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Research article

Thoracolumbar Fascia and Lumbar Muscle Stiffness in Athletes with A History of Hamstring Injury

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Abstract

The purpose of this study was to examine the differences in thoracolumbar fascia (TLF) and lumbar muscle modulus in individuals with and without hamstring injury using shear wave elastography (SWE). Thirteen male soccer players without a previous hamstring injury and eleven players with a history of hamstring injury performed passive and active (submaximal) knee flexion efforts from 0°, 45° and 90° angle of knee flexion as well as an active prone trunk extension test. The elastic modulus of the TLF, the erector spinae (ES) and the multifidus (MF) was measured using ultrasound SWE simultaneously with the surface electromyography (EMG) signal of the ES and MF. The TLF SWE modulus was significantly ($p < 0.05$) higher in the injured group (range: 29.86 ± 8.58 to 66.57 ± 11.71 kPa) than in the uninjured group (range: 17.47 ± 9.37 to 47.03 ± 16.04 kPa). The ES and MF modulus ranged from 14.97 ± 4.10 to 66.57 ± 11.71 kPa in the injured group and it was significantly ($p < .05$) greater compared to the uninjured group (range: 11.65 ± 5.99 to 40.49 ± 12.35 kPa). TLF modulus was greater than ES and MF modulus ($p < 0.05$). Active modulus was greater during the prone trunk extension test compared to the knee flexion tests and it was greater in the knee flexion test at 0° than at 90° ($p < 0.05$). The muscle EMG was greater in the injured compared to the uninjured group in the passive tests only ($p < 0.05$). SWE modulus of the TLF and ES and MF was greater in soccer players with previous hamstring injury than uninjured players. Further research could establish whether exercises that target the paraspinal muscles and the lumbar fascia can assist in preventing individuals with a history of hamstring injury from sustaining a new injury.

Key words: Biceps femoris strain, Spine, myofascial, injured hamstring.

Introduction

Hamstring strains account for almost a quarter of injuries in soccer (Kekelekis et al., 2022; Ekstrand et al., 2023). Despite extensive efforts to reduce the incidence of hamstring injuries, recent reports indicate that the rate of such injuries continues to increase by up to 3-5% per year (Ekstrand et al., 2023), while approximately 20-30% of athletes suffer the same injury again (van Beijsterveldt et al., 2013). For this reason, investigating strategies to reduce such injuries is particularly important.

Systematic reviews of literature have shown that athletes with a history of hamstring injury may show some deficits in muscle strength (Maniar et al., 2016) and a reduced fascicle length of the injured muscle (Kellis and Sahinis, 2022). Using shear-wave elastography (SWE), some studies have found no differences in active muscle SWE modulus, which is an index of tissue stiffness, in the injured compared to uninjured limbs (Kawai et al., 2021; Freitas et al., 2023) but others have reported an elevated stiffness in the injured limb (Freitas et al., 2022). Therefore, the influence of injury on hamstring muscle function remains unclear.

Owing to their multifactorial origin, variable symptoms and diagnostic imaging findings, several types of hamstring injuries have been identified (Mueller-Wohlfahrt et al., 2013). Spinal-related hamstring injuries have been described as those injuries which have a spinal/lumbopelvic origin and can be either nerve-related or functional-related (Mueller-Wohlfahrt et al., 2013). This implies that hamstring and lumbopelvic function are interrelated but relevant evidence to support such an association is missing. In an early study, forward simulations of running showed that hamstring elongation can be caused by contraction of erector spinae (ES) muscle (Thelen et al., 2006). Research has also shown that altered lumbo-pelvic function is a significant risk factor for hamstring injury (Schuermans et al., 2017). More recently, some studies found that training programs which include lumbo-pelvic control exercises caused a reduction of hamstring muscle stiffness, which led researchers to suggest that spinal-related exercises should be part of prevention or rehabilitation programs of hamstring injuries (Kuszewski et al., 2018; Mendiguchia et al., 2021). This is further supported by a recent systematic review which concluded that spinal exercise programs can significantly reduce hamstring injury (Al Attar and Husain, 2023). For this reason, examination of the mechanisms that explain the association of hamstring injuries and function of the myofascial tissues in the lumbar spinal area is worthwhile.

