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Acute and Chronic Effects of Exercise in Health

Isokinetic ankle muscle strength is reduced in recreational runners with medial tibial stress syndrome and is not associated with pain

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Abstract - Aim: The purpose of this study was to investigate the strength and ratios of the plantar flexors and ankle dorsiflexors in recreational runners with medial tibial stress syndrome and to assess the association between muscle strength and the level of pain in this population. **Methods:** Two groups (control and medial tibial stress syndrome) of eighteen runners each participated in this cross-sectional study. Isokinetic dynamometry was used to evaluate muscle strength, and for the analysis, the normalized isokinetic peak torque controlled by gender was used. **Results:** The medial tibial stress syndrome group showed lower normalized isokinetic peak torque in the dorsiflexors in the concentric ($p = 0.008$) eccentric ($p = 0.011$) contraction, as well as a lower plantar flexor, normalized isokinetic peak torque in the concentric ($p = 0.001$) and eccentric ($p = 0.02$) when compared to the control group. However, there was no difference in the normalized isokinetic peak torque ratio representative of the stance ($p = 0.62$) and swing phase ($p = 0.16$), and the level of pain was not correlated with the strength concentric ($p = 0.32$) and eccentric ($p = 0.621$) of plantar flexors, nor to the concentric ($p = 0.21$) and eccentric of dorsiflexors ($p = 0.54$). **Conclusion:** Recreational runners with MTSS showed decreased muscle strength in the sagittal plane of the ankle, no correlation with the level of pain, and no changing the ratio between plantar flexors and dorsiflexors.

Keywords: isokinetic, jogging, muscle strength, overuse injury, stress fractures.

Introduction

Running is one of the most popular physical activities, and the number of runners has increased considerably in recent years in Brazil and throughout the world[1]. Many people who seek a healthier lifestyle opt for running, mainly because it is considered a low-cost and easy-to-execute exercise[2]. However, runners are more likely to have numerous injuries, especially those involving the musculoskeletal (MSK) system, such as calcaneal tendinopathy, patellofemoral pain, iliotibial band syndrome, and plantar fasciopathy, and medial tibial stress syndrome (MTSS)[3]. MTSS affects 16% of recreational runners, making it the most frequent incident in this population[3], representing 15% of all injuries among recreational runners[4].

MTSS is defined as physical exercise-induced pain along the medial tibial border (MTB), and it is identified by painful palpation of at least five consecutive centimeters of the MTB[5]. Although MTSS etiology is not precisely known[6,7], it is considered an overuse condition resulting from an injury due to tibial bone overload with associated periostitis. It is commonly diagnosed in individuals participating in recurrent impact exercises, such as running, walking, and jumping[8].

Considering that MTB is the region adjacent to the path of the plantar flexors and dorsiflexors as well as the site of pain complaints in MTSS[9,10], interactions between these factors are likely, such as a decrease in muscle strength of plantar flexors, because the MTB is a place for insertion of bundles of the soleus muscle[11].

Pain, as in other MSK disorders, is the main clinical symptom in MTSS[5], and it is known that its presence is an important mediator in muscle performance. Individuals with pain, on average, have been shown to produce less muscle strength compared to healthy controls[12]. Several physical and psychological mechanisms are used to explain the interaction between painful MSK pathologies and muscle strength[13]. However, there are MSK pathologies that do not follow this pattern, such as neck pain[14] and iliotibial band syndrome[15]. The impact on levels of muscle strength caused by MTSS is still relatively unknown. To the best of our knowledge, only one study has evaluated ankle muscle strength in the sagittal plane in individuals with MTSS, but it did not assess the relationship between pain symptoms and muscle strength[16]. Thus, understanding how MTSS can compromise ankle muscle strength and its relationship to pain is essential for the development of interventions that seek to rehabilitate recreational runners.

In the context of this previous research, the current study aims to evaluate 1) the isokinetic strength of the ankle dorsiflexors and plantar flexors in recreational runners with MTSS; 2) the ratio between ankle dorsiflexor and plantar flexor strength, and 3) the relationship between muscle strength and pain levels. We hypothesized that runners with MTSS would present weaker ankle dorsiflexors and plantar flexors, as well as asymmetries in the ratio between plantar flexors and dorsiflexors compared to runners without the syndrome, and there would be a correlation between muscle strength and pain.

