Eccentric Peak Torque Analysis of Subjects Suffering from Chronic Ankle Instability

Amr Almaz Abdel-aziem[1], Amira Hussin Draz[2]

[1]Assistant Professor of Biomechanics, Department of Biomechanics, Faculty of Physical Therapy, Cairo University, Egypt.

[2]Lecturer of Basic Sciences, Department of Basic Sciences, Faculty of Physical Therapy, Cairo University, Egypt.

Abstract

The purpose of this study was to examine the effect of chronic ankle instability (CAI) on eccentric peak torque of the ankle musculature. The study included fifty participants divided into two groups; the first group consisted of twenty five subjects suffering from CAI, the second group consisted of twenty five subjects with no prior history of ankle injury as control group. Eccentric peak torque of invertors, evertors, plantar-flexors and dorsiflexors was recorded for each participant at angular velocities 30 and 90^o/sec by using (Biodex Medical Systems, Inc, Shirley, NY, USA). Analysis of variance (ANOVA) revealed that there was a significant deficit for eccentric inversion, eversion, and plantar flexion peak torques between CAI group and control group at both angular velocities ($p < 0.05$). However, no significant difference was identified for eccentric dorsiflexion peak torque at both angular velocities ($p > 0.05$). There was no significant increase in eccentric torque of invertors, evertors, plantar-flexors and dorsiflexors when the angular velocity increased from 30 to 90°/sec for normal and CAI group ($p > 0.05$). Eccentric strengthening of invertors, evertors, and plantar-flexors must be considered during rehabilitation of subjects suffering from chronic ankle instability.

Key Words: Eccentric contraction, ankle muscles, chronic ankle instability.

(Rec.Date: *Nov 29, 2012* - Accept Date: *Jan 11, 2013*)

Corresponding Author*:* Amr Almaz Abdel-aziem, 7 Ahmed Elziat Street, Bean Elsariate, Faculty of Physical Therapy, Cairo University, Giza, Egypt.
Phone: 00966544113825 (KSA) – 00201006229996
E-mail: amralmaz@yahoo.com

Introduction

The ankle is the most commonly injured joint in the body and 85% of those ankle injuries are inversion sprains [1]. The mechanism of a lateral ankle sprain is typically a violent inversion/hypersupination of the ankle complex [2]. Numerous ankle sprains and a subjective feeling of the ankle ‘‘giving way’’ result. Chronic ankle instability (CAI) limits the patient in both activities of daily living and athletic activity [3].

Ankle joint stability is maintained by both static and dynamic mechanisms. Dynamic joint stability relies heavily on a properly functioning neuromuscular network. Disruption in the pathway may predispose the ankle to further injury and future instability [4]. Dynamic joint stabilization is achieved by cocontraction of the muscles surrounding a joint. During activities that involve the lower limb, such as running, cutting, and jumping, the athlete relies on muscular cocontraction, in particular eccentric control, to minimize forces between the ground and the ankle foot complex [5]. As a result, subjects who are imbalanced this muscular cocontraction ability may be susceptible to injury because they do not have the muscular ability to smoothly dissipate these forces in a coordinated manner. The excessive stress on the surrounding joint tissues often predisposes the ankle joint injury [6].

Several authors [7-11] have reported decrements in CAI ankle concentric evertor isokinetic strength. Comparing an assessment of the ankle dorsal and plantar flexor muscles strength manually and by the isokinetic dynamometry, Andersen and Jakobsen [12] revealed that the manual testing leads to significant underestimation of frequency and severity of the muscles weakness. Therefore the results of patients’ clinical examinations manually could be inaccurate. Leanderson et al. [13] measured by the isokinetic dynamometry the ankle evertor muscle peak torque value and found deficit after ankle sprains.

Tropp [9] and Hartsell and Spauling [14] have identified both concentric and eccentric eversion torque deficits; whereas others have concluded that no eversion deficit exists, regardless of mode or speed of contraction. [15] McKnight and Armstrong [16] and Baumhauer et al. [17] found no significant invertor deficits. Termansen et al. [18] studying the plantar-flexors reported concentric torque deficits in participants with a history of a lateral ankle sprain.

Eccentric muscle contraction could be considered a critical component of ankle control during virtually all ankle joint movements [19]. Furthermore, eccentric muscle actions are more representative of dynamic ankle stabilization mechanisms [2]. Therefore, the purpose of the present study was to examine the effect of chronic ankle instability on eccentric peak torque of invertors, evertors, plantar-flexors and dorsiflexors.

