences and to our knowledge there are no studies evaluating active and passive knee extension after 6 months post-HSI. Despite Askling et al. [113] evaluated athletes after a mean of 2 months after injury and reported significant differences between injured and the uninjured leg in passive, but not active knee flexibility (using different flexibility tests).

Core stability has a controversial role as an HSI risk factor and the use of core strengthening as its prevention [114,115], however most of the known studies correlating HSI and core stability only evaluate this variable prior to injury and as a risk factor to its event. In this study we tried to evaluate core strength and resistance by using trunk endurance isometric exercises. We found no statistical differences between HG and CG in the score of all 4 tests, and there are no known studies available to compare our results. Further studies should focus core stability post-HSI to evaluate its role in HSI treatment and reinjury prevention.

Hop tests have been increasingly used by literature as a functional measure, because they require muscular strength, as well as joint stability and coordination of lower limbs. They are also commonly used in sport settings as a clinical evaluator, because they allow to functionally compare one injured limb with the uninjured one quickly, and without requiring equipment, and are often used as a return to play predictor after injury. Single hop tests have been used in literature to predict and evaluate the HSI risk [116]. One study suggests that triple-hop distance (THD) tests improve clinical usefulness and reliability in detecting deficits and imbalances, as well as rehabilitation progression after injury [101]. Regarding these we have used the triple hop test protocol in our study, however we found no statistical significant differences in the triple-hop test scores between HG injured and uninjured side or/and CG dominant and non-dominant side.

Proprioception contributes to movement, postural and motor control, as well as joint stability and general balance; as the result of afferent input to the central nervous system from mechanoreceptors; joint position sense is a form of proprioception, defined as the awareness of the studied joint position, by the capacity of correctly reposition a pre-determined angle after another movement of the limb. The lack of this capacity, along with other proprioceptive deficits may be a risk factor to joint and muscle injuries [95,117], and evidence also suggests that following injury, there are alterations in proprioception [102]. Furthermore increasing evidence supports the use of proprioceptive exercises in sports rehabilitation [117]. In our study, significant differences were found only when full knee extension was used as initial position; to our knowledge this is the first study evaluating both knee proprioception in amateur football players with history of HSI for more than 6 months, however there are studies that indicate that may be alterations in proprioception after previous injury [102] and further studies should be conducted in order to understand its role in HSI prevention and rehabilitation, and what alterations may occur in proprioception after suffering a HSI [47].

Evidence suggests that studies should not disregard multiple risk factors and their inter-relationship in HSI injury-reinjury cycle [28,29]. Taking this into our objectives, this study tried to find correlation between strength, myoelectrical bicep femoris activity and medial hamstrings activity, proprioception, flexibility, core stability and functional performance. To our knowledge this is the first study correlating several neuromuscular factors after HSI history. After correlation analysis we found that there was a statistical significant correlation between bicep femoris muscle activation during high velocity eccentric strength testing at 100ms after onset of contraction and knee joint position sense using 90° knee flexion as initial position, although between groups statistical differences was found only using full knee extension as initial position, however there seems to be interaction between bicep femoris myoelectrical activity and proprioception, since correlation was found between these two variables. There is also lack of evidence in this field, being previously studied only the interaction between fatigue and knee joint position sense test, as studies found correlation in basketball [118], soccer [95] and volleyball players [119] but without HSI history. Furthermore statistical significance interaction was found between H:Q conventional ratio at 240ºdeg.s^{-1} isokinetic concentric testing and triple-hop distance test score in the HG. Previous studies have found high correlation between high velocity isokinetic testing and triple-hop distance scores in healthy football players, and concluded that the triple-hop distance is a valid predictor of lower limb strength and power [101,120], used often as return to play criteria [38]. Despite in our study there wasn't significant differences between injured and uninjured sides, the interaction between isokinetic conventional H:Q ratio and triple-hop distance test score should not be disregarded as previous studies found differences in H:Q ratios in athletes with HSI history [44,48], especially in functional ratios, which was not used in the present study. However future research should focus its correlation to hop tests, as these are considered valid predictors of lower limb strength and power [101]. This test is also reliable and easy to use, without requiring much material, and should be incorporated in return to play criteria after hamstring injury since isokinetic strength testing seems not to be required for completion of a football-specific field test and still creates controversy among literature [83].

