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Research article

Characterizing Muscle Activity in Soccer Players with a History of Hamstring Strain Injuries during Accelerated Sprinting

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Abstract

This study aimed to characterize muscle activity in male soccer players with a history of hamstring strain injuries (HSI) during accelerated sprinting. Thirteen patients each in the HSI group (history of HSI) and in the healthy group (with no history of HSI) were included. 26 male soccer players of which 13 with and 13 without HSI history were included in this study. Ten muscles were evaluated on electromyography activity during overground sprinting. The testing protocol consisted of a maximal sprint over a distance of 30 meters. One running stride was divided into the early stance phase, late stance phase, early swing phase, mid-swing phase, and late swing phase, and the average muscle activity per phase and the timing of the peak root-mean-square value appearance during each stride were calculated. Statistical analysis was performed using repeated-measures two-way ANOVA (group × phase), and multiple comparison tests were performed using the Bonferroni method when the interaction or main effect was significant. The statistical significance level was set at $p < 0.05$. Gluteus maximus (Gmax), gluteus medius (Gmed), and external oblique (EO) showed activity differences based on HSI history. Gmax was 30% lower, EO was 20% lower, and Gmed was 40% higher in HSI group. This study suggests that, despite previous findings that HSI is most likely during the late swing phase, the HSI group shows a higher injury risk in the early stance phase. This is due to differences in trunk and gluteal muscle activity between the late swing and early stance phases compared to the healthy group. In summary, HSI group had lower activity in the muscles contributing to trunk instability, especially EO and Gmax, before and after ground impact during accelerated sprinting, compared to Healthy.

Key words: Previous hamstring injury, Injury recurrence, Football, Electromyography, Trunk instability, Rehabilitation.

Introduction

Hamstring strain injuries (HSI) are the most common injury in soccer (Forsythe et al., 2022). The incidence continues to rise owing to the increasing demand for sprinting, with the HSI during training showing an upward trend since 2001 (Ekstrand et al., 2016). Numerous risk factors for the high incidence of HSI have been reported. A history of HSI is a significant risk factor, accounting for 18% of the reported HSI in soccer teams, as it poses a high risk of recurrence (Ekstrand et al., 2022). Therefore, it is necessary to analyze the history and occurrence of HSI in soccer players. Studies on HSI in soccer have also revealed that sprint-type HSI accounts for 70% of all cases, 56% of which occur during the acceleration phase (Gronwald et al., 2022). Understanding accelerated sprinting is crucial in addressing HSI because 96% of soccer sprints are shorter than 30 m and occur primarily during the acceleration phase (Bangsbo et al., 1991; Stølen et al., 2005; Di Salvo et al., 2009).

The hamstrings are articular muscles that are affected by hip, knee, and pelvic movements. Poor hip and pelvic control such as anterior pelvic tilt and lateral trunk flexion can result in hamstring stretching (Liu et al., 2017; Chumanov et al., 2007; Schuermans et al., 2017). Therefore, proper trunk and hip muscle training is necessary. Prospective studies suggest that activity in the swing phase of muscles other than the hamstrings, such as the gluteus maximus, erector spinae, and internal and external oblique muscles, is crucial for HSI prevention (Schuermans et al., 2017). Changes in muscle activity, including decreased activity in the biceps femoris and increased activity in the trunk muscles, have been observed in individuals with a history of HSI (Franettovich et al., 2016; Higashihara et al., 2019). In addition, the delayed timing of gluteal and erector spinae muscle activity has been observed in response to unpredictable trunk sway stimuli (Higashihara et al., 2022), indicating altered lumbopelvic muscle activity.

It is unclear whether these changes result from having a history of HSI or are risk factors. Muscle activity in patients with a history of HSIs may be a significant risk factor for recurrent HSI (Wangensteen et al., 2016). Despite the high recurrence rate and major risk associated with a history of HSI, no studies have been conducted on the occurrence mechanism during accelerated sprinting in previously injured players.

