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ORIGINAL

MUSCLE ACTIVATION IN RUNNERS WITH ILIOTIBIAL BAND SYNDROME

ACTIVACIÓN MUSCULAR EN CORREDORES CON EL SÍNDROME DE LA BANDA ILIOTIBIAL

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ABSTRACT

A study was performed to examine differences in hip and thigh muscle activation in male and female runners with and without iliotibial band syndrome (ITBS). The muscle activation of 21 runners (14 with ITBS and 7 healthy) was recorded during a run. No significant differences were observed in mean muscle activation between injured male and female runners. In contrast, in female runners with ITBS, there were differences in activation between the vastus lateralis and the tensor fascia lata ($p<0.05$), and between the vastus lateralis and the biceps femoris ($p<0.05$). With regard to male runners with ITBS, differences in activation were observed between the gluteus maximus and the tensor fascia lata, and between the gluteus maximus and the biceps femoris ($p<0.05$). These findings contribute to a better understanding of iliotibial band syndrome and may be useful for designing of targeted treatments for the ITBS.

KEY WORDS: electromyography, knee, iliotibial band syndrome.

RESUMEN

Esta investigación examinó las diferencias en la activación muscular en los músculos de la cadera y muslo en corredores y corredoras con y sin el síndrome de la banda iliotibial (SFBI). Se registró la actividad neuromuscular en 21 corredores durante la carrera (14 SFBI y 7 sanos). No se han encontrado diferencias significativas en la actividad muscular media entre los corredores y corredoras lesionados. Sin embargo, en el caso de las corredoras lesionadas, se han encontrado diferencias entre el vasto lateral y el tensor fascia lata, y entre el vasto lateral y el bíceps femoral ($p<0,05$ en ambos casos). En el caso de los corredores hombres lesionados, se han encontrado diferencias entre el glúteo mayor y el tensor fascia lata, y entre el glúteo mayor y el bíceps femoral ($p<0,05$ en ambos casos). Estos hallazgos proporcionan un mayor entendimiento de la lesión y ayudarían a un tratamiento más específico.

PALABRAS CLAVE: electromiografía, rodilla, síndrome de la banda iliotibial.

INTRODUCTION

Iliotibial band syndrome (ITBS) is a clinically diagnosed condition[1], whose initial symptoms include pain during running at the lateral knee[2,3]. Symptoms appear progressively due to continued rubbing of the iliotibial band against the lateral femoral epicondyle during the stance phase of the gait cycle[4]. According to Fairclough et al.[5], the point of greatest friction (impingement zone) occurs at 30º of knee flexion. This leads to an irritation and an inflammation of the tissue, bursa or fat underneath the iliotibial tract. The function of the iliotibial band is to stabilise the hip and knee, whilst also limiting hip adduction and knee internal rotation[6,7].

ITBS is the second most common injury and main cause of lateral knee pain in runners[8,9]. A direct relationship exists between increasing training volume and injury incidence in the development of ITBS[8,10]. At a kinematic level, some authors have found differences in the flexion and extension patterns of the knee in runners who have previously suffered ITBS in comparison to healthy runners[11,12]. Nonetheless, no differences have been found in knee flexion and extension patterns in runners suffering from ITBS at the time of the study [11,13]. This indicates the possibility that differences may exist in other axes of movement, different to those concerning flexion-extension and the movement patterns of other joints[14]. Excessive hip adduction[12,15-20] and knee internal rotation[7,11,12,18,20] have been cited as risk factors for suffering ITBS. In exchange, no differences have been found in hip adduction or in knee internal rotation in runners with current symptoms[21-25]. This difference indicates that a higher strain rate in the iliotibial band in order to stabilise the hip and knee is characteristic of injured runners[26]. These findings confirm that stated by Foch et al.[27], which is that kinematic alteration depends on the injury status of the runner.