Detailed anatomical descriptions have shown that the ischial tuberosity, which forms the proximal origin of the hamstring muscles, is serially connected to the sacrotuberous ligament (Vleeming et al., 1995; Willard et al., 2012). This ligament then attaches to the thoracolumbar fascia (TLF), a thick combined structure of aponeurotic tissue that spreads in various directions along the spine, enveloping various organs and attaching to various muscles such as the latissimus dorsi, gluteus maximus, ES and multifidus (MF) (Vleeming et al., 1995; Willard et al., 2012). This means that changes in the position of the lumbar and thoracic spine as well as the pelvis can alter the length of the TLF. In turn, the TLF is considered a significant contributor to spinal stability as it develops tension during

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external perturbations and changes in trunk position (Bojairami and Driscoll, 2022). There are suggestions that the TLF can assist in force transmission not only between muscles and fasciae of the lumbar spinal region but also between the lumbar area and the posterior thigh (Myers, 1997). In a cadaveric experiment, it has been found that traction applied to the biceps femoris changes the length of the TLF (Vleeming et al., 1995) while more recently an association between pelvic movement and the SWE modulus of the posterior thigh muscles (Nakamura et al., 2016) or elongation of the hamstrings (Mendiguchia et al., 2024) has been reported. Similarly, TLF stiffness had a positive association with hamstring fascia stiffness (Kellis et al., 2024). A recent study has also found that athletes with a history of hamstring strain display greater SWE modulus of the hamstring fascia in the injured leg (Kawai et al., 2021). If hamstring injury influences the kinematic patterns of movement, such as pelvic tilt, as suggested by previous studies (Mendiguchia et al., 2024) then it would be interesting to know if individuals with a history of hamstring strain would display stiffer TLF and paraspinal muscles.

Understanding the morphology and mechanical properties of the fascia and muscle-tendon system of players who suffered from a previous injury can assist us to improve re-injury prevention strategies. The purpose of this study was to examine the differences in TLF and paraspinal muscle SWE modulus surface electromyographic (EMG) activation between athletes with a history of a hamstring injury and uninjured athletes. We hypothesized that TLF SWE modulus will be greater in the injured compared to uninjured athletes. It was also hypothesized that paraspinal muscle SWE modulus will be greater in the injured group compared to the uninjured. In addition, it was expected that paraspinal muscle activation would be greater in injured compared to uninjured athletes.

Methods

Participants

To determine the minimum sample size, the Sample Size calculator (Georgiev, 2023) was used. Based on previously reported fascia and muscle SWE modulus values in injured and uninjured individuals (Kawai et al., 2021), for a two-sample model, a 5% type 1 error, a 80% power, a sample ratio of 1.2, and a minimum detectable change of 2, the total sample size was 24 participants, with unequal groups of 13 and 11, respectively. Thirteen healthy active amateur soccer players (n = 13; 27.3 ± 4.6 years, 71.0 ± 4.3 kg, 174.1 ± 4.6 cm) without a previous hamstring injury and eleven players (n = 11; 28.3 ± 6.7 years, 73.5 ± 8.3 kg, 176.5 ± 8.72 m) with a previous hamstring injury participated. Injured players had a grade II hamstring strain (Mueller-Wohlfahrt et al., 2013) during the past year (7.39 ± 2.32 months) which was verified by MRI or US findings and clinical examination by a qualified medical doctor. The characteristics of injury for the injured group are displayed in Table 1. The participants gave their informed written consent, and the protocol was approved by the Institutional Ethics Committee (approval number: 18/2022).

Experimental protocol

All examinations were performed with the volunteer in the prone position with the hip in neutral position and the hands lying next to the body. A wide elastic strap was used to maintain pelvic position.

A warm-up consisting of static stretches of the hamstrings and trunk muscles was first performed. Then the participants familiarized with the protocol, first, by performing 5 submaximal knee flexions at 0° (= full extension), 45° and 90° angles against resistance provided by the experimenter, and, second, by performing 5 trunk extensions with their hands on their sides. Then, in each knee flexion angle, participants performed maximum knee flexion efforts against a hand-held dynamometer (K-Force muscle controller, sampling rate 75 Hz, Kinvent, Montpellier, France). The dynamometer consists of a force sensor which was placed just above the malleolus of the lower leg. The distance between the dynamometer placement and the lateral epicondyle was measured and it was used to calculate the torque exerted around the knee. In each joint position, the participant performed 3 maximum voluntary isometric contractions (MVC) of 5s each. The maximum torque was taken as the MVC value.

To obtain EMG reference signal from the paraspinal muscles, participants also performed MVC trunk extension efforts. From the prone position, they were instructed to lift their trunk maximally, against a strap which was placed around their mid-thoracic area (approximately between the 7 and 10th thoracic spinal process) whilst EMG was simultaneously recorded. Three 5s trials were performed and the maximum EMG was used as a reference value.

The main protocol consisted of SWE and EMG measurements in two conditions: passive and active. In the passive condition, measurements were obtained with the participant at rest whilst the knee was held for 5s at knee flexion angles of 0, 45 and 90°. In the active

Table 1. Characteristics of players with a biceps femoris long head injury, of moderate intensity.

