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Comparison of strength and proprioception parameters between subjects with and without functional ankle instability

Comparação dos parâmetros de força e propriocepção entre indivíduos com e sem instabilidade funcional de tornozelo

Comparación entre los parámetros de fuerza y propiopercepción entre sujetos con y sin inestabilidad funcional del tobillo

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ABSTRACT | After an ankle sprain 40% of individuals continue to report a sensation of joint instability that is related to musculoskeletal dysfunction called functional ankle instability (FAI). However, a mechanism like this musculoskeletal dysfunction occurs remains unknown. In this sense, the knowledge of musculoskeletal changes that occur in individuals with FAI may be an important factor to plot more effective preventive interventions. Thus, the aim of this study was to compare peak torque (PT) concentric inversion (INV) and eversion (EVE), conventional ratio (EVE/INV) and passive joint repositioning in individuals with and without FAI in recreational athletes females. The sample consisted of 22 volunteers aged 18-25 years who were divided into control group and the group with FAI. The torque rating was performed on an isokinetic dynamometer with five maximal concentric contractions at speeds of 60 and 120 graus·s^{-1} in INV and EVE movement and passive joint repositioning to target angle of 10° and 20° of inversion. PT data, conventional ratio and average absolute error of the target angle were analyzed. Statistical analysis was performed using the Student t-test for independent samples. Found that individuals with LFS showed decreased evertor strength compared to control subjects, as well as unbalanced muscle ratio, which may increase the susceptibility of this group to ankle sprains.

Keywords | Ankle Joint; Ankle Injuries; Joint Instability; Torque; Proprioception.

RESUMO | Após a entorse de tornozelo, 40% dos indivíduos continuam a relatar uma sensação de instabilidade articular que está relacionada à disfunção músculo-esquelética denominada instabilidade funcional do tornozelo (IFT). Contudo, o mecanismo como ocorre esta disfunção músculo-esquelética ainda permanece desconhecido. Nesse sentido, o conhecimento das alterações músculo-esqueléticas que ocorrem em indivíduos com IFT pode ser um fator importante para traçar intervenções preventivas mais efetivas. Dessa forma, o objetivo deste estudo foi comparar o pico de torque (PT) concêntrico de inversão (INV) e eversão (EVE), a razão convencional (EVE/INV) e o reposicionamento articular passivo em indivíduos com e sem IFT em atletas recreacionais do gênero feminino. A amostra foi composta por 22 voluntárias na faixa etária entre 18 e 25 anos que foram divididas em grupo controle e grupo com IFT. A avaliação do torque foi realizada em um dinamômetro isocinético com cinco contrações máximas concêntricas a velocidades de 60 e 120 graus·s^{-1} no movimento de INV e EVE e reposicionamento articular passivo com ângulo-alvo de 10° e 20° de inversão. Foram analisados os dados de PT, razão convencional

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e média do erro absoluto do ângulo-alvo. A análise estatística foi feita com o teste *t-Student* para amostras independentes. Foi encontrado que indivíduos com IFT apresentaram diminuição da força eversora comparados aos indivíduos controle, bem como desequilíbrio da razão muscular, que podem aumentar a predisposição deste grupo a entorses de tornozelos.
Descritores | Articulação do Tornozelo; Traumatismos do Tornozelo, Instabilidade Articular, Torque, Propriocepção.

