Journal of Athletic Training 2008;43(1):51–54

www.nata.org/jat

Eccentric Plantar-Flexor Torque Deficits in Participants With Functional Ankle Instability

Jason Fox, MS, LAT, ATC; Carrie L. Docherty, PhD, LAT, ATC; John Schrader, HSD, LAT, ATC; Trent Applegate, HSD, MPH

Indiana University, Bloomington, IN

Context: Inversion ankle sprains can lead to a chronic condition called functional ankle instability (FAI). Limited research has been reported regarding isokinetic measures for the plantar flexors and dorsiflexors of the ankle.

Objective: To examine the isokinetic eccentric torque measures of the ankle musculature in participants with stable ankles and participants with functionally unstable ankles during inversion, eversion, plantar flexion, and dorsiflexion.

Design: Case-control study.

Setting: Athletic training research laboratory.

Patients or Other Participants: Twenty participants with a history of "giving way" were included in the FAI group. Inclusion criteria for the FAI group included a history of at least 1 ankle sprain and repeated episodes of giving way. Twenty participants with no prior history of ankle injury were included in the control group.

Intervention(s): Isokinetic eccentric torque was assessed in each participant.

Main Outcome Measure(s): Isokinetic eccentric testing was conducted for inversion-eversion and plantar-flexion–dorsiflexion movements. Peak torque values were standardized to each participant's body weight. The average of the 3 trials for each direction was used for statistical analysis.

Results: A significant side-by-group interaction was noted for eccentric plantar flexion torque ($P < .01$). Follow-up t tests revealed a significant difference between the FAI limb in the FAI group and the matched limb in the control group. Additionally, a significant difference was seen between the sides of the control group ($P = .03$). No significant interactions were identified for eccentric inversion, eversion, or dorsiflexion torques ($P > .05$).

Conclusions: A deficit in plantar flexion torque was identified in the functionally unstable ankles. No deficits were identified for inversion, eversion, or dorsiflexion torque. Therefore, eccentric plantar flexion strength may be an important contributing factor to functional ankle instability.

Key Words: isokinetic dynamometer, strength, inversion, eversion, dorsiflexion

Key Points

- A deficit in plantar-flexion torque was identified in the participants with functionally unstable ankles.
- No deficits were noted for inversion, eversion, or dorsiflexion torque.
- Eccentric plantar-flexion strength may be an important contributing factor to functional ankle instability.

Injuries to the lateral ligamentous complex of the ankle result in more time lost from participation than any other single sport-related injury.[1] After an ankle injury, residual symptoms can also affect activities of daily life; one group[2] reported that 33% of patients with a lateral ankle sprain have persistent residual symptoms 2 years after the initial injury. In 1965, Freeman[3] described this recurrent feeling of instability, or the sensation of the ankle "giving way," as functional ankle instability (FAI). In an effort to better understand the causes of this instability, researchers have tried to identify the contributing factors associated with FAI. Previous research on FAI has focused on a combination of factors, including muscular strength, mechanical instability, and proprioception.[4–7]

Authors specifically investigating strength deficits at the ankle have logically focused on peroneal muscle weaknesses due to their direct anatomical proximity to the static ligamentous structures affected by an inversion injury.[5–12] Peroneal muscle weakness has been theorized to cause diminished dynamic stability and, therefore, contribute to FAI.[6] However, the previous literature related to the presence of peroneal deficits in individuals with functionally unstable ankles is conflicting.[5,8,13–15] Some investigators have identified both concentric[4,13,15] and eccentric[4,15] eversion torque deficits, whereas others have concluded that no eversion deficit exists, regardless of mode or speed of contraction.[7–9]

Additionally, while the evertor muscles can counter a varus force,[6] proper dynamic stabilization of the ankle can only be achieved through a coordinated effort of all the surrounding muscles.[16] This coordination would involve some combination of concentric, eccentric, isometric, or kinetic motion of all muscle-tendon units surrounding and moving the ankle joint complex. Efficient function and protection of the joints would, at times, involve cocontractions for stability as well as the commonly recognized agonist-antagonist activity in order to facilitate reciprocal planar motion. Therefore, more experimental studies are needed on all muscles of the lower leg. Authors analyzing the invertor muscles in functionally unstable and uninjured ankles have also reported conflicting results. Significant torque deficits have been noted during both concentric[5,11] and eccentric[9,15] muscle contractions, whereas others found no significant invertor deficits.[4,7,10,14,17] Research investigating plantar-flexor and dorsiflexor muscles is very limited. One group[18] studying the plantar flexors reported concentric torque deficits in participants with a history of a lateral ankle sprain; other authors[14] found no significant difference in plantar-flexion or dorsiflexion torque between FAI and control participants.