Participant Nr	Injury location	Mechanism	Time to return to play (weeks)	Time since injury (months)	Was this a re-injury?	Any spine-related symptoms/pathologies?
1	proximal	Sprinting	6.5	8.5	Yes	Non-specific low back pain
2	proximal	Sprinting	7	7.9	No	-
3	distal	Sprinting	7.5	8.2	No	-
4	Middle	Undefined	5	5.8	No	Non-specific low back pain
4	proximal	Kicking	5.5	6.3	Yes	
5	proximal	Tackling	4.5	6.2	Yes	
6	proximal	Sprinting	9	4.1	No	Non-specific low back pain
7	Proximal	Change in direction	7.8	5.3	Yes	
8	Distal	Sprinting	8.1	5.9	No	Herniated disc
10	Distal	Sprinting	7.7	12	No	
11	Proximal	Sprinting	7.8	11.1	No	

condition, the participant performed submaximal knee flexion contractions at each knee joint angle as well as a submaximal trunk extension. For the knee flexion contractions, the target force level value was preset at 60% MVC, and the participant had approximately 2 s to gradually reach that level and then hold for approximately 5s. In addition, from the prone position, the participants were requested to lift their upper body at an angle of 30° relative to the horizontal and hold this position for 5s. Based on previous estimates, prone trunk extension against body mass corresponds approximately to 60% of trunk extension MVC (Smidt and Blanfield, 1987) Three trials per condition were recorded.

SWE measurements

Elastography measurements were made using a LOGIQ E9 ultrasound (US) unit (R5 version, General Electric, Chicago, USA) system with a 9L (2–8 MHz) linear transducer (6 cm). The system build-in software automatically calculates the Young's elastic modulus in kilopascals (kPa), using the equation $E = \rho \cdot V^2$, where E is Young's modulus and ρ is tissue density (assumed to be 1 g/cm^3) and V is the velocity of shear waves (Drakonaki, 2012).

The precise locations for SWE measurements were first identified on the left body side using B-mode US and they were marked on the skin (Figure 1). The fourth lumbar (L4) vertebra spinal process was identified first in axial plane and the probe was then shifted laterally to the left side at 2.5 cm away from the L3 spinous process at the L3-L4 level to visualize the paraspinous muscles. The probe was then shifted longitudinally and parallel to the muscle fibers in order to acquire muscle stiffness measurements. In the same location, the experimenter also increased the US image zoom, to obtain clear image of the fascia, which was defined as the echogenic striated linear structure lying deep to the subcutaneous layer and just superficially to the ES (Wilke et al. 2019). US gel was applied to the areas of imaging to ensure good sonic coupling between the probe and skin.

Using the manufacturer's software, the SWE modulus of the tissues was measured using rectangular color-coded boxes (elastograms) which were superimposed on each B-mode image (Figure 1) and they were sized 1.5 cm × 2 cm and 4 x 3 cm, for TLF and muscles, respectively. Then manually selected circular regions of interest (ROIs) were placed only on the hyperechoic fascia layer, excluding subcutaneous fat and muscle (for TLF modulus) or on the respective muscle excluding the fascia planes (for muscle modulus). The ROIs were carefully determined by the same examiner to cover most of the respective TLF or muscle area available in the elastogram. For the paraspinal muscles, superficial ROIs were drawn on the ES between the ES aponeurosis and the epimysial fascia of the MF and separate ROIs were placed on the MF, between the epimysial fascia of the MF and the cortical bone of the mamillary process (Blain et al., 2019). The mean SWE modulus values in each ROI and the mean values of the three ROIs acquired in each of the three trials were calculated. All examinations were performed by the same radiologist with more than 18 years of experience in US and US Elastography.

EMG recording and analysis

EMG activation was obtained simultaneously with the paraspinal muscle SWE recordings. Surface bipolar electrodes with an inter-electrode distance of 1cm were used to record the EMG signal using two wireless Shimmer3 EMG units (Shimmer Research Ltd, Dublin, Ireland) (Figure 1).