Methods

Design

This cross-sectional study of a quantitative and analytical nature was performed in accordance with the recommendations of the Declaration of Helsinki and approved by the relevant research ethics committee under protocol number 2.430.845, and informed consent was obtained from all participants. The collections were completed between September 2018 and March 2019.

Participants

The following individuals were included: 1) recreational runners of both genders; 2) those aged 18 years or older, and 3) those diagnosed with bilateral MTSS according to the criteria of Yates and White[5]. Recreational runners were defined as those with a regular practice of running at least twice a week (running 30-350 kilometers per month in the last three months)[18-20].

We excluded individuals with the following: 1) previous history of surgery or injuries in the lower limbs in the last six months (besides MTSS); 2) use of prostheses for the lower limbs; or 3) presence of neurological and/or vascular diseases in the lower limbs[17]. Seventy-two ankles belonging to 36 individuals were evaluated; 18 runners made up the MTSS group, and 18 runners with the same inclusion criteria but without MTSS made up the control group.

Diagnosis of MTSS and pain assessment

Participants received a detailed physical examination, as established by Yates and White[5], to diagnose MTSS. The criteria included 1) pain along at least five consecutive centimeters of the MTB; 2) pain induced by physical exercise that persisted even after interruption; and 3) pain with the absence of paresthesia or irradiation to other regions. A Visual Analog Scale (VAS) for pain was used to record the level of pain right before the isokinetic strength test.

Physical characteristics and level of physical activity

Participant data were collected using a two-section structured form produced by the authors. The first section contained questions about the volunteer's anthropometric characteristics (i.e., age, gender, body mass index (BMI), weight, and height), and the second one contained data on the running practice (i.e., frequency, time spent, and monthly distance covered)[17]. Anthropometric height and weight data were collected following the protocol of Marfell-Jones et al. [21]. The BMI was calculated from the measures of weight and height by using the following formula: BMI = weight (kg)/(Height)^2 (m).

Evaluation of isokinetic muscle strength

The Biodex System 4 Pro® isokinetic dynamometer (Biodex Medical Systems, Shirley, NY, USA) was used to evaluate the peak torque of the ankle dorsiflexor and plantar flexor muscles. PT is affected by several factors, including age, gender, dominant limb, weight, height, fat index, and abdominal circumference[22]. Thus, to minimize anthropometric interference, the normalized isokinetic peak torque by bodyweight (NPT) was adopted, as it is a more reliable variable exclusive to each evaluated[23].

Before the tests, the participants warmed up for five minutes on an ergometric bicycle (with a comfortable resistance and a cadence without causing fatigue between 60 and 70 revolutions per minute)[24]. Each volunteer was positioned according to the Biodex System 4 Pro® manufacturer's manual for evaluating ankle dorsiflexor and plantar flexor muscle strength. The ROM was determined for each individual by active traction of the plantar dorsiflexors and plantar flexors up to the joint limit[25]. Each participant's leg mass was then measured, correcting for gravity with Biodex software. The dynamometer was calibrated at the beginning of each testing session.

Five repetitions at 60°/s angular velocity were used to record NPT in the concentric/eccentric and eccentric/concentric modes for ankle dorsiflexion and plantar flexion. These parameters are considered the most appropriate for recording muscle strength[26]. Before each contraction mode, the participants performed five submaximal repetitions to familiarize themselves with the test, with 60 s of rest between the repetitions[27]. All tests were bilateral and standardized, and the order of the evaluated members was randomly defined. During the tests, volunteers were instructed with verbal engagement to maintain maximum strength during contractions[27].

Based on muscle groups with the longest use during running, we decided to calculate two types of ratios between plantar flexors and dorsiflexors to represent the same muscle actions between the ankle flexors and extensors during the swing and stance phase of the running cycle. The first ratio was DFconc/PFecce (concentric dorsiflexion divided by eccentric plantar flexion), which measured the muscle contractions during the swing phase of the running cycle, and the second ratio was PFconc/ DFecce (Concentric plantar flexion divided by eccentric dorsiflexion), which provided the stance phase of the running cycle[28].

Sample size

The Researcher's Tool Kit was used to calculate the sample size (https://www.dssresearch.com/resources/calculators/sample-size-calculator-average-size-calculator-average)[29]. The sample was calculated for a significance level of 0.05 and power of 0.80 to detect a difference in a plantar flexion peak torque of 8 Nm, with a standard deviation of 28.2[16]. Based on these criteria, at least 18 individuals per group were required.