Strain in the iliotibial band (ITB) may be affected by contraction of the gluteus maximus, tensor fascia lata and vastus lateralis muscles[28-30]. During the deceleration phase, the increase in hip adduction in runners with ITBS demands a large contribution from the hip muscles in order to respond to this increased hip adduction moment[31]. It has been suggested that a factor in the development of ITBS is the inability of the hip muscles to offset the adduction moment. This may be because of weakness or neuromuscular dysfunction[9,13,19,32]. Muscular fatigue has also been demonstrated to cause changes in running technique employed by runners with ITBS[11,21,33]. One characteristic of muscular fatigue is a change in the electromyographic signal produced during a submaximal isometric contraction[34].

Three studies were found which examined electromyography (EMG) within participants suffering from ITBS. Baker et al.[21] demonstrated that tensor fascia lata muscle activation in injured runners increased at 3 minutes of running in comparison to a control group. Brown et al.[34] stated that the gluteus medius of female runners with ITBS did not demonstrate a deterioration in gross strength, but, showed lesser resistance to fatigue. Foch et al.[35] demonstrated that gluteus medius activation is similar in runners who have suffered from the iliotibial band syndrome in comparison to healthy runners. More EMG data are required to better elucidate effects on the muscular functioning of the hip and thigh in runners suffering from ITBS.

Current research considers only the leg that is affected by the injury, ignoring the potential response of this in the non-affected leg. In other conditions such as anterior cruciate ligament (ACL) rupture, differences in neuromuscular activity between the two legs following operation have been studied[36]. In the case of ITBS, Suárez et al.[25] reported that no kinematic differences exist between both legs. Fredericson et al.[31] state that the injured leg produces lower abduction strength than the uninjured leg. However, no research study is recorded to have compared the muscular activation of the hip muscles and the thigh muscles of both legs in individuals suffering from ITBS during a run, leading to the development of the present research.

Since there is no clear consensus about the way in which injuries affect the muscle activation of runners who suffer injury at the exact moment of being analysed, the purpose of the present study was to determine differences in muscle activation of the hip and thigh muscles, comparing males and females injured with ITBS. Given that females are twice as likely to suffer this condition[8], a secondary aim was to determine the differences in muscle activation of the hip and thigh muscles between injured women and those not reporting this injury at the time of being analysed. Based on the study conducted by Baker et al.[21], it was hypothesised that differences would exist between the muscle activation of male and female runners suffering from the ITBS. It was further hypothesized that female runners with ITBS at the time of the study would demonstrate an alteration in their muscular activation pattern in comparison to healthy female runners.

MATERIAL AND METHODS

Participants

21 trained, recreational runners were divided into three groups: injured females, injured males and non-injured female runners (age range: 24-58 years; height: 1.70 ± 0.08 m; body mass: 64.9 ± 12.65 kg) and voluntarily participated in this cross-sectional study (Table 1). All participants fulfilled the following inclusion criteria: (1) older than 18 years, (2) minimum weekly training volume of 20 km, (3) previous medical diagnosis, (4) not suffering any other knee-related conditions. Furthermore, participants of ITBS group satisfied these additional criteria (5) typical medical history, pain during running, (6) pain in the lateral femoral epicondyle during the study. After receiving detailed information about the study aims and procedures, each participant signed a written informed consent form enabling their participation. This complied with the ethical standards laid out by the Declaration of Helsinki[37]. The present study was approved by the ethical committee of the Polytechnic University of Madrid, Madrid, Spain.

Table 1. Participants

	ITBS males	ITBS females	Healthy
n	9	5	7
Height (m)	1.77 (.05)	1.65 (.06)	1.62 (.05)
Weight (kg)	77.19 (7.75)	56.94 (4.8)	54.2 (6.82)
BMI (kg.m-2)	24.64 (1.94)	20.91 (2.49)	20.49 (1.82)
Speed (m/s)	3.04 (0.43)	2.74 (0.44)	2.66 (0.31)

* Average values presented (standard deviation)
** BMI: Body mass index

Procedure

Participants were evaluated individually over a single day. The testing session began with the collection of anthropometric data, measurement and placement of the electromyographic sensors. Participants ran with their usual running shoes on a flat surface. The test area was marked out using cones and consisted of a surface measuring five metres wide and 15 metres long. The route to be run was carefully explained to each participant, with runners being free to choose their running speed[11,14,25,38]. The run was ended once four trials had been obtained of each leg. No information was given to the runners about the data collection process with the aim of avoiding alterations to normal running technique. Prior to data collection, runners carried out a standard warm-up within the test circuit which lasted for 10 minutes.