Given these discrepancies in the inversion and eversion literature and the lack of research on the plantar flexors and dorsiflexors, additional studies evaluating isokinetic ankle torque values are necessary. Additionally, eccentric muscle contraction could be considered a critical component of ankle control during virtually all ankle joint movements.[19] Therefore, our purpose was to specifically examine differences in isokinetic eccentric inversion, eversion, plantar-flexion, and dorsiflexion torque in normal and functionally unstable ankles.

METHODS

The sample consisted of 40 participants, including 20 participants with a history of unilateral FAI (12 women, 8 men; age = 20.65 ± 2.64 years, height = 171.65 ± 11.05 cm, mass = 72.30 ± 9.50 kg) and 20 participants with stable ankles (15 women, 5 men; age = 20.90 ± 2.36 years, height = 171.95 ± 9.57 cm, mass = 69.21 ± 16.44 kg). Participants were recruited from academic classes and athletic training rooms in a large university community. Before beginning the study, each participant completed and signed the informed consent document, approved by the institutional review board, which also approved the study.

All participants completed the Ankle Instability Instrument to determine group membership in either the control group or the FAI group.[20] The control group consisted of individuals without prior history of ankle injury. An injury was defined as any sprain, strain, or fracture of the ankle. The FAI group consisted of any individual who had experienced a lateral ankle injury without fracture and at least 1 incident of giving way in the past month and had sought medical attention for this condition. Of the 20 FAI participants, 8 (40%) had FAI on the right side and 12 (60%) had FAI on the left side. Initial ankle injury was diagnosed as mild in 3 cases, moderate in 7 cases, and severe in 5 cases; 5 participants could not remember the initial injury. Participants' last ankle sprain occurred in the past year in 14 participants (70%) and more than a year ago in 6 participants (30%); a structured rehabilitation program was completed by 15 participants (75%). The FAI participants also reported various amounts of giving way: 3 (15%) on a daily basis, 7 (35%) on a weekly basis, and 10 (50%) on a monthly basis.

Test Procedures

The participants reported to the athletic training research laboratory on 1 occasion. Both the dominant and nondominant limb ankles were tested in all participants. Limb dominance was established by the foot the participants would use to kick a ball. The participants warmed up for 5 minutes on a stationary bicycle at a comfortable pace between 60 and 70 revolutions per minute. The participants were then tested in both inversion-eversion and plantar-flexion–dorsiflexion movements using the KinCom III isokinetic dynamometer (Chattanooga Group, Chattanooga, TN). The test speed was 90°/s for all ranges of motion. It has been established through Kaminski and Hartsell's[16] quadratic trend that 90°/s is the optimal testing speed for eversion movements. The order of the test side and movement was counterbalanced for all participants.

Participants were in a supine position for all movements. The ipsilateral knee was flexed to 10°, supported with a cushioned bolster, and secured distally with a hook-and-loop strap. Both hips were also secured with a hook-and-loop strap. Knee positioning at 10° of flexion allowed for a more isolated movement pattern from the ankle during inversion and eversion.[21] This also diminished the potential for dynamic hamstring activity falsely contributing to the generated torque.[21] Depending on the testing plane of movement, the foot and ankle were positioned into either the inversion-eversion or plantar-flexion–dorsiflexion attachment with hook-and-loop straps and additional athletic tape 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 90°/s was performed for familiarization of the speed of movement and the eccentric mode of testing. This was followed by 10 continuous repetitions throughout the range of motion. Two additional 10-repetition bouts were conducted with a 60-second rest period between bouts. Kaminski and Dover[22] used similar testing procedures in their reliability testing.

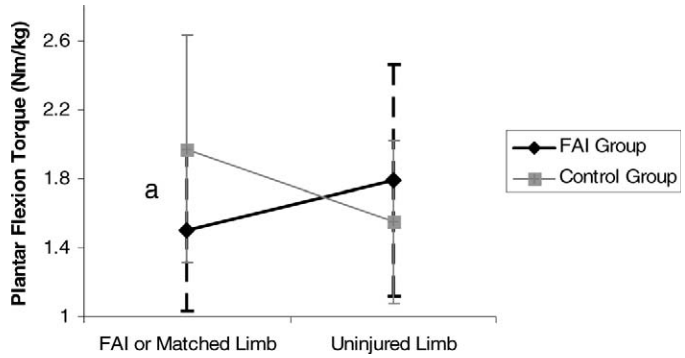

Figure. Differences between eccentric plantar-flexion peak torque/body weight in the functional ankle instability (FAI) and control groups. [a]Indicates significant difference between the FAI limb in the FAI group and the matched limb in the control group.

Statistical Analysis

The injured ankle of the FAI group was matched by side and limb dominance to an ankle in the control group. All torque measures were standardized to the participant's body weight. The peak torque was then obtained for each bout, and the average of the 3 standardized peak torque values was used for the statistical analysis. All data were imported into SPSS (version 11.5 for Windows; SPSS Inc, Chicago, IL). A repeated-measures analysis of variance was calculated for each movement. Each had 1 within-subjects factor of side (injured ankle [FAI or matched in the control participants] and uninjured ankle) and 1 between-subjects factor of group (FAI or control). The α level was set at $P < .05$. Follow-up *t* tests were conducted on all significant findings.

RESULTS

A significant side-by-group interaction was noted for eccentric plantar-flexion torque ($F_{1,38} = 7.92$, $P < .01$, $\eta^2 = .17$; Figure). Follow-up *t* tests revealed a significant difference between the FAI limb in the FAI group (1.50 Nm/kg) and the matched limb in the control group (1.96 Nm/kg). Additionally, a significant difference was seen between the sides of the control group ($P = .03$).

No significant interaction was identified for eccentric inversion ($F_{1,38} = 0.56$, $P = .46$, $\eta^2 = .01$, power = .11), eversion ($F_{1,38} = 1.38$, $P = .25$, $\eta^2 = .04$, power = .21), or dorsiflex-

Table. Eccentric Peak Torque/Body Weight (Nm/kg) for all Isokinetic Movements in Control and Functional Ankle Instability (FAI) Groups (Mean ± SD)

Movement	Control Group (n = 20) Peak Torque/Body Weight		Group (n = 20) Peak Torque/Body Weight	
	Matched Limb	Uninjured Limb	FAI Limb	Uninjured Limb
Inversion	0.52 ± 0.12	0.52 ± 0.15	0.53 ± 0.12	0.56 ± 0.13
Eversion	0.54 ± 0.15	0.58 ± 0.16	0.57 ± 0.12	0.56 ± 0.12
Plantar-flexion	1.96 ± 0.66[a]	1.56 ± 0.47[a]	1.50 ± 0.47[a]	1.79 ± 0.67
Dorsiflexion	1.29 ± 0.57	1.38 ± 0.51	1.46 ± 0.69	1.39 ± 0.48

[a]Significant differences between the FAI limb in the FAI group and the matched limb in the control groups and the sides of the control group ($P < .05$).

ion ($F_{1,38} = 0.36$, $P = .55$, $\eta^2 = .01$, power = .09) torques. Additionally, no significant main effect for side or group was noted in any of the analyses ($P > .05$). The means and SDs for the peak torque/body weight percentages are located in the Table.

DISCUSSION

Our intent was to examine eccentric ankle torque during inversion, eversion, plantar-flexion, and dorsiflexion movements in FAI and uninjured ankles. Although previous research has been inconclusive, we hypothesized that a deficit would be observed in participants with FAI. However, we found that only the eccentric plantar-flexion peak torque was significantly different in the functionally unstable ankle of the FAI group compared with the matched ankle in the control group.

Plantar-Flexor and Dorsiflexor Muscle Groups

Only limited research has been conducted focusing on plantar-flexion[14,17,18] or dorsiflexion[12–14,17,23] torque deficits in individuals with a history of ankle instability. Additionally, the previous findings investigating plantar-flexion torque were inconclusive. One set of authors[14] reported no plantar-flexion torque deficits, one group[17] identified an increase in plantar-flexion torque in the injured limb, and another group[18] concurred with our findings of a decrease in plantar-flexion torque in the injured limb. It is difficult to draw comparisons among these studies because participants with FAI[14] or a history of a lateral ankle sprain[17,18] were tested. Additionally the mode of testing varied among these studies: McKnight and Armstrong[14] and Baumhauer et al[17] tested participants concentrically, and Termansen et al[18] tested participants isometrically.