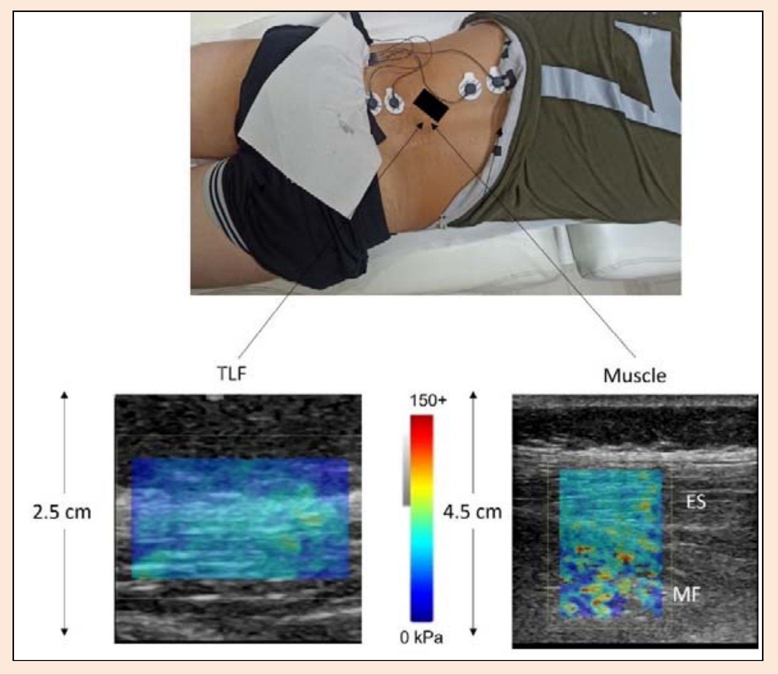

Figure 1. The experimental set-up. The ultrasound probe was placed 2.5 cm away from the L3 spinous process at the L3-L4 level to visualize the thoracolumbar fascia (TLF), the erector spinae (ES) and deep multifidus (MF). Bipolar electrodes were also placed on the ES and MF. TLF modulus was estimated by taking several circular regions of interest inside a rectangular coded box of 1.5. x 2 cm and ES and MF moduli were determined separately by drawing smaller circles within a 4 x 3 cm rectangular box. The color scale was extracted from the software and is enlarged so that the measurement scale is easily visible.

The electrodes were placed on the longissimus lumborum, approximately two fingers width laterally from the spinal process of 1st lumbar ligament (L1) (Hermens et al., 2000). For MF, the electrodes were placed at the level of L5 spinous process, 2 cm from the midline. The electrode positions were marked on the skin, the skin was shaved and cleaned with alcohol wipes. A common ground electrode was placed on a bony landmark on the left wrist.

The signal was received by each sensor and sampled using a 24-bit analog-to-digital converter with a sampling rate of 1024 Hz and a gain of 1000. The signal was filtered using a band-pass filter (between 15 Hz and 450 Hz) and full wave rectified. The root mean square (RMS) was calculated with a step of 50ms. Following EMG data collection, the maximum RMS value produced during the isometric MVC was taken as a reference measurement. Subsequently, the RMS during each testing condition was normalized to the MVC value.

Statistical analysis

Statistical analysis was performed using the Statistical package for social sciences (v 29.0. IBM Corp, Armonk, NY, USA). Normal distribution was confirmed using Shapiro-Wilk tests. A three-way analysis of variance (ANOVA) was used to examine group differences in passive modulus and normalized EMG at rest between three tissues (TLF, ES, MF) and three angles (0°, 45° and 90°). A separate ANOVA was used to examine group differences in active modulus and EMG between tissues and four joint positions (knee flexion angle of 0°, 45° and 90° and 30° trunk extension). Differences in knee flexion MVC torque between groups were examined using a two-way ANOVA. Effect sizes were also calculated using the partial eta squared (η^2) or d values (Cohen, 1988). If significant, post-hoc Tukey tests were applied to examine significant differences between pairs of means. The level of significance was set at a = 0.05.

Results

Of the 11 injured athletes, 3 had non-specific low back pain and one had herniated disk. Of the 13 athletes of the uninjured group, there were 2 with non-specific low back pain and one with spinal stenosis. A chi-squared test indicated that the frequency of individuals with spinal-related problems did not differ between the two groups ($p > .05$).

Passive SWE modulus values are displayed in Figure 2. TLF modulus ranged from 17.47 ± 9.37 to 20.08 ± 3.42 kPa for the uninjured and from 29.86 ± 8.58 to 33.11 ± 15.62 kPa for the injured athletes. For the ES and MF, the modulus ranged from 11.65 ± 5.99 to 15.69 ± 4.84 kPa and from 14.97 ± 4.10 to 20.94 ± 10.28 kPa for the uninjured and injured groups, respectively. The ANOVA did not show a significant interaction effect as well as a main effect for angle on the passive SWE modulus values ($p > 0.05$). There was a statistically significant main effect for group ($F_{1,22} = 15.79$, $p = 0.0001$, $\eta^2 = 0.967$) as SWE modulus (averaged across angles) was greater for the injured compared to uninjured ($p < 0.05$). A statistically significant main effect for tissue ($F_{2,44} = 46.97$, $p = 0.0001$, $\eta^2 = 0.999$) followed by post-hoc Tukey tests indicated that the TLF had greater SWE modulus than ES and MF ($p < 0.05$).