Data collection

For descriptive analysis, means, body height (cm) and body mass (kg) were determined using a stadiometer and a scale (Pino Blue Soehnle® Corp., Germany). All measures were taken with participants wearing only their underwear. Body mass index (BMI) was calculated by taking the body mass and height of participants (kg.m-2).

After providing informed consent and completing the questionnaires, participants were prepared for EMG measurements. Body hair was shaved, and the skin was gently abraded with sandpaper and cleaned with alcohol to enable optimal detection of muscular signals. Electrodes were placed on the vastus lateralis (VL), biceps femoris (BF) gluteus maximus (GMAX), gluteus medius (GMED), and tensor fascia lata (TFL) muscles of both extremities. Sensor placement was performed following recommendations laid out in the SENIAM protocol[39]. The VL placement was at 66% on the line from the antero-superior iliac spine, to the lateral side of the patella. The BF placement was at 50% of the line between the ischial tuberosity and the lateral epicondyle of the tibia. GMAX sensor placement was at 50% on the line between the sacral vertebrae and the greater trochanter. Finally, the GMED sensor was placed at 50% of the distance between the line from the iliac crest to the trochanter, whilst TFL placement was at 1/6 of the proximal distance from the antero-superior iliac spine. Wireless electrodes were used for surface electromyography (Trigno Delsys® 1000 Hz). Average activation was recorded during the stance phase of the GMAX, VL, TFL, BF and GMED muscles. In order to determine the phases defining the running gait cycle, a 3D Vicon capture system was used (120Hz) alongside Kistler force plates (1000HZ). EMG data were filtered, rectified and normalised using average activation during the gait cycle and a Butterworth bandpass filter with cut-off frequencies of 20Hz and 300Hz was applied to all signals. The signal was filtered using root mean square (RMS) calculations, applying a sampling window of 0.05’’ and an overlap of 0.025’’.

Average EMG values were taken for the injured leg of males and females in order to make comparisons between them. Likewise, electromyographic activity of the injured leg was compared with that of the healthy leg. Further, activation in the VL, GMAX, GMED, TFL and BF muscles was compared between injured males and females. Finally, activation of the same muscles was compared between the injured leg of female runners and the dominant leg of healthy female runners.

Statistical analysis

Data comparison between the three groups was performed using SPSS 20.0 (SPSS Inc., Chicago, IL, USA) via two ANOVAS. For the first comparison between injured male and female runners, a repeated measures ANOVA with four factors was employed. Muscle (5), leg (2) and repetitions (3) provided the repeated measures factors, with the independent factor being sex (2). For the second comparison conducted between healthy and injured female runners, a repeated measures ANOVA was again employed with four factors. Again, muscle (5), leg (2) and repetitions (3) provided the repeated measures, whilst the independent factor described whether one was injured or healthy (2). For the presentation of results, variables were grouped in relation to the hypotheses proposed in the introduction section. The significance level was set at $p<0.05$. Results were interpreted according to effect sizes using Cohen's d values. Threshold values for effect sizes were established as follows: large effect greater than 0.8, and medium effect between 0.5 and 0.8[40].

RESULTS

In relation to the analysis of EMG measures of the injured leg of male and female runners (Table 2), no significant differences were found in any of the three repetitions analysed when comparing average activation in each muscle (Figure 1).

Table 2. Parameters (average ± standard deviation), % of the gait cycle, EMG of the muscles of the injured leg of injured runners.

