Talofibular Interval Changes After Acute Ankle Sprain: A Stress Ultrasonography Study of Ankle Laxity

Theodore Croy, Susan Saliba, Ethan Saliba, Mark W. Anderson, and Jay Hertel

Introduction: Quantifying talocrural joint laxity after ankle sprain is problematic. Stress ultrasonography (US) can image the lateral talocrural joint and allow the measurement of the talofibular interval, which may suggest injury to the anterior talofibular ligament (ATFL). The acute talofibular interval changes after lateral ankle sprain are unknown.

Methods: Twenty-five participants (9 male, 16 female; age 21.8 ± 3.2 y, height 167.8 ± 34.1 cm, mass 72.7 ± 13.8 kg) with 27 acute, lateral ankle injuries underwent bilateral stress US imaging at baseline (<7 d) and on the affected ankle at 3 wk and 6 wk from injury in 3 ankle conditions: neutral, anterior drawer, and inversion. Talofibular interval (mm) was measured using imaging software and self-reported function (activities of daily living [ADL] and sports) by the Foot and Ankle Ability Measure (FAAM).

Results: The talofibular interval increased with anterior-drawer stress in the involved ankle (22.65 ± 3.75 mm; P = .017) over the uninvolved ankle (19.45 ± 2.35 mm; limb × position F1,26 = 4.9, P = .035) at baseline. Inversion stress also resulted in greater interval changes (23.41 ± 2.81 mm) than in the uninvolved ankles (21.13 ± 2.08 mm). A main effect for time was observed for inversion (F2,52 = 4.3, P = .019, 21.93 ± 2.24 mm) but not for anterior drawer (F2,52 = 3.1, P = .055, 21.18 ± 2.34 mm). A significant reduction in the talofibular interval took place between baseline and week 3 inversion measurements only (F1,26 = 5.6, P = .026). FAAM-ADL and sports results increased significantly from baseline to wk 3 (21.9 ± 16.2, P < .0001 and 23.8 ± 16.9, P < .0001) and from wk 3 to wk 6 (2.5 ± 4.4, P = .009 and 10.5 ± 13.2, P = .001). Conclusions: Stress US methods identified increased talofibular interval changes suggestive of talocrural laxity and ATFL injury using anterior drawer and inversion stress that, despite significant improvements in self-reported function, only marginally improved during the 6 wk after ankle sprain. Stress US provides a safe, repeatable, and quantifiable method of measuring the talofibular interval and may augment manual stress examinations in acute ankle injuries.

Keywords: imaging, joint instability, strain

Lateral ankle sprains are a common injury occurring during sports or military training and result in talocrural joint laxity, swelling, and disability.1–3 Approximately 30% of patients suffering an initial ankle sprain will develop chronic ankle instability, a condition characterized by recurrent ankle sprains, prolonged symptoms, and dysfunction.4–6 Grading of ankle sprains attempts to quantify injury to the anterior talofibular ligament (ATFL) using a categorical scale based on the degree of laxity, information that has been used to make treatment decisions.7,8 Unfortunately, grading ankle laxity based on manual anterior-drawer and talar-tilt exams is problematic and unreliable.9 Kerkhoffs et al10 identified a mean increase in anterior talar translation of 2.2 ± 1.2 mm among 9 ATFL sectioning experiments and indicated that talocrural laxity can be used as a measure of ATFL injury. Ankle arthrometry studies have demonstrated an increase in in vivo anterior talar displacement of 5.5 mm over the uninvolved ankle at 3 days after ankle sprain.2 Glaser et al11 reported 7.4 mm of talar translation using ultrasonography (US) in acutely sprained ankles in neutral and stressed positions; findings of ATFL damage that were further supported by surgical findings. Mechanical laxity of the talocrural joint has been shown to contribute significantly to the onset of chronic ankle instability, and initial management may be improved with changes in both diagnosis and appropriate therapy.12

Stress US can be used for real-time evaluation of the ankle and allows the visualization of injured ankle ligaments, particularly the ATFL.13,14 Acute ATFL injuries may appear stretched, edematous, or torn while under anterior-drawer stress.15,16 Brasseur et al17 reported that the apparent length of the ATFL can be measured by measuring the interval between the lateral malleolus origin and the talus in acute sprain copers and those with chronic
ankle instability using stress US. It is unclear if stress US can identify changes in joint integrity over time and if changes in joint integrity are accompanied by changes in self-reported function.