Differences in trunk and hip muscle activity during accelerated sprinting in individuals with a history of HSI may lead to biomechanical issues, such as anterior pelvic tilt and trunk lateral flexion, compromising proper pelvic control. This, in turn, could increase the tensile load on the hamstrings, thereby contributing to recurrent strains. Therefore, this study aimed to characterize the muscle activity in soccer players with a history of HSI during accelerated sprinting.

Methods

Participants

This study was a comparison between three groups: the dominant foot of the Healthy group with no history of HSI (Healthy), and the injured side (injured) and non-injured

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side(uninjured) of those with a history of HSI. The participants comprised male soccer players aged 18 to 30 years, with 13 individuals in the HSI group (age 23.7 ± 3.9 years, height 173.2 ± 4.9 cm, weight 66.8 ± 4.0 kg) and 13 in the healthy group (age 23.6 ± 2.3 years, height 170.0 ± 6.6 cm, weight 63.5 ± 4.9 kg) without a history of previous HSI. The sample size for this study was determined using G*Power 3.1.3 software (Heinrich Heine University, Dusseldorf, Germany). It was set as a two-way repeated measure analysis of variance (ANOVA) with a significance level of 0.05 and a power of 0.8. As a result, it was confirmed that a sample size of 10 was sufficient.

Participants were active soccer players who were able to sprint. The inclusion criteria for the HSI group were previous sprinting-related HSI, with the injury occurring in a non-contact fashion during sprinting, inability to participate in competition due to hamstring pain for at least one week, and current participation in normal training for at least three months after the most recent injury. To be included in the study they also should not have any factors that could affect muscle activity or biomechanics during sprinting. Patients with pain, hamstring, sacroiliac, or lumbar spine dysfunction, lumbar intervertebral joint discomfort, or a history of lower-extremity surgery within the past 2 years were excluded. Time since most recent injury for the HSI group ranged from 3 to 36 months, while the Healthy group had no previous history of HSI. Participants reported no hamstring pain or discomfort during sprinting in this study. Measurements were taken at least 24 h after the last team activity to mitigate the effects of fatigue.

Ethical issues

This study was approved by the Human Research Ethics Committee and adhered to the principles of the Declaration of Helsinki. Written informed consent was obtained from each participant (Approval No. 2022-528).

Measurement method

The measurement area consisted of a straight section measuring 30 m in length and 2 m in width on an outdoor artificial turf field with a designated measurement zone spanning 10 - 20 m. After an adequate warm-up, the participants initiated the sprint from an arbitrary standing position located 15 m before the center of the measurement area, aiming to traverse the area with maximum effort. The participants were instructed to achieve the maximum speed as quickly as possible. A 2-minute rest period was allowed between each trial to mitigate fatigue effects, and data from three trials were collected. The participants wore the same spikes used during normal training and the measurements were conducted on both sunny and cloudy days.

Surface electromyography

Surface electromyography (EMG) was conducted using a Trigno Wireless EMG System (Delsys Inc., Boston, MA, USA) with 10 electrodes attached. Bipolar surface Ag/AgCl electrodes, positioned at a fixed distance of 10 mm between electrodes, were attached bilaterally to the long head of the biceps femoris (BF), semitendinosus (ST), gluteus maximus (Gmax), gluteus medius (Gmed), and external oblique muscle (EO), following SENIAM recommendations (Hermens et al.,2000). The same investigator finalized the electrode positions by palpating each muscle belly during isometric contractions. Data were collected at a sampling frequency of 2000 Hz. Before electrode application, the area of each electrode application site was shaved using a disposable razor and wiped with alcohol-soaked deodorant cotton.