	ITBS Females	ITBS Males	Difference	P-value	d
GMAX (% gait cycle)	136.48% (41.27%)	153.18% (32.62%)	16.70% (37.20%)	0.26	0.45
VL (% gait cycle)	235.45% (117.63%)	174.13% (93.0%)	61.32% (106.03%)	0.16	0.58
TFL (% gait cycle)	110.74% (20.98%)	109.28% (16.58%)	1.45% (18.91%)	0.84	0.08
BF (% gait cycle)	116.10% (29.06%)	108.42% (22.97%)	7.67% (26.19%)	0.47	0.29
GMED (% gait cycle)	145.47% (51.35%)	138.11% (40.59%)	7.36% (46.28%)	0.69	0.16

*EMG = Electromyography; % gait cycle; GMAX = Gluteus maximus; VL = Vastus lateralis; TFL = Tensor fascia lata; BF = Biceps femoris; GMED = Gluteus medius.

** Average values presented (standard deviation)

+ Significant differences between the injured leg of injured males and females

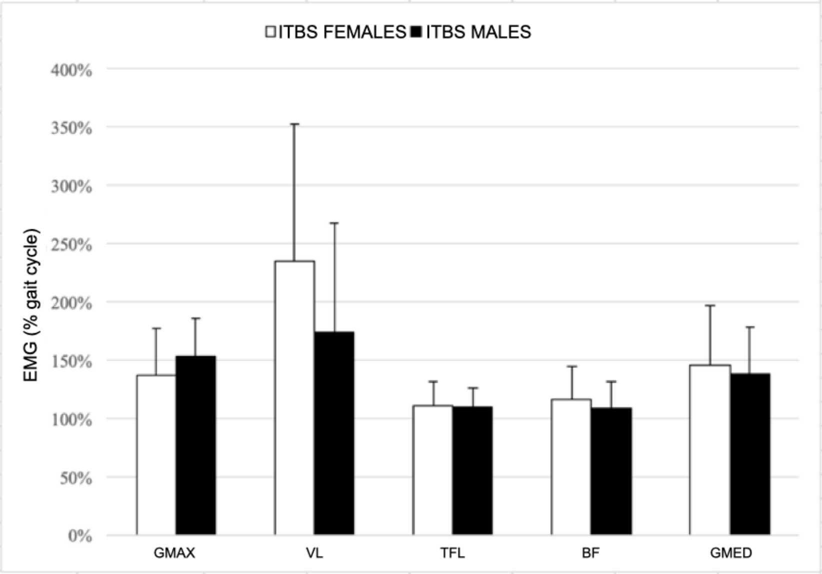

Figure 1. Muscular activation of injured runners**.**
*EMG = Electromyography; % gait cycle; GMAX = Gluteus maximus; VL = Vastus lateralis; TFL = Tensor fascia lata; BF = Biceps femoris; GMED = Gluteus medius.

Significant differences were found ($p<0.05$) when performing a comparison between the muscles studied in the injured leg of injured female runners. In relation to the comparison between VL and TFL, differences produced a (124.71% ± 84.49%) large effect size (1.48). The difference between VL and BF (119,35% ± 85,68%) was also significant ($p <0.05$), with a large effect size (1.39). The VL (235.45% ± 117.64%) was the muscle to show the greatest activation, followed by the GMAX (145% ± 7%) and the GMED (142% ± 9%). These differences were not found to be significant. The TFL (110% ± 4%) and BF (112% ± 5%) revealed significantly lower activation values.

Significant differences exist ($p<0.05$) between the muscles studied in the injured legs of injured male runners. With regards to the comparison between GMAX and TFL, differences (43.90% ± 25.88%) produced a large effect size (1.70). A significant difference was also found between the GMAX and BF ($p<0.05$). This difference (44.76% ± 28.22%) also pertained to a large effect size (1.59).
Data produced from this research show that no differences emerge between muscular activation in the muscles of the injured and non-injured leg of injured female runners (Table 3).