Latest research has given relative importance to the role of neuro-inhibitory mechanisms underpinning post-HSI maladaptations and our study results seems strengthen some of previous research hypothesis and findings. Bicep femoris myoelectrical activity has been previously studied whether in early [14] and late [85] times of eccentric contractions, our EMG evaluation of HG injured side also resulted in lesser myoelectrical bicep femoris activity after early onset of eccentric contractions, presenting several differences to HG uninjured side in almost all times and at both eccentric velocities, ranging from 5% to 12%. This can have several implications in HSI reinjury due to muscle inability to produce early eccentric force and decelerate the hip during running, positioning the bicep femoris long head at longer muscle length and increasing its work during terminal swing phase, prematurely fatiguing the hamstrings and increasing the likelihood of the bicep femoris long head to exceed its mechanical limits and re-suffer a new HSI [4,14,50,59,73,85,87]. However we found no differences in isokinetic eccentric torque production or peak torque angle, suggesting that the injured hamstring may have compensation of other muscles, such as ipsilateral gluteus maximus and ipsilateral external oblique [15,53] or mechanisms not examined in this study, such as decrease of the peak hip flexion during running, as a subconscious mechanism to reduce hamstring terminal swing phase overlengthening [20]. Furthermore, a recent study has reported that hamstring and injured side may also have maladaptive muscle activity ratios and asymmetries in pelvic and lower limb patterns during sprint, especially in the terminal swing phase; such as an increase in the contralateral rectus femoris and ipsilateral erector spinae muscle activity can increase bicep femoris strain [15]. Another clinical relevance of these study results is that a decrease of bicep femoris myoelectrical activity may contribute to the sabotage of rehabilitation programs as previously described in literature [21], 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 [21]. 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 [22]. To our knowledge this is the first study to correlate post-HSI bicep femoris myoelectrical deficit on onset of eccentric contraction and proprioceptive testing, however neuromuscular inhibition can be also a possible explanation for this correlation, as alterations may be also present in central processing of afferent mechanoreceptors information; moreover there is no literature around proprioceptive deficits after HSI, but this interaction should not be disregarded as deficits in both myoelectrical activity and proprioception may increase the likelihood of reinjury, as lesser myoelectrical activity may allow muscle overlengthening during sprint and proprioceptive deficits can alter individuals perception of joint positioning during running, even more when fatigue is associated [121] leading to the perception that the hamstrings are working on a normal range of motion and muscle length when in reality repeated overlengthening is occurring, and hamstrings are repeatedly exceeding its mechanical limits without perceptions due to proprioceptive decline [121].

Therefore, it is crucial to develop specific return to play criteria after HSI, focusing risk factors for reinjury and their inter-relationship; for instance Askling and colleagues have developed an active hamstring flexibility test as a complement to clinical evaluating before return to play that has been found reliable and valid [113], similar to these, one study also found clinical parameters of self-predicted time to return to play and passive straight leg raise decline were correlated to time to return to play [122], or perhaps the use of the single leg bridge test may be also useful for return to play, being that this test seems to have some level of HSI prediction [123]; therefore other functional tests should be studied and implemented in post-HSI return to play criteria, in order to decrease athletes neuromuscular maladaptations after months of return to play, as seen on the present study as well as others previously conducted, increasing the likelihood of reinjury [14,20,83–85,88,102].

A recent systematic review with meta-analysis [124] gathered recent conservative treatments of HSI and concluded that interventions adding lengthening exercises reduce the return to play time when compared to conventional rehabilitation programs, however they had no effect on re-injury incidence; curiously this meta-analysis also demonstrated that platelet-rich plasma injections not to be effective in HSI rehabilitation, despite increasing evidence around it [19,124–127]. Lengthening exercises have been previously studied and found effective in HSI rehabilitation [72,128], even more after a recent cohort study found that rehabilitation after HSI using eccentric strengthening exercises at longer muscle lengths resulted in no reported long-term reinjuries in athletes that complied to rehabilitation (n=42) [129,130]; compliance is crucial regarding eccentric training regarding HSIs[130], as Timmins and colleagues have recently demonstrated that short-term resistance eccentric training may produce changes of bicep femoris long head fascicle length and other architectural adaptations, however they also found that these alterations were reversed following 28 day without eccentric training [131]. Hopefully this study strengthen the assumption that risk factors and neuromuscular adaptations seems to persist several months after HSI occurrence and long after RTP [21], and the inter-relationship between neuromuscular alterations should not be disregarded in future studies, as it may give us a better insight of neuromuscular inhibition and their role in HSI prevention, this study also strengthen Fyfe et al. (2013) conceptual framework of the role of neuromuscular inhibition following HSI in the development of maladaptations that could lead to recurrence [21]. this to our knowledge is the first study that follows this new proposed conceptual frameworks, and reinforces the need for a more non-reductionist view regarding HSI [28]; showing that myoelectrical activity can influence hamstrings proprioception and vice-versa and hypothesizing in what ways can this influence HSI rehabilitation and recurrence. Therefore it is important that future studies focus this inter-relationship of risk-factors and neuromuscular adaptations post and prior HSI occurrence, and focus in what ways they can influence injury occurrence, rehabilitation programs and recurrence prevention.