Materials and methods

Subjects

Fifty subjects were included in this research. The healthy group consisted of twenty five participant (16 male and 9 female, age range 19-26 years, height= 174.9 ± 5.5 cm, mass = 73.33 ± 7.76 kg) with no prior history of pathology to either lower extremity. The CAI consisted of twenty five participant (17 male and 8 female, age range 19-27 years, height= 176.13 ± 6.6 cm, mass = 74.13 ± 6.77 kg).

The CAI subjects participated in this study were randomly selected according to the following inclusion criteria; (1) a history of at least 1 unilateral lateral ankle sprain that required immobilization for at least 3 days; (2) at least 1 episode of giving way within the past year; (3) at least 1 recurrent sprain between 3 and 6 month before study participation; (4) report of pain, instability, and/or weakness in the involved ankle; (5) attribution of these signs to the initial ankle injury; (6) failure to resume all pre-injury level of activities; (7) no previous ankle fractures; (8) no previous head and acute lower extremity injury within the past 3 months; (9) no formal rehabilitation of the involved ankle. These requirements have been used previously as inclusion criteria for individuals with CAI [20, 21]. an episode of re-injury between 3 and 6 months before enrolled in this investigation was required to ensure that subjects still had physical manifestations of CAI but that acute symptoms were resolved [21].

Written consent was obtained from each subject before testing, and all subjects were screened to ensure that no lower extremity neuromuscular or musculoskeletal problems or contraindications for isokinetic testing, after being informed about the study and test procedures, and any possible risks and discomfort that might ensue. The study was approved by the research ethical committee of the Faculty of Physical Therapy, Cairo University.

Testing Procedures

The subjects warmed up for 5 min on a stationary bicycle at a comfortable pace between 60 and 70 revolutions per minute and 5 min of stretching exercise for invertors, evertors, plantar-flexors and dorsiflexors. The participants were then tested in both plantarflexion/dorsiflexion (figure 1) and inversion/eversion (figure 2) movements by using the Biodex multi joint system 3 isokinetic dynamometer (Biodex Medical Systems, Inc, Shirley, NY, USA).

Figure 1. Foot position during measurement of dorsiflexors and plantar-flexors eccentric peak torque

Figure 2. Foot position during measurement of invertors and evertors eccentric peak torque

The test angular velocities were 30 and 90°/sec for all movement patterns inversion/eversion and plantarflexion/dorsiflexion. The angular velocity 90°/sec is the optimal testing speed for eversion movements [6]. Moreover, during eccentric muscle performance must use the low-medium range of velocity spectrum, because using high velocities is not risk free [22].

Each subject was seated on the biodex chair, with the angle of hip 80° flexion (0° neutral position). In ankle plantarflexion/dorsiflexion test and inversion/eversion a knee pad was placed under distal femur and secure with a strap allowing for approximately 20° to 30° of knee flexion, also ensure that the subjects's lower leg is parallel to the floor, this also diminished the potential for dynamic hamstring activity falsely contributing to the generated torque [23].

The foot and ankle were positioned into either the inversion/eversion or plantarflexion/dorsiflexion attachment with straps to secure the foot. Once positioned, the participant's active range of motion was used to determine the start and stop angles. For each testing motion, a warm-up of 10 repetitions at 30 and 90^o/sec was performed for familiarization of the speed of movement and the eccentric mode of testing. This was followed by 5 continuous repetitions throughout the range of motion [24], and a two-minute rest was permitted between the test for inversion/eversion and plantarflexion/dorsiflexion to prevent the buildup of fatigue [5].

Statistical analysis

The peak toque (expressed in Nm) of the ankle joint muscles at angular velocities 30 and 90^o/sec was recorded. The highest value of each bout of repetitions was used. Data were analyzed by using a Statistical Package for Social Sciences (SPSS version 16) Analysis of variance (ANOVA) was used to compare between normal and CAI group at angular velocities 30 and 90^o/sec. Level of significance was set at 0.05 for all statistical tests.

Results

Descriptive statistics for ankle joint muscles peak torque (Nm) for normal and CAI groups at angular velocities 30 and 90^o/sec are presented in Table 1.