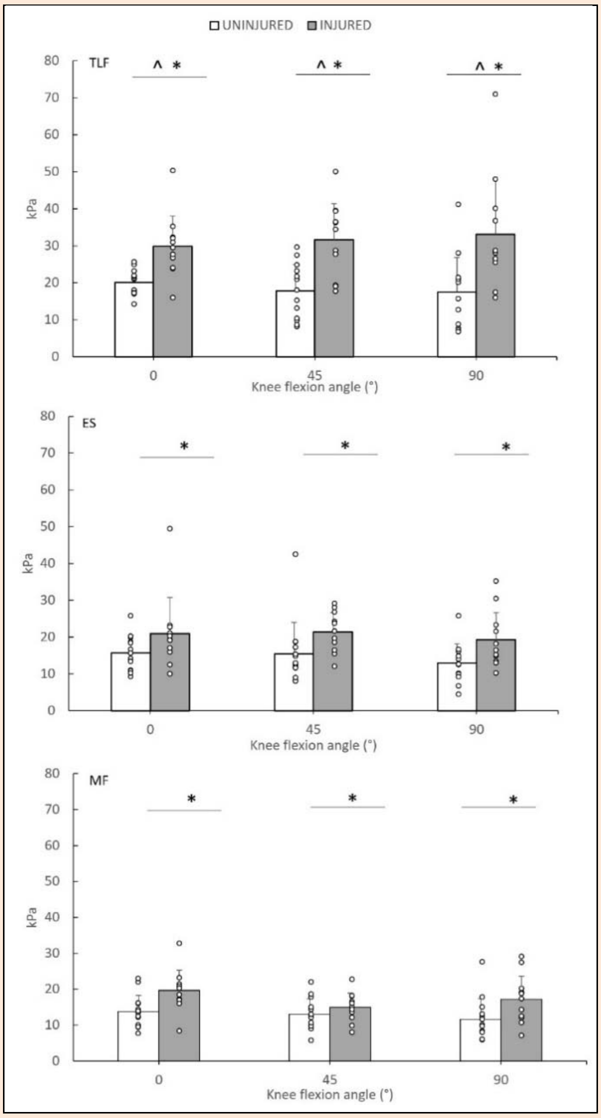

Figure 2. Mean group passive SWE modulus values of thoracolumbar fascia (TLF), erector spinae (ES), multifidus (MF) values at knee flexion angles of 0, 45 and 90°. Error bars indicate standard deviation and circle dots are individual case values (* indicates statistically significant difference compared to the uninjured group; ^ values collapsed across angles and groups are statistically significant greater than ES and MF, $p < .05$).

Active SWE modulus values are presented in Figure 3. TLF modulus ranged from 31.15 ± 8.94 kPa to 47.03 ± 16.04 kPa and from 39.82 ± 11.89 to 66.57 ± 11.71 kPa for the uninjured and injured groups, respectively. The ES and MF modulus ranged from 23.88 ± 8.03 Kpa to 40.49 ± 12.35 Kpa for the uninjured and from 26.19 ± 5.87 to 66.57 ± 11.71 kPa for the injured athletes. The ANOVA did not show a significant interaction effect on active SWE modulus values ($p > 0.05$). There was a statistically significant main effect for group ($F_{1,22} = 20.24$, $p = 0.0001$, $\eta^2 = 0.990$), as SWE modulus (averaged across angles) was greater for the injured compared to uninjured ($p < 0.05$). A statistically significant main effect for tissue ($F_{2,44} = 46.97$, $p = 0.0001$, $\eta^2 = 0.999$), which was followed by post-hoc Tukey tests indicated that the TLF had greater SWE modulus than ES and MF ($p < 0.05$). Similarly, the main effect for angle ($F_{3,66} = 38.42$, $p = 0.0001$, $\eta^2 = 0.998$) followed by post-hoc Tukey tests showed that SWE modulus (averaged for all groups and tissues) was greater in trunk extension compared to values which were recorded during various knee flexion tests ($p < 0.05$). In addition, SWE modulus at 0° knee flexion was greater than that recorded at 90° ($p < 0.05$).

Table 2 presents the normalized EMG results. The ANOVA showed a statistically significant main effect of Group ($F_{2,44} = 4.022$, $p = 0.05$, $\eta^2 = 0.508$) on passive EMG only, as injured athletes showed a greater overall passive EMG compared to uninjured ones. There was no difference in EMG between muscles but there was a significant effect of angle on EMG at rest ($F_{2,44} = 6.95$, $p = 0.002$, $\eta^2 = 0.908$) and contraction ($F_{2,44} = 72.81$, $p = 0.0001$, $\eta^2 = 0.999$). Post-hoc analysis showed that the average EMG (averaged for all muscles and testing conditions) at rest was greater at 0° compared to 90° while the active EMG was greater during trunk extension compared to knee flexion angles ($p > 0.05$).

Knee flexion MVC torque (Figure 4) was greater in the uninjured compared to the injured group ($p < 0.05$). Post-hoc Tukey tests indicated that MVC torque at 0° and 45° were greater compared to MVC torque at 90° angle ($p < 0.05$).