Limitations and future studies

In this study there are some limitations that should be considered. First the small sample size could possibly hide some differences between the dependent variables studied, as well as their possible interactions, it is possible that future studies with larger samples can detect further correlations within these variables. Regarding electromyography analysis in this study we used the peak activation of each contraction to calculate the percentage of activation of the bicep femoris and medial hamstrings in that same contraction, most studies often the myoelectrical values in millivolts and not in activation percentage [14,49,85,86]. Few data from EMG analysis may be withdrawn erroneously due to, during eccentric testing, some participants kept contracting the hamstrings between the end of the eccentric movement and the beginning of another repetition, consequently having higher onset activity than if the muscles were resting prior to effort, as well as higher values during 30, 50 and 100ms in that repetition, however we should not disregard this limitation. During isokinetic and EMG recording two athletes of the hamstring injured group reported pain and/or discomfort, and although they were fully recovered from HSI and returned to sport for at least 6 months, this could influence our study results. Furthermore despite evidence supports that self-report of injury location is reliable within one year of suffering the injury [132], participants had to confirm their injury severity by ultrasound, or, when not possible, confirm with the Physiotherapist responsible for his rehabilitation; also it is important to mention that only one HG participant Physiotherapist has reported eccentric strengthening as part of its rehabilitation program. Moreover, this study only had 3 participants with recurrent HSI, being most of participants the first time they had suffered a serious injury in their lower limb; future studies should examine if our findings are more related to recurrent injuries. Isokinetic eccentric testing was also limited to 30deg.sec^{-1} and 120deg.sec^{-1} velocity, which do not reproduce all the hamstrings functional efforts during running [14], and future studies should consider testing at higher velocities. Another limitation is that during the knee joint position sense testing the patient was in a seated position; however future studies should evaluate joint position sense with the participant in prone, to increase gravitational effort, consequently increasing hamstring eccentric effort during the repositioning phase.

Conclusion

In the present study, we found significant decrease in the injured bicep femoris myoelectrical activity after onset of contraction during eccentric testing and proprioceptive deficits in the when compared to uninjured side and uninjured athletes, as well as significant correlation between these two variables.

This was the first study, to our knowledge, that supports possible interactions in neuromuscular adaptations after return to play for several months in football athletes that sustained a HSI. Furthermore this study strengthens current literature hypothesis of neuromuscular inhibition after hamstring strain injury and the inter-relationship between neuromuscular maladaptations and risk factors post injury, that may contribute for a better understanding of running-related hamstring strain injury rehabilitation and recurrence prevention.

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Annexes

Annex 1 – Participants informed consent

universidade
de aveiro

Consentimento Informado

Título do projecto: “Adaptações neuromusculares em atletas com história de lesão dos Isquiotibiais”

A presente declaração serve como consentimento informado do estudo realizado no âmbito de Mestrado em Fisioterapia. Ao assinar a mesma o atleta declara que tomou conhecimento dos seguintes pontos:

1. Recebeu informação suficiente e detalhada do estudo e da avaliação a realizar

2.Compreendeu o que o estudo implica e o que lhe irá ser pedido

3.Foi-lhe permitido fazer perguntas relativas ao estudo/avaliação e que todas as dúvidas foram esclarecidas

4.Compreende que pode abandonar o estudo, em qualquer altura, sem necessidade de dar qualquer tipo de explicação e sem consequência de penalização

5.Concorda participar voluntariamente neste estudo que consiste apenas numa avaliação