Effect of CAI on eccentric peak torque

For the plantar-flexor muscles there was a significant difference between the normal and CAI eccentric peak torque values at angular velocity of 30°/sec as well as at 90°/sec, p = 0.036 and 0.027 respectively. However, for the dorsiflexor muscles there was no significant difference between the normal and CAI eccentric peak torque values at both angular velocities, p = 0.557 and 0.579 respectively.

Considering the invertor muscles there was a significant difference between the normal and CAI eccentric peak torque values at angular velocities 30 and 90°/sec, p = 0.035 and 0.007 respectively. For eccentric contraction of evertor muscles there was a significant difference between the normal and CAI eccentric peak torque values at both angular velocities, p = 0.037 and 0.042 respectively.

Table 1. The mean values of peak torque (±SD) for the ankle joint muscles for the normal and CAI at angular velocities 30 and 90°/sec

Groups	Degree	Plantarflexion Mean±SD	Dorsiflexion Mean±SD	Inversion Mean±SD	Eversion Mean±SD
Normal	30^{o}/sec	78.24±9.23	40.28±7.90	29.04± 6.80	24.76±6.46
	90^{o}/sec	81.04±10.69	42.32±9.07	32.32±7.24	26.76±5.92
CAI	30^{o}/sec	73.04±6.77	38.84±8.34	25.16±6.02	21.20±5.42
	90^{o}/sec	75.56±7.31	40.96±9.21	27.32±5.38	23.28±5.98

Effect of angular velocity on eccentric peak torque

There is no significant increase in the plantar-flexor muscles eccentric torque when the angular velocity increased from 30 to 90°/sec for normal and CAI group, p = 0.255 and 0.305 respectively. Moreover, there is no significant increase in eccentric torque of dorsiflexor muscles as the angular velocity increased from 30 to 90°/sec for normal and CAI group, p = 0.406 and 0.388 respectively.

There is no significant increase in the invertor muscles eccentric torque when the angular velocity increased from 30 to 90°/sec for normal and CAI group, p = 0.073 and 0.236 respectively. Moreover, there is no significant increase in eccentric torque evertor muscles as the angular velocity increased from 30 to 90°/sec for normal and CAI group, p = 0.238 and 0.220 respectively.

Discussion

This study was conducted to examine the effect of functional ankle instability on eccentric peak torque of invertors, evertors, plantar-flexors and dorsiflexors. The testing procedure of the current study conducted on the eccentric mode of muscle contraction and didn't include concentric contraction that is due to Dvir [5] stated that it is not advisable to draw comparisons between concentric and eccentric values. Eccentric contraction involves lengthening of the muscle while attempting to resist the force, while concentric muscle contraction involves shortening of the muscle-tendon unit [25].

In order to achieve a certain force, lower levels of motor-unit activity are required with eccentric actions. Consequently, additional units not being used are available and can provide higher increments than with concentric contractions. For the same test velocity, eccentric strength is greater than concentric strength, and the order of strength depends on contraction mode (eccentric, isometric, concentric) [26].

Moreover, the maximal moment developed concentrically by the muscle decreases concurrently with increments in test velocity, whereas for eccentric actions, the tension generated by the muscle remains similar, regardless of test velocity which is coincident the results of the present study that proved that the plantar-flexors, dorsiflexors, invertors and evertors muscles eccentric peak torques doesn't significantly increased as the angular velocity increased [5].

Hartsell et al. [27] established eccentric evertor muscle weakness comparing patients with normal subjects, which is coincident with the results of the present study. Eccentric evertor strength weakness might be explained as follows, biomechanical changes around the ankle joint caused by unstable ankle deficiency might affect eccentric activity to a greater degree than healthy ankle joints. In addition, evertor muscle atrophy might affect eccentric activity at the cellular level [28].

Additionally, McKnight and Armstrong [16] Baumhauer et al. [17] Fox et al. [29] did not find a significant difference in eccentric invertor torque between the lateral ankle sprain patients, and uninjured subjects, which is against the result of the current study. Their results contradict previous findings of Hartsell and Spaulding [14] who found invertor deficits in participants with CAI. One potential reason for these discrepancies is the mode and speed of testing. Testing speeds of previous investigations ranged from 30 to 240^{o}/sec and mode of testing included both eccentric and concentric contractions. All these variety in testing procedures makes it difficult to interpret and compare previous findings.

Ryan [30] theorized that the inversion deficits might have resulted from selective inhibition or deep peroneal nerve dysfunction as a result of overstretching the peroneal nerve. Moreover he speculated that lateral ankle sprain renders the invertor motor- neuron pool less excitable, while the evertor motor-neuron pool is not affected as much, which could be the reason for invertor weakness in lateral ankle sprain.

Fox et al. [29] proved that there is a decrease in plantar-flexor torque for participants suffering from lateral ankle instability which is concurred with the findings of the current study that could be the result of several different factors. First, the deficit could be the result of damage to the gastrocnemius-soleus complex during the initial injury. Hertel [3] identified damage to both the ligamentous and musculotendinous structures after a lateral ankle sprain. The gastrocnemius-soleus complex crosses the talocrural joint, so this complex could be damaged by a severe inversion stress. Second, reduced motor unit excitability could occur after an initial ankle sprain and lead to decreased plantarflexion torque.

McVey et al. [31] identified arthrogenic muscle inhibition of the soleus muscle in participants with unilateral ankle instability. The authors suggested that changes in afferent feedback could contribute to both muscle inhibition and lateral ankle instability. Finally, little is known about the muscle-fascia interfaces and their relationship to injury. The formation of fibrous tissue in the myofascial interface would theoretically lead to inhibition of the muscle's ability to lengthen during activity [29]. The results of dorsiflexion torque of participants with a history of lateral ankle instability did not have deficits at angular velocities 30 and 90^{o}/sec, this results agree with the results of the previous studies [4, 16, 17, 29] regardless of population, mode of testing, or type of contraction.

This study was limited by the following: First, the sample study was untrained subjects. So, the reader must be careful during application of these results on physically active subjects or athletes. Second, this study utilized a relatively young sample. Therefore, the results of the present study will be more suitable for similar age group and further research evaluate the effect of CAI on the eccentric peak torque of ankle musculature in other age groups would be interested especially elder subjects. Finally, the angular velocities used during conduction of this study were 30 and 90^{o}/sec which considered slow and moderate velocities. So, further research can be conducted at faster angular velocities.

Conclusion

This study evaluated the eccentric peak torque of invertors, evertors, plantar-flexors and dorsiflexors of chronically unstable ankles and found a deficit in inversion, eversion, and plantarflexion eccentric peak torque at angular velocities 30 and 90^{o}/sec. No deficit identified for dorsiflexion eccentric peak torque at both angular velocities. So, Eccentric training of invertors, evertors, and plantar-flexors lead to more effective rehabilitation programs of subjects suffering from chronic ankle instability and prevent the incidence of recurrent ankle sprain.

Conflict of interest

Author didn’t receive any form of fund or technical support from any agencies for this research study.

References

1. Ebig M, Lephart SM, Burdett RG, Miller MC, Pincivero MD. The effect of sudden inversion stress on EMG activity of the peroneal and tibialis anterior muscles in the chronically unstable ankle. J Ortho Sport Phys Ther. 1997;26:73-7.
2. Gutierrez GM, Jackson ND, Dorr KA, Margiotta SE, Kaminski TW. Effect of fatigue on neuromuscular function at the ankle. J Sport Rehabil. 2007;16:295-306.
3. Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. J Athl Train. 2002;37:364-75.