The weeks following an ankle injury are characterized by an acute episode of disability with ankle pain, laxity, swelling, limited joint motion, and gait difficulty; however, these symptoms often rapidly improve over days to weeks after the injury. By 6 weeks after injury, 95% of West Point cadets with ankle sprains had returned to sports in a study by Gerber et al, with 100% returning to full activity at 6 months. Self-reported function improves dramatically, with either standard care or accelerated rehabilitation. The initial mechanical ankle laxity may be present acutely and could persist over 8 weeks with increased anterior talar translation and inversion rotation, and it may or may not improve, even with rehabilitation. Hubbard reported that feelings of ankle instability are reported in 7% to 42% of subjects up to 1 year after injury, symptoms that are likely related to ATFL damage. There is a need for quantitative evaluation of acute ligament damage after ankle sprain as a means to better identify therapeutic programs that may lead to better patient outcomes.

The purpose of this study was to evaluate the effects of acute lateral ankle injury and time on the talofibular interval using stress US and to investigate the changes in self-reported function over a 6-week period. We hypothesized that acutely sprained ankles would demonstrate increased talofibular interval measurements during anterior-drawer or inversion-stress maneuvers and that these increases would remain over the 6 weeks after ankle sprain while self-reported function scores would improve.

**Methods**

We recruited university students and local community citizens to participate in our research. Potential participants were contacted via e-mail, newsletters, and posted flyers. Figure 1 delineates a flowchart of subjects through the study.

**Study Design**

This study was a cohort design created to follow a group of individuals who had recently suffered a lateral ankle sprain over the first 6 weeks of their recovery.

**Participants**

Individuals were included if they had recently suffered a lateral ankle sprain within the 14 days before the baseline visit and agreed to follow-up visits at 3 and 6 weeks from injury. Subject demographics are shown in Table 1.

![Figure 1 — Flowchart of subjects through study. Abbreviations: LTFU, lost to follow-up.](image)
Volunteers were excluded if they were >14 days from injury, had a history of surgery or fracture of the ankle, or had broken skin around the foot/ankle region. One subject suffered a contralateral ankle injury 6 months after the original ankle injury, and another suffered 2 injuries to the same ankle. All 4 injuries were entered for analysis. Subjects provided written informed consent, and the study methods were approved by the University of Virginia institutional review board. Subjects lost to follow-up (n = 3) during the study period were analyzed according to an intent-to-treat method. Each subject was financially compensated for completion of the study.

Procedures

US imaging was performed 3 times (baseline, week 3, and week 6) on both the involved and uninvolved ankle with a GE Logiqbook PRO (Westborough, MA) portable US unit using a 38-mm linear-array transducer probe operating at 10 MHz and scanning at a depth of 30 mm. Both ankles were imaged under 3 conditions (neutral position, anterior-drawer stress, and ankle-inversion stress) with 3 images captured during each condition. US testing procedures used in this study have been previously published in subjects without ankle injuries and with a history of lateral ankle sprain.

Anterior drawer was applied using a modified Telos GA-II/E multijoint stress device (Telos, Weiterstadt, Germany) with the subject in a side-lying position and the tested ankle resting in the device with the heel supported and blocked from movement. The examiner applied a gradual amount of posteriorly directed force up to 125 N with a padded transducer against the tibia, simulating the motion of an anterior-drawer test. Inversion stress was applied also by the Telos device while the subject was supine and the rear foot secured into a pivoting attachment allowing inversion and eversion motion. The examiner manually inverted the ankle to a perceived and tolerable end point (mean = 25°), and then the ankle was fixed in that position while imaged. Between imaging trials, the forces were released and then reapplied for subsequent imaging. Digital images were stored as jpeg files for later measurement.

Measurements were performed by a single examiner, blinded to ankle condition (neutral, anterior drawer, inversion), side (involved or uninvolved), the time since injury (baseline, 3 or 6 weeks), and the results of the measurement. All measurements were performed with ImageJ software, a public-domain, Java-based image-processing program developed by the National Institutes of Health (Bethesda, MD). Each US image had a field of view of 13.3 by 10.8 cm in size and 521 by 412 pixels in resolution (Figure 2). A digital caliper was used to standardize the linear measurement to 13.8 pixels/mm for all images. The dependent variable of interest was the talofibular interval length, operationally defined as the distance between the lateral malleolar origin and talar insertion of the ligament when viewed on an ultrasound image.

### Table 1 Participant Demographics (n = 25), Mean ± SD

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>21.83 ± 3.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.20 ± 8.60</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>72.66 ± 13.80</td>
</tr>
</tbody>
</table>

Figure 2 — Acute lateral ankle sprain (A) in a neutral position and (B) with ankle inversion. The line depicts the anatomic origin of the anterior talofibular ligament on the anterolateral aspect of the lateral malleolus (LM) crossing the ligament and terminating on the talar insertion. Hypoechoic fluid is observed in the anterolateral gutter (arrow).
image. An increase in the talofibular interval hypotheti-
cally means an increase in talocrural-joint laxity as the
talus translates anteriorly or rotates medially relative to
the fibula. The measurement reliability for these methods
ranges from .77 to .91 between examiners from .93 to .96
for a single examiner.  

Subjects were screened and completed the Modified
Ankle Instability Instrument at the first visit. The Foot
and Ankle Ability Measure (FAAM) activity of daily living
(ADL) and sports subscales were completed at the first
visit and at week-3 and week-6 follow-up visits. This
self-reported disability scale consists of a 21-point ADL
portion and an 8-point sports subscale with test–retest
reliabilities of .89 and .87, respectively.  

Statistical Analyses

An a priori sample-size estimate was calculated using
a power analysis for the talofibular interval difference
from the anterior-drawer measure. In a pilot study, we
found a mean talofibular interval difference of 1.79 mm
between neutral and anterior drawer stress and estimated
that a minimum sample size of 18 subjects was needed
to achieve adequate statistical power of .8 to detect a
difference in anterior-drawer measurements.

Two 2 × 2 analyses of variance (ANOVAs) were
used to evaluate the talofibular interval at baseline across
limb (involved vs uninvolved) and position (neutral vs
anterior drawer and neutral vs inversion stress). Two
2 × 3 repeated-measures ANOVAs were then used to
evaluate the mean talofibular interval differences between
position (neutral and anterior drawer or neutral and
inversion) over time (baseline, 3 weeks, 6 weeks) in the
involved limb only. Significant results at baseline were
analyzed post hoc with paired t tests, and significant
results over time were analyzed with simple contrasts
comparing baseline with week 3 and week 3 with week
6. A repeated-measures MANOVA analyzed both FAAM-
Sport and FAAM-ADL scores over time, and significant
results were analyzed with repeated-contrast multipl-
comparison procedures. Level of significance was set a
priori at P < .05.