Joint angles

The angles of the hip and knee joints during each stride were calculated for each running phase. Markers were affixed to the bilateral acromion, greater trochanter, lateral knee joint epicondyle, and external knee joints. The hip joint angle was defined as the angle formed by the line connecting the acromion, greater trochanter, and lateral epicondyle of the knee joint. The knee joint flexion angle was defined as the angle formed by the line connecting the greater trochanter, lateral epicondyle of the knee joint, and malleolus lateralis. Video data were captured using a high-speed camera (EX-ZR1000; CASIO, Japan) at a frame rate of 240 fps. The camera was positioned to cover a 10-20 m section (5 m before and after the 15 m point in the measurement area). To synchronize the time with the EMG data, an optical signal was captured immediately before entering the measurement area, and the electrical signal from the optical signal generator (DKH PH-145 all-surrounding optical presenter) was recorded together with the EMG data.

Data analysis

Three strides of each foot were averaged and analyzed, with a stride defined as the distance from the ground surface of the foot to the ground contact of the same foot until the foot contacted the ground again. The running speed was calculated as the time required to traverse the measured section. A single stride was defined as the distance from the initial foot contact to the subsequent contact of the same foot. To calculate the timing of the appearance of the maximum root mean square (RMS) value, data for one gait cycle was interpolated to 101 points (IGOR Pro 4.04J; WaveMetrics, Inc.), and the stride cycle was defined as 100%. To thoroughly analyze the average muscle activity for each phase, one stride was classified into the following five phases: early stance, late stance, early swing, middle swing, and late swing. Early stance encompassed from initial foot contact to maximal knee flexion during stance, late stance from maximal knee flexion during stance to toe-off, early swing from toe-off to maximal knee flexion during swing, mid-swing from maximal knee flexion to maximal hip flexion, and late swing from maximal hip flexion to initial foot contact.

Motion analysis was performed using a two-dimensional motion analysis system (Frame Dias System. DKH Co., Ltd., Japan). The joint angle data were filtered using a second-order low-pass Butterworth filter to block frequencies above 6 Hz. EMG data analysis utilized Delsys EMG Works Analysis software (Delsys Inc., Boston, MA, USA). A bandpass filter with cutoff frequencies ranging from 20 Hz to 450 Hz was used. After filtering, the RMS of each muscle was calculated and smoothed using the moving average method for 100 ms. The filtered data were normalized by the mean value of muscle activity during the trial. The average muscle activity of each muscle in the five phases and the timing of the appearance of the maximum RMS value in one cycle were determined.

Statistical analysis

All statistical analyses were performed using the SPSS ver. 14.0 (SPSS Statistics 29.0 IBM). For the comparison of speeds between groups, the Shapiro-Wilk test was used to confirm normality followed by an unresponsive t-test. The three groups included Healthy and injured, uninjured. A repeated-measures two-way ANOVA (groups × phase) was conducted between the three groups and five phases for each muscle (early stance, late stance, early swing, middle swing, and late swing phase) to examine the main effects and interaction effects. For the peak timing of muscle activity, a repeated-measures two-way ANOVA (groups × muscle) was conducted among the three groups to examine the main effects and interactions. Multiple comparison tests were conducted as post-tests for the factors for which significant main effects and interactions were found using the Bonferroni method. Statistical significance was set at $p < 0.05$. Hedge's g was used as the effect size, with $g \geq 0.20$ defined as a small effect size, $g \geq 0.50$ as a medium effect size, and $g \geq 0.80$ as a large effect size. The effect sizes were reported when statistical significance was observed.

Results

The characteristics of the participants are presented in Table 1. The mean running speed of the HSI group (8.11 ± 0.25 m/s) showed no significant difference compared to that of the Healthy group (8.18 ± 0.31 m/s) ($p = 0.48$). This result compares the two groups as required to achieve the aim of this study.

BF

Figure 1 shows the results for BF. No significant interaction between groups and phases was identified for BF ($F(8,144) = 0.993$, $p = 0.444$, partial $\eta 2 = 0.052$). Furthermore, there was no main effect observed between groups ($F(2,36) = 0.790$, $p = 0.461$, partial $\eta 2 = 0.042$).