Nome do Participante: ____

Assinatura do Participante: ____

Nome do Investigador: ____

Assinatura do Investigador: ____

Data: ____/____/______

Annex 2 – Hamstring group Questionnaire

L - Adaptações Neuromusculares em futebolistas com história de lesão dos Isquiotibiais

Este formulário faz parte da Dissertação de Mestrado em Fisioterapia pela Escola Superior de Saúde da Universidade de Aveiro, em conjunto com a Faculdade de Desporto da Universidade do Porto.
Este questionário visa identificar futebolistas com história de lesão dos Isquiotibiais (músculos posteriores da coxa); demora cerca de 5 minutos a responder. Por favor reencaminhe se conhecer atletas que possam ser incluídos no estudo.

Pode obter mais informações através da página do Facebook:
https://www.facebook.com/pages/Adapta%C3%A7%C3%B5es-Neuromusculares-ap%C3%B3s-les%C3%A3o-dos-Isquiotibiais-no-futebol/638402609638466

*Obrigatório

Nome *
Primeiro e último chega

Idade *

Peso

Altura

Clube onde joga actualmente *

Qual a posição em que normalmente joga? *

- ☐ Guarda-redes
- ☐ Defesa
- ☐ Médio
- ☐ Avançado
- ☐ Outra:

Qual é o tipo de campo onde joga? *

- Sintético
- Pelado
- Relva
- Outra: ____

Perna dominante *

~~Qual o teu membro inferior dominante (com qual normalmente chutas?)~~

- Direita
- Esquerda

Cidade/Concelho onde vive

____

Contacto *

Telefone/email/Facebook

____

Profissão

____

História de lesão

Há quanto tempo teve lesão nos Isquiotibiais? *

- Há menos de 3 meses
- Nesta época (2014/2015)
- Época passada (2013/2014)
- Há mais de 2 anos

Como aconteceu?

Por exemplo, foi ao fazer um sprint, saltar, disputa de bola, etc....

____

Quanto tempo de paragem competitiva? *

- Menos de 1 semana
- 2 semanas
- 3 semanas
- Mais de 4 semanas

Exame médico *

Qual foi o exame complementar que realizou?

- Ecografia
- Ressonância Magnética
- Raio x
- Outro
- Nenhum

Onde foi feita a recuperação?
No clube, clinica (qual), etc..

Qual o membro lesado? *

- direito
- esquerdo

« Anterior   Continuar »

Foi a primeira lesão naquele local?

- Sim
- Não

Após retorno à actividade desportiva, teve alguma recaída? *

- Sim
- Não

Se sim, quanto tempo foi de novo a paragem competitiva?

- Menos de 1 semana
- 2 semanas
- 3 semanas
- Mais de 4 semanas

Já teve alguma lesão grave anterior a esta? *

- Sim
- Não

Se sim, qual?

Já alguma vez foi submetido a cirurgia?

- Sim
- Não

Annex 3 – Control Group Questionnaire

N- Adaptações Neuromusculares em futebolistas com história de lesão dos Isquiotibiais

Este formulário faz parte da Dissertação de Mestrado em Fisioterapia pela Escola Superior de Saúde da Universidade de Aveiro, em conjunto com a Faculdade de Desporto da Universidade do Porto.
Este questionário visa identificar futebolistas com história de lesão dos Isquiotibiais (músculos posteriores da coxa); demora cerca de 5 minutos a responder. Por favor reencaminhe se conhecer atletas que possam ser incluídos no estudo.

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*Obrigatório

Nome *

Primeiro e ultimo chega

[ ]

Idade *

[ ]

Peso

[ ]

Altura

[ ]

Clube onde joga actualmente *

[ ]

Qual a posição em que normalmente joga? *

Avançado

- ☐ Guarda-redes
- ☐ Defesa
- ☐ Médio
- ☐ Avançado
- ☐ Outra: [ ]

Esquerdo

- ○ Direita
- ○ Esquerda

Cidade/Concelho onde vive
Viana do Castelo

Contacto
Telefone/email/facebook

Profissão

Historial Saúde

Já teve alguma lesão grave? *

Desde que idade joga futebol? *

Alguma vez foi submetido a cirurgia? *

- ○ Sim
- ○ Não

Se sim, qual?

Qual o tipo de campo onde joga? *
Pelado

- ○ Sintético
- ○ Pelado
- ○ Relva
- ○ Outra: