Assessment of the effect of inversion ankle sprain on the velocity capabilities of the dorsal and plantar flexors of the foot in a group of women

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Abstract

Background: The ankle joint, also known as the talocrural joint, classified as a hinge synovial joint, is formed by the complex articulation of the ankle, tibia, and fibula. The tripartite junction of the ankle, tibia, and fibula combine to form the ankle joint, which demonstrates the complexity of the human skeletal system. Up to 30% of all sports injuries are injuries to the ankle joint, and ankle sprains account for up to 70% of all injuries.

Aims: This study aimed to assess the effect of inversion talocrural joint (ankle joint) sprain on the velocity capabilities of the soleus and dorsiflexor muscles of the feet in a group of women.

Material and methods: The study group consisted of 33 young women. The experimental group consisted of 16 women with a history of inversion ankle sprain injury, while the control group consisted of 17 women without ankle sprain injury. All participants were tested using the ZPS4-U "JBA STANIAK" force measurement set.

Results: In our study, the mean values of the maximum force gradient increase (MFGI) in the control group were higher for the dorsal flexors by approximately 13% compared to the plantar flexors. Variables characterizing the MFGI within the control and experimental groups and in intergroup analyses showed no significant statistical differences ($p>0.05$).

Conclusions: Inversion sprain of the ankle joint does not affect the achieved velocity capabilities of the dorsal and plantar flexors of the foot in the study group of women. Taking into account the parameters analyzed, no statistically significant differences were found.

Key words

ankle joint, talocrural joint, inversion ankle sprain, dorsal flexors, plantar flexors, velocity rate, maximum force gradient increase.

Introduction

The ankle joint, also known as the talocrural joint, classified as a hinge synovial joint, is formed by the complex articulation of the ankle, tibia, and fibula. This unusual convergence of skeletal elements culminates in the formation of the so-called ankle joint. The ankle joint shows the complexity of anatomical cooperation, serving as a prime example of how synergy between bones can provide a finely tuned mechanism for movement and stability. The tripartite junction of the ankle, tibia, and fibula combine to form the ankle joint, which demonstrates the complexity of the human skeletal system [1].

The primary actions exhibited by the ankle joint complex encompass plantarflexion and dorsiflexion, manifesting within the sagittal plane. Abduction and adduction motions occur within the transverse plane, while inversion and eversion movements transpire in the frontal plane. Through intricate interplays of these motions across both the subtalar and tibiotalar joints, a remarkable spectrum of three-dimensional movements emerges, denoted as supination and pronation. These terms encapsulate the orientation of the plantar surface of the foot. Supination is characterized by a concerted interplay of plantarflexion, inversion, and adduction. This harmonized trio of actions collaborates to orient the sole medially, showcasing a finely tuned coordination that marks this particular foot position. On the other hand, the phenomenon of pronation entails the orchestration of dorsiflexion, eversion, and abduction. This orchestrated blend of movements culminates in repositioning the sole to face laterally, illustrating a distinct anatomical arrangement [2].

According to statistical data, currently, 10% to 30% of all sports injuries are injuries to the ankle joint, and sprains of this joint account for up to 70% of all injuries, of which about 85% of these injuries are inversion sprains of the ankle joint [3-5]. Biomechanical research in sports and physiotherapy uses the characteristics of muscle velocity characteristics as a clinical indicator [6]. The characteristics of the variables provide information about the dynamic capabilities of muscles [7,8].

Aims

This study aimed to assess the effect of inversion talocrural joint (ankle joint) sprain on the velocity capabilities of the soleus and dorsiflexor muscles of the feet in a group of women.

Material and methods

Study participants

The study included 33 young women. The experimental group consisted of 16 women with a history of inversion ankle sprain injury, while the control group consisted of 17 women without ankle sprain injury.

Qualification criteria

Inclusion criteria for the experimental group were an ankle joint sprain sustained in one lower limb not earlier than one year prior to the study and individual consent from the participants to measure the velocity capabilities of the dorsal and plantar flexor muscles of the foot. A history of other orthopedic injuries, or congenital defects, or neurological conditions in the lower limbs, which could affect the results of the planned measurements, was considered an exclusion criterion for the study. Information on eligibility and exclusion from the study was obtained from a questionnaire. The study in the control group was conducted among women who met the study eligibility criteria: no history of trauma in the ankle joint area or other joints of the lower limbs, no neurological conditions, orthopedic conditions, or congenital defects in the lower limbs that could affect the results of the planned measurements.

Study protocol

The study procedure for qualified subjects in both groups included measurement of body weight and height. This was followed by testing the velocity capabilities of the dorsal and plantar flexors of the foot on a purpose-built measuring station.

The measuring station consisted of an adjustable seat, stabilization belts, and a ZPS4-U force measuring set on a stabilization frame. The measuring station was properly connected and configured with a computer equipped with the MAX version v. 6.0 "JBA STANIAK" measurement program. Before the test, each study participant performed a 5-minute standard warm-up of the lower extremities, considering the muscle groups involved in the experiment. The female subjects were informed about the purpose and course of the study. They were also instructed about the possibility of opting out of the study.