Compared to the early stance phase, the values were significantly lower during the late stance phase ($p < 0.001$) and early swing phase ($p < 0.001$), but significantly higher during the mid swing phase ($p < 0.001$) and late swing phase ($p < 0.001$). Additionally, compared to the late stance phase, the values were significantly higher during the mid swing phase ($p < 0.001$) and late swing phase ($p < 0.001$). Furthermore, when compared to the early swing phase, the values were significantly higher during the mid swing phase ($p < 0.001$) and late swing phase ($p < 0.001$).

The mean values and standard deviations for muscle activity during each phase of sprinting are presented below for the injured, uninjured and Healthy.

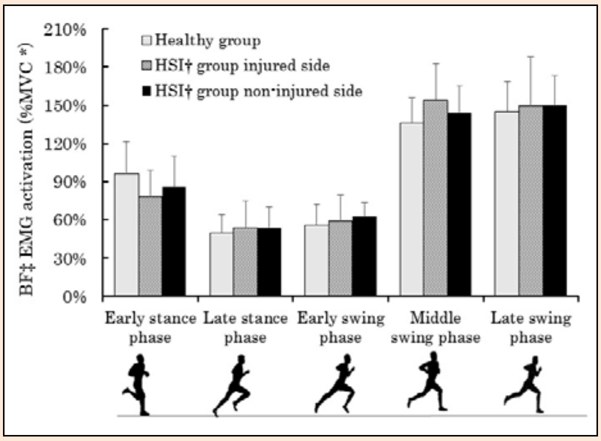

Figure 1. Normalized mean activity and standard deviation of BF for each sprint phase. *: EMG data were normalized by the mean value of muscle activity during the trial. HSI†: Hamstring strain injury, BF‡: Biceps femoris long head muscle.

ST

Figure 2 shows the results for ST. An interaction between group and phase was confirmed for ST ($F(8,144) = 2.312$, $p = 0.023$, partial $\eta 2 = 0.114$). Post-test results revealed that the muscle activity on injured during the mid-swing phase was significantly higher than that in Healthy ($p < 0.001$, ES $g = 1.531$). During the same phase, uninjured showed higher values than the Healthy ($p = 0.008$, ES $g = 0.89$).

Gmax

Figure 3 shows the results for Gmax. No significant interaction between group and phase was identified for Gmax ($F(8,144) = 1.975$, $p = 0.054$, partial $\eta 2 = 0.099$).

Table 1. Information on participants for HSI‡ group.

Participant	Age (years)	Hight (cm)	Weight (kg)	Injured limb	Time since injury * (months)	Total number of HSI †	Activity at time of injury
1	24	163	61	non-dominant leg	4	3	Sprinting
2	29	177	73	non-dominant leg	6	2	Sprinting
3	24	176	61	dominant leg	23	2	Sprinting
4	18	172	64	non-dominant leg	23	1	Sprinting
5	19	176	62	dominant leg	36	1	Sprinting
6	18	176	67	non-dominant leg	35	2	Sprinting
7	23	172	68	non-dominant leg	6	2	Sprinting
8	23	169	68	dominant leg	3	1	Sprinting
9	23	175	68	dominant leg	6	3	Sprinting
10	29	172	70	dominant leg	6	1	Sprinting
11	29	172	68	dominant leg	9	3	Sprinting
12	22	183	73	dominant leg	6	2	Sprinting
13	27	169	65	dominant leg	26	3	Sprinting

Time since injury *: The length of time since the most recent return to HSI. Total number of HSI †: Number of previous HSI and abbreviations (HSI) indicate hamstring strain injury. HSI‡: Hamstring strain injury.

However, a main effect was observed between groups (F(2,36) = 6.542, p = 0.004, partial η2 = 0.267), and Post-hoc tests revealed that injured had considerably lower muscular activity during the late swing phase than Healthy (p = 0.007, ES g = 1.33). During the same phase, uninjured showed considerably lower values than Healthy (p = 0.009, ES g = 1.26).