Table 3. Parameters (mean ± standard deviation), % gait cycle, EMG comparison between the legs of injured female runners.

	ITBS leg	Healthy leg	Differences	P-value	d
GMAX (% gait cycle)	146.17% (37.10%)	126.79% (37.50%)	19.38% (37.30%)	0.44	0.52
VL (% gait cycle)	259.32% (115.35%)	211.59% (71.22%)	47.73% (95.86%)	0.41	0.50
TFL (% gait cycle)	108.11% (33.98%)	113.37% (21.75%)	5.26% (28.53%)	0.82	0.18
BF (% gait cycle)	103.57% (24.44%)	128.63% (24.17%)	25.06% (24.31%)	0.11	1.03
GMED (% gait cycle)	160.81% (47.24%)	130.14% (50.75%)	30.67% (49.03%)	0.38	0.63

*EMG = Electromyography; % gait cycle; GMAX = Gluteus maximus; VL = Vastus lateralis; TFL = Tensor fascia lata; BF = Biceps femoris; GMED = Gluteus medius.

** Mean values presented (standard deviation)

+ Significant differences between muscles of the healthy leg and the injured leg of injured female runners

In the case of injured male runners, data confirm that there are no differences between muscular activation in the muscles of the injured leg and muscles of the non-injured leg (Table 4).

Table 4. Parameters (mean ± standard deviation), % gait cycle, EMG between the different legs of injured male runners.

	ITBS leg	Healthy leg	Differences	P-value	d
GMAX (% gait cycle)	144.50% (39.35%)	161.88% (39.77%)	17.38% (39.56%)	0.38	0.44
VL (% gait cycle)	170.78% (122.35%)	177.48% (75.54%)	6.70% (101.68%)	0.88	0.07
TFL (% gait cycle)	111.93% (36.05%)	106.65% (23.07%)	5.28% (30.26%)	0.77	0.17
BF (% gait cycle)	111.31% (25.92%)	105.54% (25.63%)	5.77% (25.78%)	0.63	0.22
GMED (% gait cycle)	145.84% (50.11%)	130.38% (53.82%)	15.46% (52.00%)	0.57	0.30

*EMG = Electromyography; % gait cycle; GMAX = Gluteus maximus; VL = Vastus lateralis; TFL = Tensor fascia lata; BF = Biceps femoris; GMED = Gluteus medius.

** Mean values presented (standard deviation)

+ Significant differences between muscles of the healthy leg and the injured leg of injured runners

No significant differences in muscular activation were found (Figure 2) when comparing the muscles of the dominant leg of healthy female runners and the injured leg of injured female runners (Table 5).

Table 5. Parameters (mean ± standard deviation), % of gait cycle, EMG differences between injured female runners and healthy female runners.

	ITBS females	Healthy females	Differences	P-value	d
GMAX (% gait cycle)	126.79% (31.34%)	128.45% (31.34%)	1.66% (31.34%)	0.93	0.05
VL (% gait cycle)	211.59% (57.03%)	157.48% (57.03%)	54.11% (57.03%)	0.14	0.95
TFL (% gait cycle)	113.37% (19.57%)	92.44% (19.57%)	20.93% (19.57%)	0.10	1.07
BF (% gait cycle)	128.63% (36.91%)	107.66% (36.91%)	20.97% (36.91%)	0.35	0.57
GMED (% gait cycle)	130.14% (40.59%)	150.22% (40.59%)	20.08% (40.59%)	0.42	0.49

*EMG = Electromyography; % gait cycle; GMAX = Gluteus maximus; VL = Vastus lateralis; TFL = Tensor fascia lata; BF = Biceps femoris; GMED = Gluteus medius.