Statistical analysis

The data distributions of normality were evaluated by the Shapiro-Wilk test. The results were summarized in means, standard deviations (SD), percentages, and frequencies. The primary outcome assessed was the NPT using the Analysis of Covariance (ANCOVA) controlled by gender, kilometers run daily, and kilometers accumulated in the last 3 months, which was presented with differences between the groups and their 95% confidence intervals. Gender control was necessary because torque production between men and women is significantly different for ankle muscles[30], as well as the control of distances run to minimize the impact of the advantage of more trained individuals[31]. The Pearson correlation coefficient calculation was used to test the relationship between pain level and NPT.

All inferential analyses were performed with the Statistical Package for the Social Sciences software (SPSS Version 25.0. IBM Inc., Chicago, IL USA) and a significance level set at 5% ($p < 0.05$).

Results

A total of 36 runners (72 ankles) were evaluated in this study, and their characteristics were recorded (Table 1).

In the analysis of the mean NPT measured at 60°/s angular velocity (Table 2), runners with MTSS presented a lower mean NPT than the controls for ankle dorsiflexor

Table 1 - Participants 'anthropometric and training characteristics

Characteristics	Control (n = 18) Mean (SD)	MTSS (n = 18) Mean (SD)	p-value
Age (years)	33.2 (13.66)	27.6 (7.40)	0.138
Height (m)	1.62 (0.08)	1.67 (0.09)	0.06
Weight (kg)	62.3 (9.01)	67.8 (9.94)	0.091
BMI (kg/m^2)	23.6 (2.11)	24.1 (2.74)	0.527
Female (%)	44.4	66.6	0.19
Right-handed (%)	100	94.4	1
Pain VAS	-	7.69 (1.47)	-
Weekly frequency (days)	4.25 (1.29)	4.05 (1.55)	0.686
Daily distance (km)	6.05 (2.23)	4.45 (1.41)	0.015*
Daily time (minutes)	32.11 (9.88)	44.58 (32.5)	0.134
Total distance in previous three months (km)	302.76 (185.63)	193.83 (89.9)	0.032*

Table 2 - Comparison of means of normalized isokinetic peak torque between MTSS and control group

Variables	Control (n = 18) Mean (SD)	MTSS (n = 18) Mean (SD)	Mean difference (CI 95%)	p-value
Dorsiflexors (60°/s)				
Concentric				
Normalized Peak Torque (Nm/kg)	37.49 (10.44)	23.48 (10.13)	14.01 (3.82 to 24.19)	0.008*
Eccentric	69.99 (35.72)	47.46 (28.68)	22.52 (5.28 to 39.76)	0.011*
Normalized Peak Torque (Nm/kg)				
Plantar flexors (60°/s)				
Concentric				
Normalized Peak Torque (Nm/kg)	59.58 (27.91)	39.68 (17.98)	19.89 (8.03 to 31.75)	0.001*
Eccentric				
Normalized Peak Torque (Nm/kg)	95.46 (39.41)	73.14 (34.31)	22.32 (2.87 to 41.77)	0.02*

MTSS: Medial Tibial Stress Syndrome; SD: Standard Deviation; Nm/Kg: Newton meter per kilogram; CI 95%: Confidence Interval of 95%; *$p < 0.05$ According to Ancova.

muscle strength in the concentric (p = 0.008) and eccentric phases (p = 0.011), and lower NPT for ankle plantar flexor muscle strength in the concentric (p = 0.001) and eccentric phases (p = 0.02).

There was no significant difference between groups regarding the isokinetic NPT ratios for the stance and swing phases (Table 3).

There was no correlation between pain level and NPT of concentric plantar flexion (p = 0.32, r = 0.16), eccentric plantar flexion (p = 0.63, r = −0.08), concentric dorsiflexion (p = 0.21, r = −0.21), and eccentric dorsiflexion (p = 0.54, r = −0.10) (Figure 1).

Table 3 - Ratios between normalized isokinetic peak torque of dorsiflexors and plantar flexors.

Isokinetic strength ratios	Control (n = 18)	MTSS (n = 18)	Mean difference	p-value
	Mean (SD)	Mean (SD)	(CI 95%)	
DFconc/PFecce (Swing)	0.38 (0.15)	0.29 (0.15)	0.8 (-0.03 to 0.21)	0.161
PFconc/DFecce (Stance)	0.9 (0.27)	0.96 (0.39)	-0.06 (-0.31 to 0.18)	0.621

MTSS: Medial Tibial Stress Syndrome. SD: Standard deviation. CI 95%: Confidence Interval of 95%. DFconc: Concentric dorsiflexion. PFecce: Eccentric plantarflexion. PFconc: Concentric plantar flexion. DFecce: Eccentric dorsiflexion.

