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

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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.
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. 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. 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’ 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 quadratic trend that 90°/s is the optimal testing speed for inversion 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. This also diminished the potential for dynamic hamstring activity falsely contributing to the generated torque. 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 used similar testing procedures in their reliability testing.

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 control]), 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 (F1,38 = 7.92, P < .01, η2 = .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 (F1,38 = 0.56, P = .46, η2 = .01, power = .11), eversion (F1,38 = 1.38, P = .25, η2 = .04, power = .21), or dorsiflexion-torques standardized to 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.
increased plantar-flexion torque. Previous authors identified the ability could occur after an initial ankle sprain and lead to decreased peak 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 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 after a lateral ankle sprain. The gastrocnemius-soleus complex age to both the ligamentous and musculotendinous structures and their relationship to injury. The formation of fibrous tissue FAI. Finally, little is known about the muscle-fascia interfaces and the muscle's ability to lengthen during activity. 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. 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. Regardless of population, mode of testing, or type of contraction, this finding is consistent.

**Plantar-Flexor and Dorsiflexor Muscle Groups**

Only limited research has been conducted focusing on plantar-flexion or dorsiflexion torque deficits in individuals with a history of ankle instability. Additionally, the previous findings investigating plantar-flexion torque were inconclusive. One set of authors reported no plantar-flexion torque deficits, one group identified an increase in plantar-flexion torque in the injured limb, and another group 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 or a history of a lateral ankle sprain were tested. Additionally the mode of testing varied among these studies: McKnight and Armstrong and Baumhauer et al tested participants concentrically, and Ternansen et al 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 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 identified arthrogenic muscle inhibition of the soleus muscle in participants with unilateral FAI. The authors suggested that changes in different feedback could contribute to both muscle inhibition and FAI. 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 muscle's ability to lengthen during activity. Further research is needed in this area to substantiate these findings.

**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.

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

<table>
<thead>
<tr>
<th>Movement</th>
<th>Control Group (n = 20) Peak Torque/Body Weight</th>
<th>Group (n = 20) Peak Torque/Body Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Matched Limb</td>
<td>FAI Limb</td>
</tr>
<tr>
<td></td>
<td>Uninjured Limb</td>
<td>FAI Limb</td>
</tr>
<tr>
<td>Inversion</td>
<td>0.52 ± 0.12</td>
<td>0.53 ± 0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.56 ± 0.13</td>
</tr>
<tr>
<td>Eversion</td>
<td>0.54 ± 0.15</td>
<td>0.57 ± 0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.56 ± 0.12</td>
</tr>
<tr>
<td>Plantar-flexion</td>
<td>1.96 ± 0.66a</td>
<td>1.56 ± 0.47a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.79 ± 0.67</td>
</tr>
<tr>
<td>Dorsiflexion</td>
<td>1.29 ± 0.57</td>
<td>1.38 ± 0.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.46 ± 0.69</td>
</tr>
</tbody>
</table>

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 (F1,38 = 0.36, P = .55, η2 = .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.

**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. Conversely, the more recent studies, including ours, did not identify any significant eversion torque deficits in FAI participants. These 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 and agree with others who also did not identify a significant deficit. One potential reason for these discrepancies is the mode and speed of testing. Testing speeds of previous investigations ranged from 30 to 300°/s, and mode of testing included both eccentric and concentric contract-
tions. Such variety in testing procedures makes it difficult to interpret and compare previous findings.

**Limitation**

Reliability of the KinCom dynamometer has been established. 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**


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.

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