** Mean values presented (standard deviation)

+ Significant differences between muscles of the dominant leg of healthy female runners and the injured leg of injured female runners

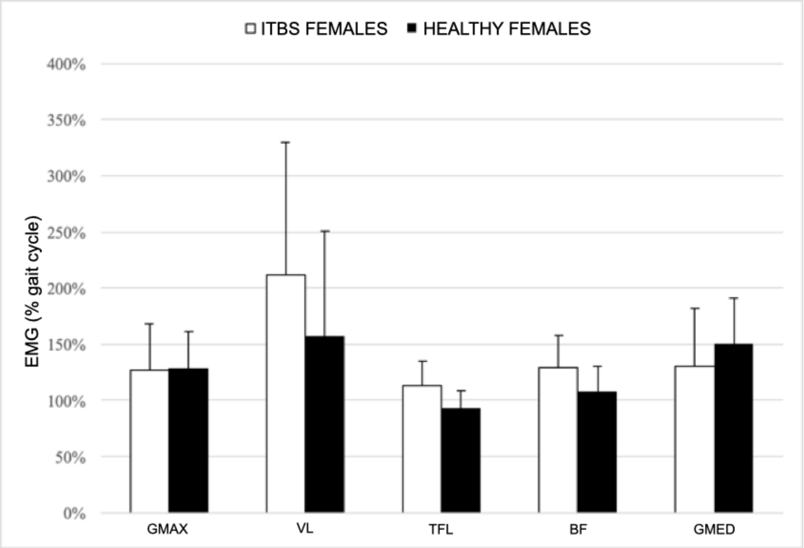

Figure 2. Muscular activation in injured and healthy female runners**.**

*EMG = Electromyography; % gait cycle; GMAX = Gluteus maximus; VL = Vastus lateralis; TFL = Tensor fascia lata; BF = Biceps femoris; GMED = Gluteus medius.

DISCUSSION

The aim of the present study was to determine differences in the muscle activation of the hip and thigh muscles between injured males and females with ITBS. Further, given that females are twice as likely to suffer from this condition[8], another aim was to determine differences in muscle activation of the hip and thigh muscles between injured females and those who were not injured at the time of being analysed. In this way, it was proposed that runners with ITBS would exhibit different EMG patterns to non-injured runners.

In contrast to our hypothesis, significant differences were not identified in the present study in the average EMG data recorded within a group with ITBS, when considering the independent variable of gender (Figure 1). Nonetheless, a difference was demonstrated in the comparison between the different muscles of individuals within each group. Only three previously conducted studies have examined muscle activation in the hip and thigh muscles of runners with ITBS[21,34,35]. A study carried out by Baker et al.[21] was performed with a sample of injured runners comprising both males and females. This makes comparisons with the present data difficult as we do not have individual gender groups available. In the cases of Brown et al.[34] and Foch et al.[35], female runners were analysed, however, no comparison between sexes was offered. With respect to sex and iliotibial band injury, to the present date no study has been identified which uses EMG to examine muscle activation in the injured leg relative to the non-injured leg. For this reason, we cannot compare these findings to those of the present study.

Previously, some authors examined differences between healthy runners and injured runners via kinematic analysis, concluding that the state of injury produces a kinematic alteration[14,25]. Thus, more research studies are needed into EMG and iliotibial band syndrome in order to be able to make conclusive statements on this topic.

In the comparison between muscles, a difference was found between sexes, producing a large effect size. In both injured males and females, the muscle with greatest activation was the VL. This could be due to the contact between the fascia of this muscle and the ITB. For this reason, this activation will be affected in patients with ITBS. On the other hand, comparisons relating to other muscles produced different outcomes for males and females, giving rise to small differences in the movement patterns according to gender. In females, the relationship between VL and TFL, and between VL and BF was significant and produced a large effect size. In males, a positive association was found between GMAX vs TFL and GMAX vs BF.