Discussion

In this study, previously injured athletes had higher TLF SWE modulus values than uninjured individuals. In addition, the SWE modulus of the ES and MF muscles was greater in the injured group than in the non-injured group. There was also a greater normalized EMG of the ES and MF during passive testing in the injured compared to the uninjured group.

The greater TLF SWE modulus found in the injured athletes compared to the uninjured athletes confirms the first hypothesis of the study (Figures 2-3). To the best of our knowledge, there are no reports on TLF stiffness in individuals with a history of hamstring injury. Due to the retrospective nature of this study, it is not known whether the greater TLF stiffness occurred after the injury or was already present beforehand. If it occurred after injury, then one may hypothesize that there is an alteration in the dynamics of myofascial units that are arranged in series between the lumbar fascia and the fascia that surrounds the (injured) hamstring muscle. This is based on two observations: firstly, that injury affects the fascia and muscle tissue of the injured area and, secondly, that there is a linkage between hamstring fascia and TLF function.

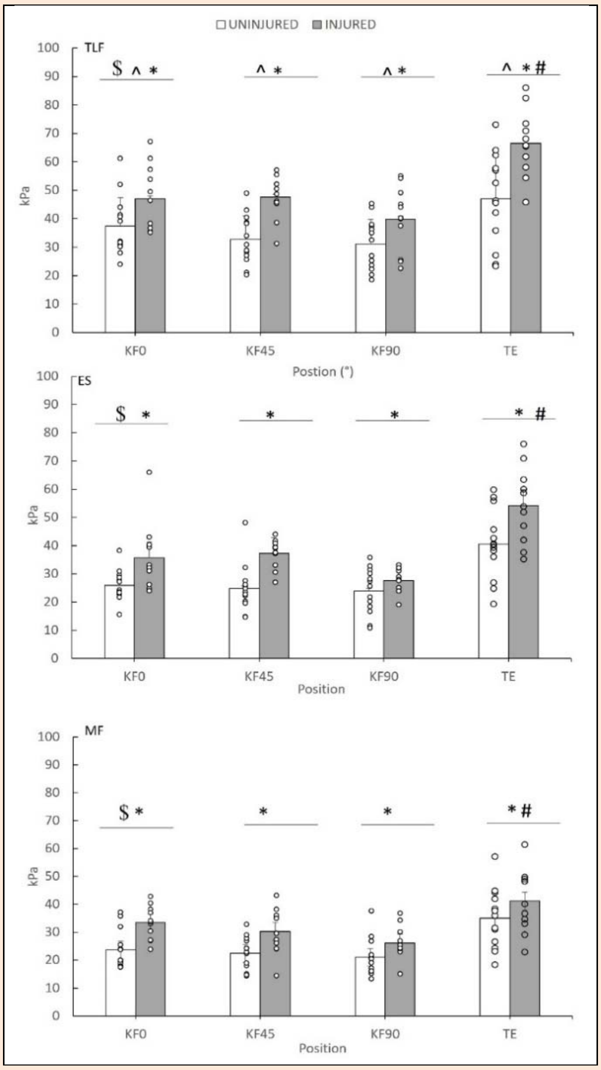

Figure 3. Mean group active SWE modulus values of thoracolumbar fascia (TLF), erector spinae (ES), multifidus (MF) values during submaximal contractions of the knee flexors at 0 (K0), 45 (K45) and 90° (K90) knee flexion angles and during prone trunk extension of 30° (TE). Error bars indicate standard deviation and circle dots are individual case values (* indicates statistically significant difference between groups, ^ values collapsed for groups and angles are greater compared to ES and MF values; # values collapsed for groups and tissues are greater compared to K0, K45 and K90; $ values collapsed for groups and tissues are greater than K90, $p < 0.05$).

First, hamstring injury is often associated with structural damage to the (hamstring) fascia, leading to scar tissue formation months after the injury (Sanfilippo et al., 2013). As a result, there are alterations in gliding between fascial layers as well as between fascia and muscle

Table 2. Mean (±SD) normalized EMG (percentage of maximum voluntary contraction) of the erector spinae (ES) and multifidus (MF) in injured and uninjured athletes.

	Knee angle (°)	ES		MF	
		Uninjured	Injured	Uninjured	Injured
Passive	0	5.92 ± 3.88	9.53 ± 5.99*	8.12 ± 3.41	10.01 ± 4.04*
	45	5.55 ± 3.72	9.74 ± 5.83*	8.80 ± 4.85	9.15 ± 5.03*
	90	3.86 ± 1.97	8.47 ± 5.16*	6.63 ± 4.00	7.31 ± 3.51*
Active	0	22.30 ± 12.84^	28.79 ± 15.56^	26.85 ± 9.20^	34.21 ± 11.61^
	45	21.74 ± 11.60	26.00 ± 18.13	26.50 ± 11.60	30.82 ± 16.87
	90	17.39 ± 8.13	17.62 ± 11.75	21.92 ± 12.35	23.93 ± 13.79

* significantly greater compared to the uninjured group, ^ values collapsed for groups greater compared to the active knee flexion test at 90°; # values collapsed for groups greater than values at 0, 45 and 90° active knee flexion tests, $p < 0.05$.