Compared to the early stance phase, values were significantly lower during the late stance phase (p < 0.001) and early swing phase (p < 0.001), but significantly higher during the mid swing phase (p < 0.001) and late swing phase (p < 0.001). When compared to the late stance phase, values were significantly higher during the mid swing phase (p < 0.001) and late swing phase (p < 0.001). Additionally, compared to the early swing phase, values were significantly higher during the mid swing phase (p < 0.001) and late swing phase (p < 0.001).

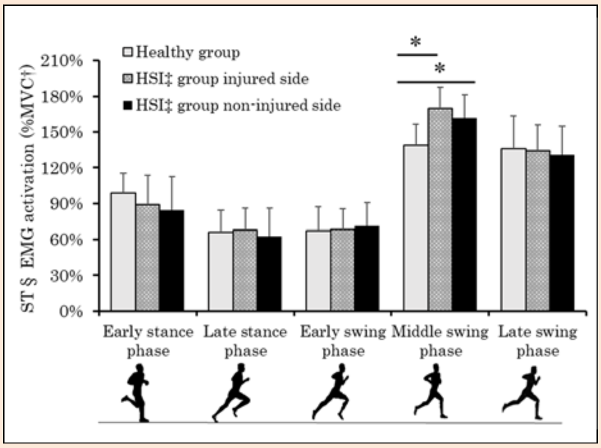

Figure 2. Normalized mean activity and standard deviation of ST for each sprint phase. *: Significant difference (p < 0.05). MVC†: EMG data were normalized by the mean value of muscle activity during the trial. HSI‡: Hamstring strain injury

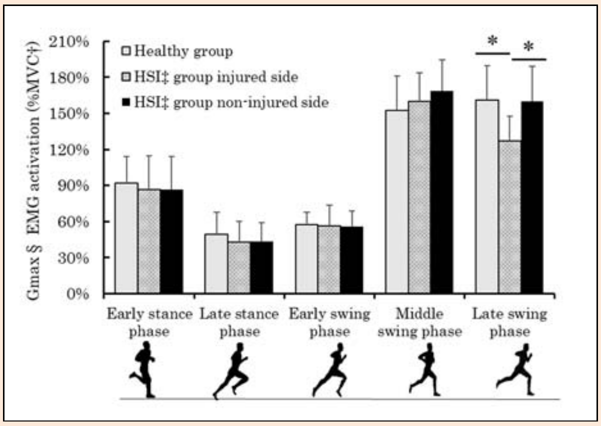

Figure 3. Normalized mean activity and standard deviation of Gmax for each sprint phase. *: Significant difference (p < 0.05). MVC†: EMG data were normalized by the mean value of muscle activity during the trial. HSI‡: Hamstring strain injury Gmax§: Gluteus maximus muscle

Gmed

Figure 4 shows the results for Gmed. Similarly, no significant interaction between group and phase was found for Gmed (F(8,144) = 1.124, p = 0.351, partial η2 = 0.059). Nonetheless, a main effect between groups was evident (F(2,36) = 3.315, p = 0.048, partial η2 = 0.156), and post-hoc analysis indicated significantly higher muscle activity in the both sides of HSI group during the early stance phase compared to the Healthy (p = 0.011, ES g = 1.17). Additionally, in the same phase, uninjured exhibited significantly higher values than the Healthy (p = 0.016, ES g = 1.0).

Compared to the early stance phase, values were significantly lower during the late stance phase (p < 0.001), early swing phase (p < 0.001), and mid swing phase (p < 0.001), but significantly higher during the late swing phase (p = 0.003). Additionally, compared to the mid swing phase, values were significantly higher during the late swing phase (p < 0.001).