Data reported by the present study should be considered, however, with caution, above all at the time of proposing functional recovery stages for runners. Understanding the level of activation of determined muscles may give us an idea about how fatigue may affect different structures. Brown et al.[34] found that in the post-fatigue state, runners with ITBS demonstrated significantly lower initial mean frequency values than in the pre-fatigue state. Decreases in the magnitude of the mean initial frequency of injured runners suggests that the GMED muscle of runners with ITBS is less resistant to fatigue than that of their healthy counterparts. These outcomes underline the importance of resistance training for the GMED as a component of rehabilitation for runners.

With regard to the comparison between legs, no significant differences were found between the injured and uninjured leg, neither for males nor females with ITBS ($p > 0.05$). In the case of other conditions, such as anterior cruciate ligament (ACL) rupture, EMG differences between legs prior to and following operation have been analysed. This analysis found altered neuromuscular activity one year following ACL reconstruction, in comparison to the healthy leg[36].

Within existing research studies on iliotibial band injury, one of the main differences between the methodologies employed relates to the running surface. This factor may lead to it being difficult to compare the present findings with those of previously published research. This incompatibility in the comparison of running surfaces has now also emerged in the kinematic analysis of running technique. Authors such as Baker et al.[21], Miller et al.[11], Messier et al.[38], Noehren et al.[12] and Phinyomark et al.[14] opted for participants to perform the run on a treadmill. On the other hand, authors such as Foch et al.[22], Grau et al.[23], Grau et al.[24], Noehren et al.[13], Suárez et al.[25] and Suárez et al.[41] chose to conduct testing over ground as this is the most precise way to reproduce the habitual surface covered by recreational runners.

Authors such as Taunton et al.[8] state that female runners are twice as likely to suffer ITBS in comparison to male runners due to their anatomic and physiological make-up. The present results did not reveal any significant differences in the comparison between average EMG values of the selected muscles between healthy female runners and those suffering from iliotibial band injury (Figure 2). The onset of electromyographic activity, in addition to its duration, can be an important factor. This factor may be even more influential than average EMG in the evaluation of contributing factors in ITBS[35]. For example, Willson et al.[42] reported that the maximum peak and average EMG of the GMED did not differ between females with and without patellofemoral pain syndrome (PFPS). However, in uninjured runners, activation occurred 24 milliseconds before and lasted 2 milliseconds longer than in the case of healthy runners. In runners with ITBS, Foch et al.[35] did not find differences in either magnitude or duration of activation of the GMED between runners who had suffered an injury and those who were fully fit.

Previously conducted studies have examined the maximum strength of the hip muscles in runners with ITBS. Fredericson et al.,[31] attributed a weaker hip abduction strength in previously injured runners. On the other hand, Grau et al.[23] stated that hip abductor weakness did not seem to play any role in the aetiology of ITBS. In accordance with these results, Brown et al.[34] have shown that hip abductor strength in the injured extremity of runners with ITBS was not significantly different from a control group. These findings are consistent with other studies whose results found that no differences exist in the isometric or isokinetic force of runners with ITBS and healthy controls[13,22,23].

CONCLUSIONS

The present research suggests that no differences exist in the muscular activation patterns of determined muscles in male and female runners with ITBS. Differences were, however, found in the comparison between individual muscles, when considering injured females and comparing the muscle activation of the VL vs the BF and the VL vs the TFL. Further, differences were found in males when comparing the GMAX vs the TFL and the GMAX vs the BF. The differences were not established between the muscular activation patterns of the injured and the uninjured leg, in neither males nor females. When determining whether differences exist in the muscle activation of the hip and thigh muscles during hard-surface running, no differences have been found between healthy females and those suffering ITBS at the time of the present research. Outcomes of the present study are important for orienting ITBS treatment. It provides data to improve understanding of this injury and the status of this injury, assisting in treatment choices. EMG offers data to professionals, enabling them to widen the treatment zone from, not only the ITB itself, but also to other muscular structures. Such treatment could even include the leg that does not present any pain during the injury. In consideration of the results obtained, we recommend that specific work be conducted in relation to the VL, TFL and BF muscles of the injured leg in female runners, and the GMAX, TFL and BF muscles of the injured leg in the case of male runners.

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