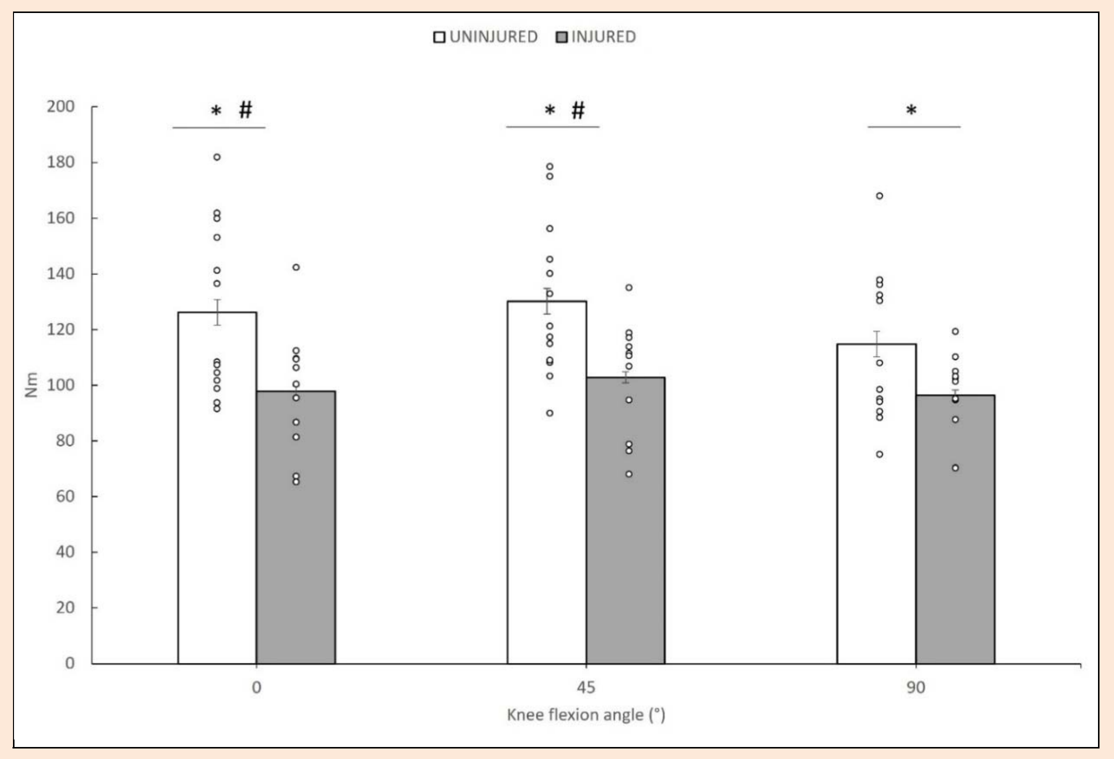

Figure 4. Maximum isometric torque values during knee flexion tests from at 0, 45 and 90° knee flexion angles. Error bars indicate standard deviation and circle dots are individual case values. * significant difference between groups; # torque, collapsed across groups, significantly different compared to 90°, $p < 0.05$.

in the area which surrounds injury (Chaitow, 2014). Studies have shown an increase in SWE modulus (Kawai et al., 2021) or a reduction in tissue motion (Silder, Reeder and Thelen, 2010) after hamstring injury which is indicative of a greater local stiffness of the fascia and the surrounding musculature of the injured area. As for the second factor, in a recent consensus statement, it has been agreed that muscles connect with fascial tissues creating a network which allows transmission of forces in various directions which also influences the mechanics of adjacent tissues (Zügel et al., 2018). Early research in cadaveric tissues have shown that biceps femoris force changes the length of TLF (Vleeming et al., 1995) while more recently an association between pelvic movement and SWE modulus of the posterior thigh muscles (Nakamura et al., 2016) and elongation of the hamstrings (Mendiguchia et al., 2024) has been reported. In addition, a positive relationship of the SWE modulus of the hamstring fascia (fascia latta) and the TLF has been found (Kellis et al., 2024). An alternative explanation for the present results is that the athletes who sustained a hamstring injury had already a greater TLF stiffness compared to the uninjured group. In the present study, clinical examination and medical files indicated that the percentage of athletes who had been diagnosed with back pain problems did not differ between the two groups, which means that any pre-existing differences in spine-related problems between two groups is unlikely.