Discussion

This study investigated the muscle strength levels of the ankle dorsiflexors and plantar flexors in recreational runners with MTSS compared to runners without MTSS; the relationship between the level of pain and muscle strength was also examined. Thus, the isokinetic NPT of the plantar flexors and ankle dorsiflexors was evaluated. The results showed a difference in NPT between both groups, without changing the strength ratio between the agonist/antagonist muscles, and such differences in ankle strength seem to be unrelated to pain levels.

To the best of our knowledge, one study in the scientific literature has compared the strength of ankle muscle groups in the sagittal plane in individuals with and without MTSS[16], showing that the strength of the dorsiflexors and plantar flexors of individuals with MTSS was not different from that of controls, which diverges from the findings observed in this research. However, Saeki et al.[16] study

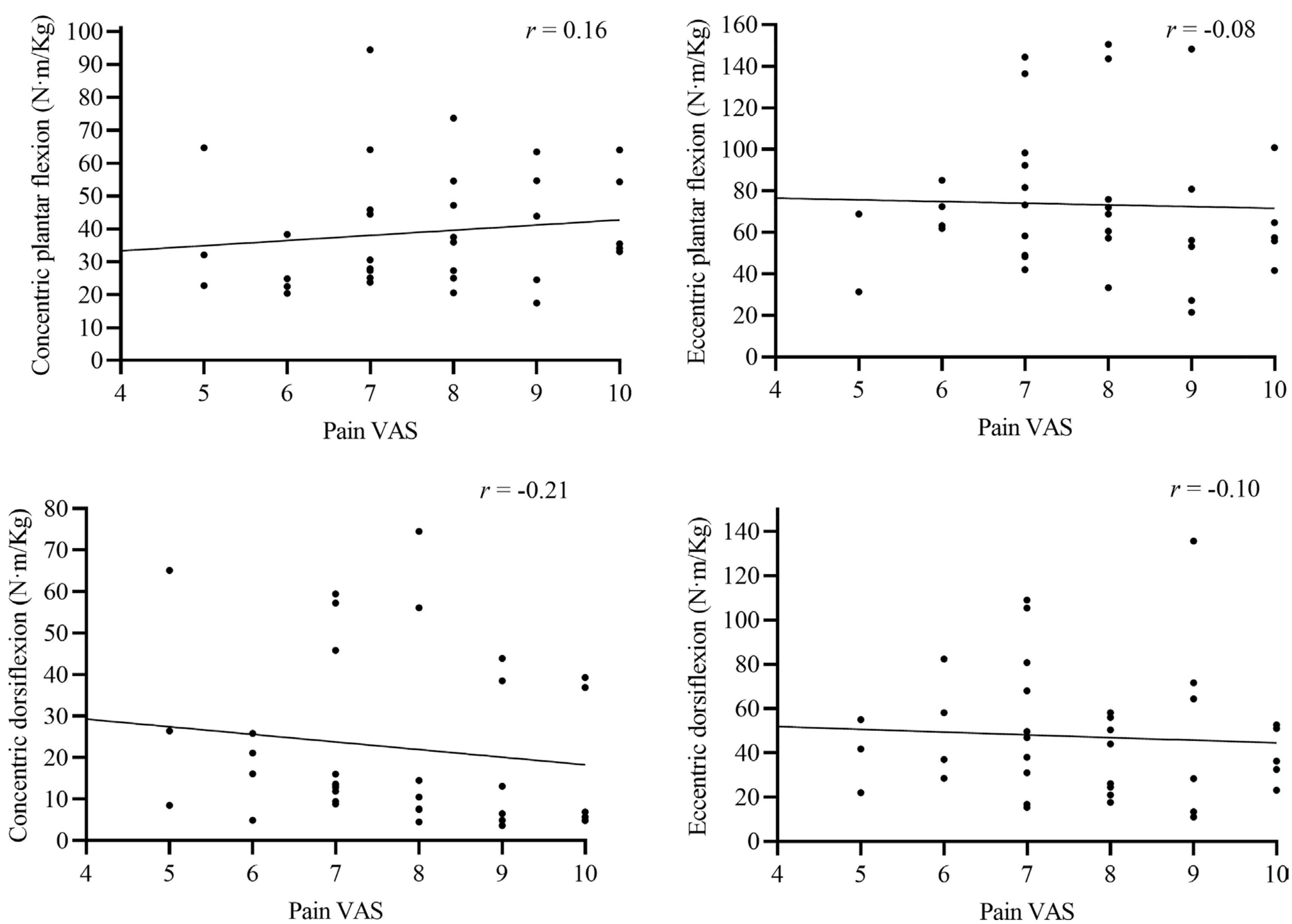

Figure 1 - Correlation results between pain and normalized isokinetic peak torque of medial tibial stress syndrome group for ankle flexors and extensors.

presented methodological differences, especially in data acquisition, compared to the present study. The authors collected only one isometric ankle muscle strength measure[16], neglecting the concentric and eccentric contractions, which could have repercussions for the lack of precision in the measurement, and this measure may be insufficient to adequately analyze a dynamic motor task such as running[32].

The main clinical complaint in runners with MTSS is a pain in the tibia region. In this study, the high pain levels of 7.69 (SD 1.47) in recreational runners with MTSS called our attention. Similar average levels of pain have been reported for individuals with the syndrome in other studies, ranging from 7.0[33], 8.0[34], and up to 8.2[35].

Although pain probably has an important role in muscle strength, our findings suggest that there are other mechanisms to explain the decreased muscle strength in the sagittal plane of the ankle joint in runners with MTSS. An alternative explanation for the decreased muscle strength may be due to the increased stiffness of the ankle muscles in the sagittal plane[36], and more stiff muscles are less able to generate muscle strength[37]. Although our study did not measure muscle stiffness, we believe that this factor may explain the results of our research.

Ratio between plantar and dorsiflexors

During the swing phase of running, the dorsiflexors muscles exert a predominantly concentric contraction, and the plantar flexors perform a slight eccentric contraction, resulting in the DFcon/FPecce ratio. In the stance phase, the plantar flexors generate concentric force with a slight eccentric force of the dorsiflexors at the end of the phase, resulting in the FPcon/DFecce ratio[28,38]. Therefore, it seems more appropriate, and in our view strength of this study, that the isotonic contractions of muscles acting in the sagittal plane of ankle joint movements were investigated, as we were then evaluating the same strength ratios that occur during a normal running cycle.