RESUMEN | Después del esguince de tobillo, el 40% de los sujetos siguen informando que hay una sensación de inestabilidad articular que se relaciona con la disfunción del musculo-esquelética llamada inestabilidad funcional del tobillo (IFT). Sin embargo, todavía no se conoce el mecanismo que es responsable por esta disfunción musculo-esquelética. En este sentido, el conocimiento de las alteraciones musculo-esqueléticas que ocurren en personas con IFT puede ser un factor importante para planear intervenciones preventivas más eficaces. De esta manera, esta investigación tiene como objetivo comparar el momento de torque (PT) de inversión concéntrica (INV) y eversión (EVE), la razón convencional (EVE/INV) y el reposicionamiento pasivo de las articulaciones en personas con y sin IFT en atletas recreacionales del género femenino. La muestra está compuesta por 22 voluntarios en la franja etaria entre 18 y 25 años, los cuales se dividieron en un grupo control y un grupo con IFT. La evaluación del torque se realizó en un dinamómetro isocinético con cinco contracciones máximas concéntricas con velocidades de 60 y 120 grados.s-1 en un movimiento de INV y EVE y reposicionamiento pasivo de la articulación con ángulo objetivo de 10° y 20° de inversión. Se analizó los datos del PT, de la razón convencional y la media del error absoluta del ángulo objetivo. Para el análisis, se utilizó la prueba t-Student para muestras independientes. Si comparados con las personas control se observó que las personas con IFT presentaron una disminución de la fuerza eversora y también un desequilibrio de la razón muscular, lo que puede aumentar la susceptibilidad de éstos a los esguinces de tobillos.
Palabras clave | Articulación del Tobillo; Traumatismos del Tobillo; Inestabilidad de la Articulación; Torque; Propiopercepción.

INTRODUCTION

The recent growth of interest in sports has seen a complementary increase in the frequency of sports injuries[1,2]. Lateral ankle sprains are among the most frequent injuries that occur as a result of sporting activities[3,4]. This type of injury can represent about 12-30% of the total number of injuries sustained during basketball, volleyball and handball[5,6]. The high incidence of lateral ankle sprains in sports occurs mainly due to the biomechanical sporting movements involved during jumping, running and direction changing movements[7].

Following an ankle sprain, about 40% of individuals continue to report a sensation of joint instability. This symptom can be present even when there is no loss of passive mechanical retention (ligament rupture). This musculoskeletal disorder, characterized by there being a sensation of joint instability, is known as functional ankle instability (FAI)[8-10]. In theory, one possible explanation for FAI is that, after an ankle sprain, there is joint edema, which presses the proprioceptive joint structures and leads to changes in neuromuscular control (arthrogenic inhibition). Thus, these neuromuscular changes might result in the inhibition of stabilizing muscles (for example the short and long fibular muscles), which would lead to a chronic loss of proprioception and muscle atrophy[24].

In this sense, FAI, besides being characterized by the loss of ability to recover static support and joint dynamic (tendency of the foot to "distort"), can present the following signs and symptoms: impaired joint proprioception, recurring lateral ankle sprains, deficiencies in functionality, reduced neuromuscular control, deficiencies in the strength of the fibular muscles and an imbalance in muscle strength between the inverters and evertors[8,10,11].

Previous studies have compared neuromuscular function (strength and proprioception) in individuals with and without FAI[9,13,15,20,21]. However, despite this theme having been well explored in the literature, neuromuscular factors that compromise the stability and function in individuals with FAI have not yet been well established[12]. In a study by Sekir (2007), concentric contractions of inversion and eversion were performed at a speed of 120°/s among individuals with and without FAI and there was found to be a lower strength of inverters in the group of unstable individuals. Whereas in study by Kaminsky[25], no difference was verified between individuals with and without FAI in concentric contractions of eversion at 60°/s. Therefore, no agreement exists regarding muscle weakness that is associated to FAI[9].

Considering that the frequency of sports injuries has grown over the past few years, due to the increasing number of people undertaking sporting exercises and sports such as handball, volleyball and basketball having resulted in a high frequency of lateral sprain injuries, the aim of this study was to compare the performance of recreational athletes with and without FAI in inverter and evertor strength, as well as the EVE/INV ratio and proprioceptive capacities of passive joint repositioning, the purpose of which to assist in the understanding in this matter and search for normative values for these populations. Thus, the hypothesis is that healthy individuals have greater inverter and evertor strength, suitable muscle balance and better proprioception when compared with individuals with FAI.