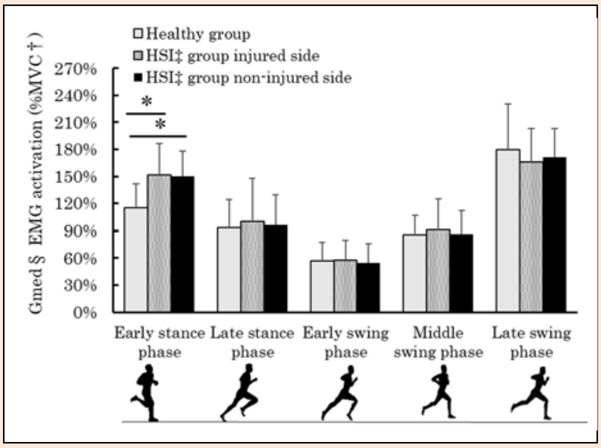

Figure 4. Normalized mean activity and standard deviation of Gmed for each sprint phase. *: Significant difference (p < 0.05). MVC†: EMG data were normalized by the mean value of muscle activity during the trial. HSI‡: Hamstring strain injury. Gmed§: Gluteus medius muscle.

EO

Figure 5 shows the results for EO. No significant interaction between group and phase was found for EO (F(8,144) = 1.739, p = 0.094, partial η2 = 0.088). Nevertheless, there was a main effect between groups (F(2,36) = 3.350, p = 0.046, partial η2 = 0.157), and post-hoc tests indicated significantly lower muscle activity on injured during the early stance phase when compared to the Healthy (p < 0.001, ES g = 1.17). A significant difference was also observed between injured and uninjured during the same phase, with injured showing significantly lower values (p = 0.005, ES g = 1.07).

Compared to the mid swing phase, values were significantly lower during the early stance phase (p < 0.001), late stance phase (p < 0.001), early swing phase (p < 0.001), and late swing phase (p < 0.001).

Timing of RMS peak value appearance

Figure 6 shows the results for Peak RMS value appearance timing when 1 stride is 100%. An interaction between the group and muscle was confirmed for the timing of RMS peak value appearance (F(8,120) = 2.536, p = 0.014, partial η2 = 0.145). Post-hoc test results showed a significant delay in the timing of the RMS peak value appearance in the Gmed on injured (p = 0.005, ES g = 1.7). In addition, the non-injured side also showed a significant delay compared to the healthy group. (p = 0.031, ES g = 1.27).

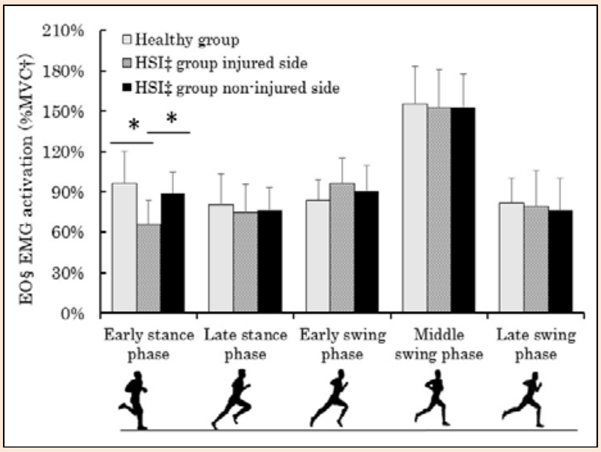

Figure 5. Normalized mean activity and standard deviation of EO for each sprint phase. *: Significant difference ($p < 0.05$). MVC†: EMG data were normalized by the mean value of muscle activity during the trial. HSI‡: Hamstring strain injury. EO§: External oblique muscle

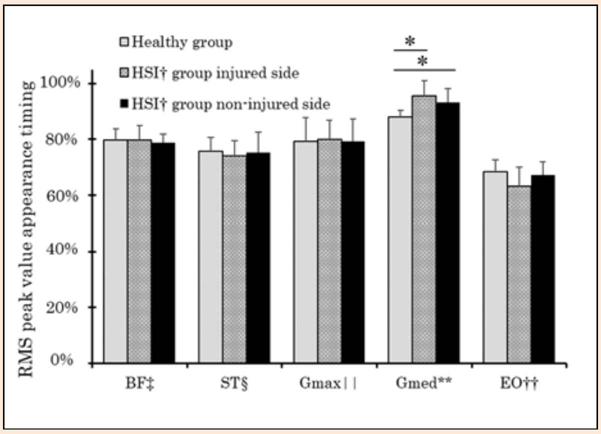

Figure 6. Peak RMS value appearance timing and standard deviation for each muscle when 1 stride is 100%. *: Significant difference ($p < 0.05$). HSI†: Hamstring strain injury, BF‡: Biceps femoris long head muscle, semitendinosus muscle, ST§: semitendinosus muscle, Gmax ||: Gluteus maximus muscle, Gmed **: Gluteus medius muscle, EO††: External oblique muscle.