The results showed that although runners with MTSS exhibited significant weakness in the sagittal plane muscles of the ankle, the strength ratio between agonist/antagonist muscles was not different from the same ratio found in healthy runners, suggesting that the dorsiflexors and plantar flexors are similarly affected in MTSS. Considering the significant weakness of the dorsiflexor and plantar flexor muscles observed in the MTSS group and the lack of studies on this relationship[39,40], we suggest that future investigations assess the impact of muscle strength in the sagittal plane of the ankle as a risk factor for MTSS and the effects of strengthening training for this muscle group on MTSS rehabilitation process.

Our findings support the assessment and monitoring of muscle strength in the sagittal plane of the ankle during the rehabilitation process of runners with MTSS, which can be important for the full recovery of the injury and for returning to sports practices.

Our research has some limitations, one of which may be the positioning of the participants indicated by the isokinetic dynamometer manual. This is because the position to assess the plantar flexor peak torque-knee flexion at 30°-is one that partially shortens the gastrocnemius muscles, meaning they do not have a full capacity to produce torque. This joint position ensures the ability to produce maximum torque only for the soleus muscle. Another possible limitation of this study is that the pain levels were measured using an analog pain scale, which is considered an extremely subjective assessment tool. In addition, pain levels were measured only before the assessment of muscle strength, which may have caused a change in pain levels during the assessment[27]. Finally, considering the differences in baseline between groups, we controlled the results for gender, kilometers run daily, and kilometers accumulated in the last three months, however, it is not possible to guarantee that the influence of these variables was fully mitigated.

Conclusion

Our study showed that recreational runners with MTSS have a significant reduction in muscle strength in the ankle flexor and extensor muscles when compared with controls without the syndrome. The observed decrease in strength did not change the ratio between the plantar flexors and dorsiflexors, and no correlation between the level of pain and muscle strength was found. Future investigations may clarify whether the reduction in muscle strength of plantar flexors and dorsiflexors is a cause or consequence of MTSS.

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