METHODOLOGY

There were 22 female volunteers who participated in the study; these were basketball, handball and volleyball players aged between 18-25 years (Table 1). The volunteers were divided into two groups: the control group (CG), made up of 11 participants with no history of ankle injury in the six months previous to the study, who showed no clinical signs of mechanical instability during the anterior drawer and talar tilt tests, and who had a score higher than 25 points in the *Cumberland Ankle Instability Tool* questionnaire (CAIT – Brazilian version); and the group with functional ankle instability (IG), which was made up by 11 volunteers with no history of inversion sprain injury in the three months previous to the study, who showed no clinical signs of mechanical instability during the anterior drawer and talar tilt tests and scored less than 25 points in the CAIT questionnaire[17]. The sample size was obtained through G*Power 3.0 software. The speed of 120°/s, obtained in a pilot study (power = 0.95, effect size = 1.5 and error α = 0.05), was considered for calculating the peak torque in inversion data. This study was approved by the Brazilian *Committee of ethics in Local Research* (protocol no. 1217/2011), and all volunteers signed an informed consent form.

Data collection procedures were performed over two days. The first day involved applying the anamnesis from the CAIT questionnaire for both ankles, thereby determining the dominance of the lower limbs and the volunteers' familiarization with isokinetic contractions.

During the anamnesis, the volunteers were questioned about their injury history in recent years and their physical activity frequency. They should have a weekly session of volleyball, handball or basketball lasting at least 3 hours. These activities were chosen as they present a high frequency of ankle sprains when compared to other injuries that occur in these sports, and also as jumping is a prevalent movement in their undertaking[26].

Table 1. Sample characterization

	GC (n=11)	GI (n=11)	p
Age (years)	21.18±2.67	21.54±2.54	0.508
BMI (kg.m^{-2})	22.90±2.32	23.97±2.65	0.142
Questionnaire score from the analyzed ankle	27.36±1.70	19.25±3.64	0.000*

* = p < 0.05 in the comparison between the control group and group with functional ankle instability; CG = control group and IG = group with functional ankle instability

The volunteers were familiarized with the exercise in the isokinetic dynamometer, in which five concentric submaximal repetitions were performed at 60 and 120 degrees·s^{-1} with an inversion and eversion movement.

During the second data collection day, a preparation was performed for physical exertion in the BIOTEC 2100® cycle ergometer for 3 minutes[18] at 75W and 70-80 revolutions per minutes[19]; the proprioception tests and the strength test were performed on the same day.

The strength and proprioception evaluations were performed using a Biodex Medical Systems® isokinetic dynamometer. During evaluations, the volunteers were positioned on the isokinetic dynamometer's seat in accordance with the manufacturer's recommendations. The ankle joint was kept at 10° of plantar flexion and the subtalar joint in a neutral position.

In order to verify the maximum active amplitude of inversion and eversion movements, for determining the extent of the isokinetic contractions, the volunteers moved the isokinetic dynamometer in an active manner as much as they could without feeling any pain in three attempts, both in inversion and eversion; a reduction of 10% of maximum amplitude was performed so as to avoid limitations in torque production.

The strength evaluation was performed during a series of five maximal isokinetic concentric (INV) inversion and eversion (EVE) contractions, with angular velocities of 60 degrees·s^{-1} and 120 degrees·s^{-1}. Proprioception, measured by the passive repositioning capability of the ankle, was evaluated through continuous passive motion of the isokinetic dynamometer, with an angular velocity of 1 degree·s^{-1}[9].

The volunteers were blindfolded before beginning the proprioceptive evaluation, this was done in order to eliminate visual clues being a factor in the results. Initially, the passive repositioning test was performed with the ankle positioned at 10° of inversion, this position was maintained for 10 seconds. After this period, the ankle was passively repositioned to the reference angle (neutral position). From this position, the device began the passive motion of the ankle and the volunteer was asked to reproduce the 10° of inversion target angle. After this protocol was performed, the subject was given a two-minute rest and then a second attempt was initiated, with the target position for repositioning adjusted to an amplitude of 20° ankle inversion[9].

The results from the strength test were analyzed by means of specific routines developed in the Matlab software (Mathworks®). These routines made it possible to obtain the values of peak torque during concentric movements of eversion and inversion and the conventional ratio between concentric eversion torque and concentric inversion torque (EVE/INV).

Whereas, for the passive repositioning of the ankle test, the mean absolute error was performed in both attempts, which is characterized by the difference between the target angle and the angle at which the volunteer's ankle is positioned during the test.