The results also showed that passive (Figure 2) and active (Figure 3) SWE modulus of the ES and MF was greater in the injured group compared to uninjured ones, confirming the second hypothesis. One may hypothesize that the greater ES and MF SWE modulus in the injured athletes is due to increases in stiffness of the injured (hamstring) tissues. However, this is not fully supported by previous research as one study (Freitas et al., 2023) found greater SWE modulus of the injured hamstring in injured athletes compared to controls while others (Kawai et al., 2021; Freitas et al., 2023) reported no differences. The present findings, however, showed that ES and MF EMG activation during passive tests was also greater in the injured group compared to injured ones (Table 2) which may (partly) explain the present results (Hug et al., 2015). Whilst there is no direct evidence that hamstring and paraspinal muscle SWE modulus are inter-related, there are studies that provide support to this association. First, research has shown that there is considerable coactivation of the ES and biceps femoris during maximum voluntary contractions of the hamstrings (van Wingerden et al., 2004). Then, van Wingerden et al. (2004) found that even a small increase in the activation of the ES, the biceps femoris and the gluteus maximus increases sacro-iliac joint stiffness. In addition, altered control of the lumbo-pelvic region, which is expressed as a reduced pelvic motion and an increased range of lumbar motion, is linked with alterations in hamstring stiffness (Zawadka et al., 2018). Finally, athletes with hamstring injury occurrence show a greater anterior pelvic tilt and thoracic side bending during sprinting (Schuermans et al., 2017) than uninjured athletes. This means that a greater neuromuscular activation in the lumbar spine may be a compensatory strategy which is used by individuals who experience a hamstring injury to control the lumbar spine and the pelvic area.

It is known that athletes with a history of hamstring injury have a great risk to sustain a re-injury in soccer (Kekelekis et al., 2022; Ekstrand et al., 2023). Differences in muscle morphology and architecture between injured and non-injured athletes are useful to design interventions for reducing re-injury risk. Previous research has supported the notion that lumbar-pelvic function is related to hamstring injury (Carregaro and Gil Coury, 2009; Mueller-Wohlfahrt et al., 2013; Kuszewski et al., 2018; Mendiguchia et al., 2021). Two recent studies have found that intervention training programs which include exercises of the lumbar and pelvic musculature influence hamstring muscle function (Kuszewski et al., 2018; Mendiguchia et al., 2021). Our results extend these observations as it is evident that not only the paraspinal muscle tissue but also the fascia tissue that surrounds this region has different mechanical properties in individuals who had a recent hamstring injury compared to uninjured individuals. Based on SWE measurements, a recent study proposed that the role of fascia that surrounds the wounded area is more prominent than the role of the injured muscle tissue (Kawai et al., 2021). Recent studies have shown that myofascial release techniques which applied in the lumbar area increase hamstring flexibility field tests scores (sit-and-rich test) (Fauris et al., 2021) which provide an additional explanation of the beneficial effect of lumbar spine exercises for hamstring injury prevention (Al Attar and Husain, 2023) and rehabilitation (Sherry and Best, 2004).

There were limitations in this study. First, as already has been mentioned, the retrospective design of this study does not allow conclusions as to whether any group differences pre-existed or they were due to injury. In addition, the number of participants was small in our effort to collect evidence from a homogeneous group of soccer players, with a biceps femoris long head injury of moderate severity which occurred within the past year. The rehabilitation protocol which was followed after injury was neither controlled nor it was recorded. Another limitation is that SWE modulus values are specific to the location of the probe along the muscle during the test (Drakonaki, 2012; Miyamoto et al., 2020). Further, even though the US probe was oriented so that is parallel to fascicle orientation, changes in fascicle position relative to the skin during tests may have resulted in an angulation between the probe and the fibers, thus altering elastography measurements. Further, changes in temperature were not recorded but they may influence SWE measurements. Finally, it is possible that contraction of other muscles, such as the gluteus maximus, the abdominals or hip flexors (Vleeming et al., 1995), and pelvic movement (although the pelvis was fastened with straps) during contraction (Takaki et al., 2016) have increased paraspinal activation.

Conclusion

SWE modulus of the TLF and ES and MF was greater in soccer players with previous hamstring injury than uninjured players. Further research could establish whether exercises that target the paraspinal muscles and the lumbar fascia can assist in preventing individuals with a history of hamstring injury from sustaining a new injury.

Acknowledgements

The authors declare that there are no conflicts of interest. The experiments comply with the current laws of the country where they were performed. The data that support the findings of this study are available on request from the corresponding author.

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Key points

- Athletes with a history of a recent hamstring injury show a greater shear-wave elastic modulus of the thoracolumbar fascia compared to uninjured athletes when performing passive and active knee flexion tests and active trunk extensions.
- Shear-wave elastic modulus and passive activation of the lumbar spine muscles was greater in athletes with a recent hamstring injury compared to uninjured athletes.
- Management of athletes with a previous hamstring injury could include exercises or interventions that alter stiffness of the lumbo-pelvic fascia and musculature.

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