In the current study, we identified a significant difference in plantar-flexion torque between the FAI limb in the FAI group and the matched limb in the control group. The decrease in torque 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[24] 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 plantar-flexion torque. Previous authors[25] identified arthrogenic muscle inhibition of the soleus muscle in participants with unilateral FAI. The authors suggested that changes in afferent feedback could contribute to both muscle inhibition and FAI.[25] 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.[26] Further research is needed in this area to substantiate these findings.

Interestingly, we did not find a plantar-flexion torque difference between the injured and uninjured sides of the FAI group. This effect could be the result of a crossover effect, whereby strength changes in one limb also occur in the contralateral limb. This has been shown to occur in the ankle strength literature. Specifically, strength training in one limb created increased peak torque in both the trained and untrained ankles.[27] It has yet to be determined if deficits in one limb could subsequently result in bilateral deficits; however, this issue needs to be further evaluated. Another consideration is that individuals prone to injury and subsequently to FAI may have an inherently suppressed ability to generate normal torques, which could predispose them to injury.

We did, however, find a side-to-side difference in the control group for 1 direction of motion. This difference was an unexpected finding. Although difficult to explain, it perhaps was an artifact of the speed of motion tested.

Dorsiflexion torque has been investigated in several studies. Those results all agree with the current results: participants with a history of either ankle injury or FAI did not have deficits in dorsiflexion torque.[12–14,17,23] Regardless of population, mode of testing, or type of contraction, this finding is consistent.

Invertor and Evertor Muscle Groups

When evaluating the timeline of ankle strength literature, most of the research showing an eversion strength deficit was conducted between 1955 and 1986.[2,13,28] Conversely, the more recent studies, including ours, did not identify any significant eversion torque deficits in FAI participants.[5–10,12] These later authors have been consistent in reporting that ankles with FAI perform the same as uninjured ankles during eversion movements, regardless of the type of contraction (concentric and eccentric) or velocity. Therefore, we can conclude that the isokinetic eversion torque deficits are not a major contributing factor to residual symptoms of giving way. However, other strength measures, such as power or work, should continue to be investigated to better understand the role they play in giving-way symptoms.

Additionally, we did not find a significant difference in eccentric invertor torque between the groups or between the FAI and uninjured limbs. Our results contradict previous findings of invertor deficits in participants with FAI[5,9,15] and agree with others who also did not identify a significant deficit.[4,7,10,14,17] One potential reason for these discrepancies is the mode and speed of testing. Testing speeds of previous investigations ranged from 30 to 240°/s,[4,5,7,9–11,14,17] and mode of testing included both eccentric[4,7,9] and concentric[4,5,10,11,14,17] contractions. Such variety in testing procedures makes it difficult to interpret and compare previous findings.

Limitation

Reliability of the KinCom dynamometer has been established.[29] However, the inversion and eversion footplate continues to enable "extra" movement, depending on the size of the participant's foot. This is a limitation of this type of isokinetic device. To reduce the effect of this unwanted movement, the hook-and-loop straps that are traditionally used were augmented with white tape to secure the foot during all testing.

Future Research

Future researchers should continue to examine the eccentric characteristics of the lower leg musculature that surrounds the ankle, with particular emphasis on the muscles that provide plantar-flexion movement. Electromyographic analysis of the muscles during isokinetic testing should also be investigated to provide a greater understanding of muscle function and recruitment order in participants with FAI.

CONCLUSIONS

We found a deficit in plantar-flexion torque in functionally unstable ankles. No deficits were identified for inversion, eversion, or dorsiflexion torque. Because most researchers have focused on eversion torque, this study is one of the few to evaluate the concept that eccentric plantar-flexion torque may be an important contributing factor to FAI. This finding could also lead to more effective protocols in the treatment and rehabilitation of FAI.