Discussion

This study aimed to characterize the muscle activity of individuals with a history of HSI during accelerated sprinting. The results showed that Gmax activity during the late swing phase on the injured was approximately 30% lower. The timing of the peak RMS value appearance of the Gmed on the injured and uninjured were delayed by 6% when compared to that in the Healthy; muscle activity was 40% higher on both sides of the HSI group during the early stance phase; and EO was 20% lower on the injured side during the early stance phase when compared to the Healthy and the uninjured.

In sprinting, a greater angular velocity of the thigh during the late swing phase is effective in acquiring the ground reaction force during contact and is a factor for high performance (Clark et al., 2020). However, increased ground reaction force is also a risk factor for the occurrence of HSI (Liu et al., 2017; Clark and Weyand, 2014). Although the hamstrings and Gmax jointly decelerate the swing leg during the late swing phase to control excessive ground reaction forces (Pandy et al., 2021), the results of this study showed low activity of the Gmax on the injured during the late swing phase. The lack of proper Gmax activity indicated that the hamstrings alone would have to decelerate the swing leg. This may place the hamstrings at risk of HSI because they are unable to control the ground reaction force during the transition from the late swing phase to the early stance phase, as it places a load on the hamstrings. However, this study alone cannot determine whether the observed factors are intrinsic. Future research should incorporate prospective studies to comprehensively address these issues.

Normally, the Gmed is involved in ground stability during running by working in advance during the late swing phase to control the pelvis in the anterior plane, thereby preventing pelvic subduction (Semciw et al., 2013; Chumanov et al., 2012). However, in the present study, the HSI group showed a delayed appearance of peak RMS values on both the injured and uninjured side. In a study examining the biomechanics during sprinting in participants with and without a history of HSI, anterior pelvic changes in the sagittal plane and those with a history of HSI showed pelvic drop during the stance phase (Nurse et al., 2023). Furthermore, patients with increased pelvic descent show increased ipsilateral Gmed activity (Evie et al., 2009). In the present study, the activity was bilaterally higher in the HSI group than in the Healthy during the early stance phase, suggesting that, similar to findings of previous studies, increased pelvic subduction during the early stance phase may have compensated for the higher activity in the Gmed (Nurse et al., 2023). Lateral trunk flexion can be a risk factor for HSI, suggesting that it alters the length-tension relationship of the pelvic peroneal muscles and prevents the pelvis from being controlled by appropriate muscle activity (Bramah et al., 2023). Therefore, pelvic descent may induce lateral trunk flexion, which may be a risk factor for the development of HSI.

Trunk muscle activity during the swing phase is important since previous prospective studies have reported that trunk muscle activity during the early swing phase reduces the risk of HSI injury (Schuermans et al., 2017). In the present study, the EO had low activity during the early stance phase and may not have been able to maintain trunk stability, including the control of pelvic movement immediately after ground contact. During limb movements, stable trunk muscle function provides the foundation for a stable torso that is able to respond to various movements and postural changes as the torso becomes the foundation, and muscle activity is appropriately performed even during sprinting (Behm and Anderson, 2006; Kibler et al., 2006). However, low trunk muscle activity increases instability immediately after ground contact. (Behm and Anderson, 2006). In the present study, low EO activity decreased trunk stability immediately after ground contact and may have contributed to the risk of occurrence by increasing the tensile load on the hamstrings during ground contact because of the inability to properly coordinate movements such as anterior pelvic tilt and trunk and hip flexion.