The PASW statistics 18.0 package (SPSS Inc.) was used for the statistical analysis. After verifying the normality of the data's distribution, using the Shapiro-Wilk test, the following were employed: the Student's *t*-test for the independent samples in the comparison between peak torque data, conventional ratio (EVE/INV) and the mean absolute error. A significance of $p<0.05$ was considered for all the analyses.

RESULTS

Figure 1 presents the values of peak torque in the isokinetic contractions of inversion and eversion of the ankle at speeds of 60 degrees$\cdot s^{-1}$ and 120 degrees$\cdot s^{-1}$. The IG showed a 32% eversion strength and 17% less than the CG (p=0.001 and p=0.013) during the maximal isokinetic contractions in eversion at the speeds of 60 degrees$\cdot s^{-1}$ and 120 graus$\cdot s^{-1}$.

Figure 2 shows the ratio values of the peak torque in the isokinetic contractions of ankle inversion and eversion at speeds of 60 degrees$\cdot s^{-1}$ and 120 degrees$\cdot s^{-1}$. The IG group showed a conventional ratio that was 28% less than that of the CG (p=0.032) during the maximal isokinetic contractions in eversion at the speed of 60 degrees$\cdot s^{-1}$.

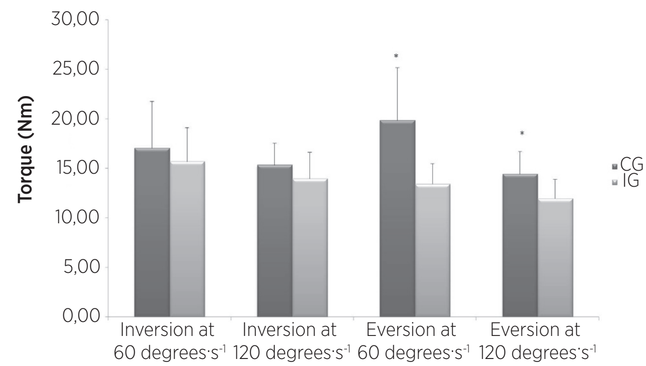

Chart 1. Peak torque values obtained during ankle eversion and i nversion at 60 degrees$\cdot s^{-1}$ and 120 degrees$\cdot s^{-1}$
CG = control group (n=11); IG = group with FAI (n=11)
* p < 0.05 compared to CG

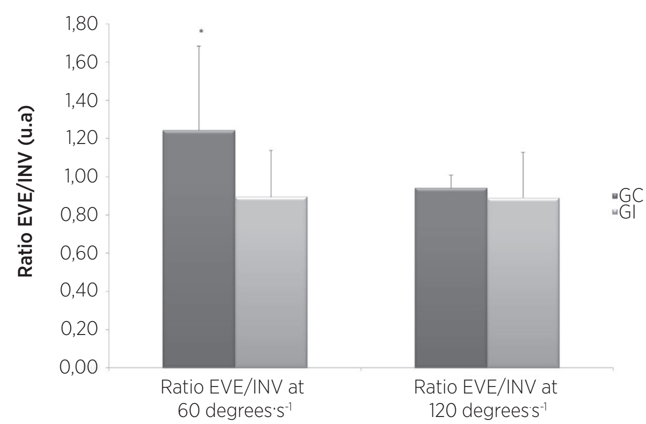

Chart 2. Peak torque ratio values obtained during ankle eversion and inversion at 60 degrees$\cdot s^{-1}$ and 120 degrees$\cdot s^{-1}$. CG = control group (n=11); IG = group with FAI (n=11)
* p < 0.05 compared to CG

Table 2 shows the values for passive repositioning of the ankle for the CG and IG groups. There was no significant difference found between the groups during the proprioception test.

Table 2. Mean values and standard deviations of passive joint repositioning obtained during inversion and eversion ankle movements at 60°/s and 120°/s for the CG and IG (n=25)

	Target Angle	GC	GI	P
Passive Repositioning	10°	3.72±3.03	2.83±1.79	0.792
	20°	3.49±1.78	2.46±1.87	0.199

CG = control group; IG = group with FAI

DISCUSSION

The findings from this study demonstrated that individuals with FAI present a reduction in ankle eversion strength and a lower EVE/INV peak torque ratio when compared with healthy individuals. Thus, our findings partially agree with the study's hypothesis that healthy individuals have a higher inversion and eversion strength than people with FAI.