4. Porter GK, Kaminiski TW, Hatzel B, Power EP, Horodyski M. An examination of stretch-shortening cycle of the dorsiflexors and evertors in uninjuried and functionally unstable ankles. J Athl Train. 2002;37(4):494-500.
5. Dvir Z. Isokinetics: Muscle testing, Interpretation and Clinical Application. London, England: Churchill Livingstone; 1995:1-22.
6. Kaminski TW, Hartsell HD. Factors contributing to chronic ankle instability: strength perspective. J Athl Train. 2002;37(4):394-405.
7. Bosien WR, Staples OS, Russell SW. Residual disability following acute ankle sprains. J Bone Joint Surg Am. 1955;37(6):1237-43.
8. Staples OS. Result study of ruptures of lateral ligaments of the ankle. Clin Orthop Rel Res. 1972;85:50-8.
9. Tropp H. Pronator muscle weakness in functional instability of the ankle joint. Int J Sports Med. 1986;12:291-4.
10. Staples OS. Ruptures of the fibular collateral ligaments of the ankle: result study of immediate surgical treatment. J Bone Joint Surg Am. 1975;57(1):101-7.
11. Pontaga I. Ankle joint evertor–invertor muscle torque ratio decrease due to recurrent lateral ligament sprains. Clin Biomech (Bristol, Avon). 2004;19(7):760-2.
12. Andersen H, Jakobsen J. A comparative study of isokinetic dynamometry and manual muscle testing of ankle dorsal and plantar flexors and knee extensors and flexors. Eur. J. Neurol. 1997;37:239-42.
13. Leanderson J, Bergqvist M, Rolf K, Westblad P, Wigelius-Roovers S, Wredmark T. Early influence of an ankle sprain on objective measures of ankle joint function. Knee Surgery Sports Traumatol. Arthrosc. 1999;7:51-8.
14. Hartsell HD, Spaulding SJ. Eccentric/concentric ratios at selected velocities for the invertor and evertor muscles of the chronically unstable ankle. Br J Sports Med. 1999;33(4):255-8.
15. Munn J, Beard DJ, Refshauge KM, Lee RY. Eccentric muscle strength in functional ankle instability. Med Sci Sports Exerc. 2003;35(2):245-50.
16. McKnight C, Armstrong CW. The role of ankle strength in functional ankle instability. J Sport Rehabil. 1997;6(1):21-9.
17. Baumhauer JF, Alosa DM, Renstrom AFH, Treino S, Beynnon B. A prospective study of ankle injury risk factors. Am J Sports Med. 1995;23(5):564-70.
18. Termansen N, Hansen H, Damholt V. Radiological and muscular status following injury to the lateral ligaments of the ankle: follow-up of 144 patients treated conservatively. Acta Orthop Scand. 1979;50:705-8.
19. Ashton-Miller JA, Ottaviani RA, Hutchinson C, Wojtys E. What best protects the inverted weightbearing ankle against further inversion? Evertor muscle strength compares favorably with shoe height, athletic tape, and three orthses. Am J Sports Med. 1996;24(6):800-9.

20. Wikstrom EA, Tillman MD, Chmielewski TL, Cauraugh JH, Naugle KE, Borsa PA. Self-assessed disability and functional performance in individuals with and without ankle instability: a case control study. J Ortho Sport Phys Ther. 2009;39(6):458-67.
21. Hass CJ, Bishop MD, Doidge D, Wikstrom EA. Chronic ankle instability alters central organization of movement. Am J Sports Med. 2010;38(4):829-34.
22. Buckley BD, Kaminski TW, Powers ME, Ortiz C, Hubbard TJ. Using reciprocal muscle group ratios to examine isokinetic strength in the ankle: a new concept [abstract] J Athl Train. 2001;36(suppl)S-93.
23. Lentell G, Cashman P, Shiomoto K, Spry J. The effect of knee position on torque output during inversion and eversion movements of the ankle. J Orthop Sports Phys Ther. 1988; 10(5):177-83.
24. Kaminski TW, Dover G. Reliability of inversion and eversion peak- and average torque measurements from the Biodex system 3 dynamometer. J Sport Rehabil. 2001;10(3):205-20.
25. Lentell G, Baas B, Lopez D, McGuire L, Sarrels M, Snyder P. The contributions of proprioceptive deficits, muscle function, and anatomic laxity to functional instability of the ankle. J Orthop Sports Phys Ther. 1995;21(4):206-15.
26. Elfman H, Dvir Z. Biomechanics of muscle. J Bone Joint Surg Am. 1975;48:363-73.
27. Hartsell HD, Wilkerson GB, Pinerola JJ, Caturano RW. Invertor vs. evertor peak torque and power deficiencies associated with lateral ankle ligament injury. J Orthop Sports Phys Ther. 1997;26:78-86.
28. Yildiz Y, Aydin T, Sekir D, Hazneci B, Komurcu M, Kalyon TA. Peak and end range eccentric evertor/concentric invertor muscle strength ratios in chronically unstable ankles: comparison with healthy individuals. J Sports Sci Med. 2003;2:70-6.
29. Fox J, Docherty CL, Schrader J, Applegate T. Eccentric plantar-flexor torque deficits in participants with ankle instability. J Athl Train. 2008;43(1):51-4.
30. Ryan L. Mechanical stability, muscle strength and proprioception in functionally unstable ankle. Aust Physiother. 1994;40(1):40-7.
31. McVey ED, Palmieri RM, Docherty CL, Zinder SM, Ingersoll CD. Arthrogenic muscle inhibition in the leg muscles of subjects exhibiting functional ankle instability. Foot Ankle Int. 2005; 26(12):1055-61.