One characteristic of soccer players during sprinting is a large hip flexion angle before and after ground contact (Masamichi et al., 2019). Previous studies have suggested that trunk forward lean, hip flexion, and knee extension during video analysis of HSI occurrences are contributing factors to HSI (Orchard, 2002). Additionally, it has been reported that sprinting with a forward-leaning trunk increases hamstring muscle length during the stance phase after ground contact (Higashihara et al., 2015). Moreover, over half of the HSI in soccer players occurs during the acceleration phase, particularly with an anterior trunk tilt (Debaere et al., 2013; Gronwald et al., 2022). This indicates that soccer players with pronounced anterior trunk tilt have a heightened risk of injury during the early stance phase, owing to hamstring stretching upon ground contact. HSI is more likely to occur during the late swing and early stance phases, with the early stance phase posing a risk owing to ground reaction forces during contact (Liu et al., 2017). The present study observed varying characteristics in the activities of the Gmax, Gmed, and EO, which are associated with hip joint stability in the sagittal and anterior pelvic planes, depending on whether individuals had a history of HSI. These findings suggest that muscle activities related to torso stability before and after ground contact are inadequate and that transitioning to the stance phase in an unstable state overload the hamstrings without appropriate pelvic muscle activity. Consequently, soccer players with a history of HSI may undergo changes in muscle activity beyond the hamstring muscles, such as the Gmax, Gmed, and EO, during ground contact, leading to a heightened risk of HSI recurrence.

The study results offer new insights that are different from those of prior research concerning muscles other than the hamstrings. HSI are reported to have a high risk of recurrence, and exercises emphasizing centrifugal loading are commonly used to prevent recurrence but have not effectively reduced their incidence (Impellizzeri et al., 2021). Additionally, the absence of significant differences in the BF EMG activation throughout the stride in this study complicates the conclusion that hamstring loading exercises are effective. Previous studies have suggested that rehabilitation programs comprising progressive agility and trunk stabilization exercises (PATS programs) or agility and stabilization exercises, may be more effective than those focusing solely on hamstring stretching and strengthening exercises (de Visser et al., 2012; Schuermans et al., 2017). Building on these findings and the results of this study, a future approach to prevent HSI recurrence in individuals with a history of HSI may necessitate exercises targeting not only injured muscles but also the surrounding muscles.

A few limitations of this study hindered the specificity of the injury sites in the recruited subjects. Consequently, the results of this study cannot be confined to the long head of the BF muscle alone but must be viewed as a result of hamstring separation in its entirety. Moreover, determining whether the characteristics of the HSI group in this study were present before or after HSI injury is challenging. Future prospective studies may obtain more definitive results regarding the characteristics of the HSI group by longitudinally measuring data before and after injury. Additionally, the type of rehabilitation that the HSI group conducted in order to return to competition also varied from subject to subject. In this study, 3-D motion analysis was not analyzed. Therefore, the results of this study should be considered as characteristics of muscle activity of individuals with a history of HSI.

Conclusion

This study examined the muscle activity characteristics in soccer players with a history of HSI during accelerated sprinting. The findings indicated that the EO, Gmax, and Gmed before and after ground contact from the late swing phase to the early stance phase exhibited distinct characteristics in healthy and previously injured players. These results imply that individuals with HSI experience insufficient muscle activity contributing to trunk stability, including that of the pelvis, before and after ground contact during accelerated sprinting. Consequently, rehabilitation exercises focusing on the behavior of these muscles during the late swing to early stance phases may be necessary in clinical practice.

Acknowledgements

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Key points

- There is a potential for muscle activity to influence the risk of reoccurrence during sprinting in soccer players with a history of HSI.
- The activity of trunk muscles in individuals with a history of HSI was lower compared to those without a history.
- Rehabilitation exercises focusing on the movements of the trunk and gluteal muscles from the late swing phase to the early stance phase may be necessary in clinical practice.

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