Our findings corroborate with previous studies[20,21] in that they demonstrated a reduction in eversion strength of 32% and 17% (mean between the deficit in eversion contraction at 60 and 120 degrees^{-1}, respectively) between healthy people and those with FAI. A study by Hartsell and Spaulding[20] they found a reduction in the ankle's concentric eversion strength of around 30% for both speeds. Based on this, it is suggested that individuals who show a 30% reduction in eversion strength may be predisposed to functional ankle instability. However, further studies are still required in order to find normative values in the population.

A study by Arnold, et al.[13], meta-analysis found strength deficits in concentric eversion ankle strength in patients with instability and concluded that individuals with FAI showed weakness in their evertors; studies found no such difference due to a lack of statistical power. This study found peak torque values of eversion at speeds of 60 degrees$\cdot$s^{-1} and 120 degrees$\cdot$s^{-1}, a 0.95 power and effect size of 1.57 and 1.89, respectively. Therefore, there is agreement with the conclusion put forward by the study's authors, due to the fact that good values of power and effect size were found in this study.

Evertor strength is important for stabilizing the ankle during dynamic exercises, this is because it increases the joint's capacity to resist the ankle inversion and return the foot to its original state, which reduces the chance of the ankle being sprained[9]. Thus, evertor force is the main mechanism that reduces the speed of joint displacement during the inversion.

However, unlike other studies[9,21], there was no difference between the groups in terms of inverter strength. As a result, it is still difficult to indicate which muscle group (inverter or evertor) is of greater importance for preventing ankle sprains. However, one parameter, that has been shown to be important to differentiate between people with FAI and healthy people durign studies, is the difference in muscular ratios[21].

Based on this, it is possible to suggest that strengthening a single muscle group is more important than maintaining the balance of strength between the inverter and evertor muscles for preventing ankle sprains.

During a study by Pontaga[21], individuals with recurring ankle sprains showed a mean decrease of 14% in the conventional ratio at speeds of 60 degrees$\cdot$s^{-1} and 120 graus$\cdot$s^{-1} in final motion amplitudes when compared to individuals with no history of ankle injury. The results from this study corroborate with our results and may suggest that a minimum reduction of at least 14% of the EVE/INV ratio can lead to individuals suffering recurring ankle injuries, causing an FAI frame.

It is reported in the literature that individuals with FAI have deficits in joint repositioning sense, which may cause recurring sprains. One of the mechanoreceptors that may be involved in the conscious proprioception of the repositioning senses are neuromuscular spindles, which act as receptors related to muscle length[22]. Therefore, after an injury, these mechanoreceptors can be damaged, thereby compromising articulation.

The findings from this study showed that there was no proprioceptive deficits among people with FAI or healthy people. Thus, it can be suggested that this result is related to the lack of sensitivity in the test used to detect proprioceptive changes, despite the literature indicating that the passive joint repositioning test is suitable for proprioception evaluation[16,23]. In addition, there is a scarcity of standardized protocols for measuring joint position sense that encompass the many variations of the type of equipment used for the angular measurement of the initial reference angle, of active or passive reproduction and of using the use of closed and open kinetic chain tests[16,24].

This study is therefore limited in terms of dividing the sample into the two groups in which the CAIT questionnaire was used; however, the cutoff score could have shown greater differences if the scoring range between the control group and the group with FAI had been more distant. In addition to the proprioceptive test, only choosing two angles for evaluation results in further limitation. Accordingly, the suggestion is that other different angles of inversion, as well as a proprioception test at angles of eversion are performed.

CONCLUSION

This study's most significant finding was that individuals with FAI show a reduction in evertor strength, as well as an imbalance between the ankle's evertor and inverter strength. As a result, athletes with FAI can be more predisposed to recurring ankle sprains, since the speed reducing mechanism of displacement of this joint for inversion is defective.

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