The subject assumed a seated position on the measuring station with a 90^{o} angle between the torso and thigh, thigh and lower leg, and lower leg and foot. After the seat was properly positioned and adjusted in height, the hip, knee, and ankle joints were stabilized with straps to prevent joint movement and eliminate the participation of other muscles serving the other joints of the lower limbs. A non-stretchable, adjustable brace was placed on the forefoot. An electronic dynamometer was installed on the brace between the foot and the frame of the test stand. The dynamometer's cable was positioned perpendicular to the axis of rotation at the ankle joint. Each measurement was preceded by calibration of the system, which consisted of determining the zero-stress level of the dynamometer after considering its own weight and mounting system.

The measurement was carried out under static conditions, in isometric contraction of the dorsal and plantar flexors of the foot, after first assuming the measuring position and stabilizing the foot from the calcaneal tuberosity. During the measurement of the velocity capabilities of the dorsal and plantar flexors of the foot, the task of the subjects was to perform the dorsal and plantar flexion movements of each foot as quickly as possible. The measurement was made at a frequency of 1000 Hz. Due to the fact that the feet were immobilized during the measurement, the result was a graph of the rate of force increase as a function of time during isometric contraction, which illustrated the recruitment rate of muscle motor units during the achievement of maximum force. Maximum rapid muscle concentration was immediately followed by its relaxation.

Measurement of the velocity capabilities of the foot muscles was carried out five times for dorsiflexion and plantarflexion with short 3-second breaks used to relax the muscles before the next measurement. The measurements were short-term and painless for the female study participants. A graph of the derivative of force versus time obtained during each contraction was then generated, and the highest values were read. The highest value of the force derivative among all five trials was selected for analysis.

$$MFGI = maxFm(t)dt$$

where, MFGI indicates maximum value of the derivative of the force with respect to time on the graph of the developing force in the function of time (maximum force gradient increase).

Statistical analysis

The obtained results of the study were archived and then statistically analyzed using Statistica v.12. The normal distribution of the studied parameters in the control group and the experimental group was checked using the Shapiro-Wilk test. The equality of variances of the variables in the groups was estimated using Levene's test. Elements of descriptive statistics were used to describe statistically the various parameters obtained in the study. In the case of variables characterized by the absence of a normal distribution, the value of the median and the quarterly deviation were calculated. A significance level of $p<0.05$ was adopted for the data analysis. For variables meeting the assumption of normality of the distribution of individual results in groups and homogeneity of variance to determine the significance of differences between the means, one-way ANOVA was used to verify the null hypothesis (H0), assuming no differences in the mean level of the variable in groups against the alternative hypothesis (H1) that there are differences. On the other hand, if the assumption of normality of the variable's distribution was not met, the non-parametric Kruskal-Wallis test with Dunn's post-hoc test was used to determine the significance of differences between the mean values. In the case of obtaining significance of differences in the Fridman test (ANOVA) $p<0.05$, pairs of variables with statistically significant differences between the means were sought using Tukey's post hoc test.

Results

In the original research study presented, an attempt was made to assess the velocity capabilities of the dorsal and plantar flexors of the foot. The results of subjects after inversion sprain of the ankle joint were analyzed, and they were compared to the results of healthy female subjects without lower limb injury.

In our study, the mean values of the maximum force gradient increase (MFGI) in the control group were higher for the dorsal flexors by about 13% compared to the plantar flexors. The highest mean MFGI value was obtained for the left dorsal flexor of the foot and was 21% higher than the lowest mean value obtained for the right plantar flexor. In the experimental group, the mean MFGI values were almost at the same level for the plantar and dorsal flexors of the foot. The highest mean MFGI value in the experimental group was obtained for the plantar flexor of the foot without a history of ankle sprain injury and was 11% higher than the lowest value obtained for the plantar flexor of the foot without a history of ankle sprain injury. The mean MFGI values for the plantar flexors in the experimental group were 11% higher in the lower limb without injury compared to the lower limb with injury. In contrast, the mean MFGI values for the dorsal flexors of the foot were at the same level in both cases.

The mean MFGI values of the dorsal flexors of the foot obtained in the control group were 14% higher than those of the analogous muscle group in the experimental group. In turn, the mean MFGI values for the plantar flexors of the foot in the experimental group were 2% higher than those of the analogous muscle group of the control group. Based on our study, there were no statistically significant differences found for the mean MFGI values.

Discussion

There is still a lack of reports in the literature concerning studies on the maximum force gradient increase (MFGI) of the muscles of the ankle joint of the foot. Research on the velocity capabilities of the plantar and dorsal flexor muscles is very limited.

A normative base of velocity capabilities appears to be necessary, which could increase the diagnostic effectiveness of isometric measurements and, at the same time, allow comparisons to be made against a population of healthy people and in the period of best physical fitness. Accurate analysis of variables can be used in physiotherapy and sports physiology to assess a person's velocity capabilities. The results of the measurements can also help in selecting physiotherapy methods and measures protecting the musculoskeletal system to avoid similar injuries in the future.

Conclusions

Variables characterizing the maximum force gradient increase (MFGI) within the control and experimental groups and in intergroup analyses showed no statistically significant differences.

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