REFERENCES

1. Garrick JG. The frequency of injury, mechanism of injury, and epidemiology of ankle sprains. *Am J Sports Med.* 1977;5(6):241–242.
2. Boisen WR, Staples OS, Russell SW. Residual disability following acute ankle sprains. *J Bone Jt Surg Am.* 1955;37(6):1237–1243.
3. Freeman MAR. Instability of the foot after injuries to the lateral ligament of the ankle. *J Bone Jt Surg Br.* 1965;47(4):669–677.
4. Willems T, Witvrouw E, Verstuyft J, Vaes PH, De Clercq D. Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. *J Athl Train.* 2002;37(4):487–493.
5. Ryan L. Mechanical stability, muscle strength and proprioception in the functionally unstable ankle. *Aust Physiother.* 1994;40(1):41–47.
6. 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): 206–215.
7. Bernier JN, Perrin DH, Rijke A. Effect of unilateral functional instability of the ankle on postural sway and inversion and eversion strength. *J Athl Train.* 1997;32(3):226–232.
8. Kaminski TW, Perrin DH, Gansender BM. Eversion strength analysis of uninjured and functionally unstable ankles. *J Athl Train.* 1999;34(3):239–245.
9. Munn J, Beard DJ, Refshauge KM, Lee RY. Eccentric muscle strength in functional ankle instability. *Med Sci Sports Exerc.* 2003;35(2):245–250.
10. Lentell G, Katzman LL, Walters MR. The relationship between muscle function and ankle stability. *J Orthop Sports Phys Ther.* 1990;11(12):605–611.
11. 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(2):78–86.
12. Schrader J. *Concentric and Eccentric Muscle Function in Normal and Chronically Sprained Ankles: Prevention Implications* [dissertation]. Bloomington, IN: Indiana University; 1993.
13. Tropp H. Pronator muscle weakness in functional instability of the ankle joint. *Int J Sports Med.* 1986;7(5):291–294.
14. McKnight C, Armstrong CW. The role of ankle strength in functional ankle instability. *J Sport Rehabil.* 1997;6(1):21–29.
15. 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):255–258.
16. Kaminski TW, Hartsell HD. Factors contributing to chronic ankle instability: a strength perspective. *J Athl Train.* 2002;37(4):394–405.
17. Baumhauer JF, Alosa DM, Renstrom AFH, Trevino S, Beynnon B. A prospective study of ankle injury risk factors. *Am J Sports Med.* 1995;23(5): 564–570.
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(6 pt 1):705–708.
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 orthoses. *Am J Sports Med.* 1996;24(6):800–809.
20. Docherty CL, Gansender BM, Arnold BL, Hurwitz SR. Development and reliability of the Ankle Instability Instrument. *J Athl Train.* 2006;41(2):154–158.
21. 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):177–183.
22. 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):205–220.
23. Porter GK Jr, Kaminski TW, Hatzel B, Powers ME, Horodyski M. An examination of the stretch-shortening cycle of the dorsiflexors and evertors in uninjured and functionally unstable ankles. *J Athl Train.* 2002;37(4):494–500.
24. Hertel JN. Functional instability following lateral ankle sprain. *Sports Med.* 2000;29(5):361–371.
25. 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):1055–1061.
26. Stanish W, Curwin S, Mandell S. *Tendinitis: Its Etiology and Treatment.* Oxford, United Kingdom: Oxford University Press; 2000:33–44.
27. Uh BS, Beynnon BD, Helie BV, Alosa DM, Renstrom PA. The benefit of a single-leg strength training program for the muscles around the untrained ankle. *Am J Sports Med.* 2000;28(4):568–573.
28. Staples OS. Result study of ruptures of lateral ligaments of the ankle. *Clin Orthop Rel Res.* 1972;85:50–58.
29. Kaminski TW, Perrin DH, Mattacola CG, Sczerba J, Bernier JN. The reliability and validity of ankle inversion and eversion torque measurements from the KinCom II isokinetic dynamometer. *J Sport Rehabil.* 1995;4(3): 210–218.

Jason Fox, MS, LAT, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Carrie L. Docherty, PhD, LAT, ATC, contributed to conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. John Schrader, HSD, LAT, ATC, contributed to conception and design and drafting, critical revision, and final approval of the article. Trent Applegate, HSD, MPH, contributed to conception and design and critical revision and final approval of the article.

Address correspondence to Carrie L. Docherty PhD, LAT, ATC, University Gymnasium, 2805 East 10th Street, Indiana University, Bloomington, IN 47408. Address e-mail to cdochert@indiana.edu.