Results

Baseline data were collected 5.9 ± 4.5 days from a plan-
tar-flexion/inversion-type ankle injury from 25 subjects
with 27 injuries. Subsequent follow-up collection periods
were at 22.2 ± 4.3 (week 3) and 45.6 ± 6.0 (week 6) days
from the date of injury. Regarding the involved limb, 13
were first-time injuries, 5 were second injuries, and the
remaining 9 reported >2 prior ankle injuries. Regarding
the contralateral limb, 9 had no prior ankle sprain, 8
subjects reported 1 prior ankle sprain, and 10 reported to
have >2 prior ankle sprains. Both anterior drawer and
inversion stress resulted in differences between the talo-
figular interval of both uninvolved and involved ankles
at baseline, but the combination of anterior-drawer stress
and the involved limb resulted in marked increases in the
talofibular interval (limb × position interaction F1,26 =
4.97, P = .035), with a mean difference of 3.19 ± 4.78 mm
(SEM = 0.92 mm, 95% CI [1.29, 5.08], t26 = 3.5, P = .002;
Table 2). No interaction was observed between limb and
inversion stress (F1,26 = 1.89, P = .180). Measurements
taken with the ankle in a neutral position without stress
were significantly greater in the involved ankle, with a
mean difference of 1.15 ± 2.75 mm (SEM = 0.53 mm,
95% CI [0.06, 2.23], t26 = 2.7, P = .039). No interaction
(F2,52 = 0.81, P = .45) or main effect (F2,52 = 3.07, P =
.055) was observed for time and anterior drawer; how-
ever, both the results indicate that a slight trend toward a
reduction in the talofibular interval during this maneuver
may have occurred over the 6-week period. Inversion
and time also did not demonstrate an interaction (F2,52
= 1.07, P = .35); however, a main effect for time was
observed (F2,52 = 4.29, P = .019) with a reduction occur-
ing between the baseline and week-3 evaluations (F1,26
= 5.6, P = .026) of 1.20 ± 2.83 mm (SEM = 0.54 mm,
95% CI [0.08, 2.32]). The talofibular interval remained
elevated with anterior drawer testing through week 6 and
remained 1.72 ± 3.3 mm greater (SEM = 0.64 mm, 95%
CI [0.41, 3.03], t26 = 2.7, P = .012) than the uninvolved
ankle measurement taken at baseline. FAAM-Sport and
FAAM-ADL demonstrated significant improvements
over time (Wilks’ lambda = .554, multivariate
F = 12.19,
P < .0001), with improvements noted on both question-
naires at each follow-up visit (Figure 3).

Table 2 Descriptive Statistics on the Talofibular Interval (mm), Mean ± SD

<table>
<thead>
<tr>
<th>Limb</th>
<th>Position</th>
<th>Baseline</th>
<th>Week 3</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uninvolved (n = 25)</td>
<td>Neutral</td>
<td>16.64 ± 2.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anterior drawer</td>
<td>19.45 ± 2.35†</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inversion</td>
<td>21.13 ± 2.08†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involved (n = 27)</td>
<td>Neutral</td>
<td>17.78 ± 2.89*</td>
<td>17.08 ± 2.37</td>
<td>17.14 ± 1.93</td>
</tr>
<tr>
<td></td>
<td>Anterior drawer</td>
<td>22.65 ± 3.76*†</td>
<td>21.31 ± 2.42</td>
<td>21.18 ± 2.34</td>
</tr>
<tr>
<td></td>
<td>Inversion</td>
<td>23.41 ± 2.81*†</td>
<td>22.20 ± 1.93‡</td>
<td>21.93 ± 2.24</td>
</tr>
</tbody>
</table>

*P < .05 vs uninvolved limb. †P < .05 vs neutral. ‡P < .05 vs baseline.
Discussion

Anterior drawer and inversion stress produce talofibular motion and interval changes that can be repeatedly imaged with US and later measured to detect significant, objective, and clinically important information regarding talocrural-joint laxity during the acute and subacute phases after a lateral ankle sprain. US imaging with the ankle in a neutral position demonstrated small but significant increases in the talofibular interval suggestive of either anterior talar malposition, internal rotation, or both. Six weeks’ time did not result in reductions in the magnitude of the talofibular interval; however, slight interval reductions were observed between baseline and week 3 during inversion stress. Excessive talofibular interval changes remained at the end of the study, despite improvements in self-reported function suggestive of talocrural laxity.

We used digital imaging software24 to measure the talofibular interval, the linear distance between the origin and insertion of the ATFL visualized in the plane of the ligament and directly along the fibers, before and during ankle-stress maneuvers. The talofibular interval changed as a result of both the stress and the injury in this study. The ATFL should restrict talofibular motion during anterior drawer as it is designed to brace the talus within the talocrural joint. Increases in anterior talar motion, either during a manual anterior-drawer test or detected on an US image taken during a similar joint load, suggest impaired ATFL function.11,26 Our results are similar to those of Glaser et al,11 who used US and dynamic joint stress to identify ATFL injuries from lateral ankle sprains in 72 subjects. Positive US exams for ATFL tears demonstrated a mean increase in ATFL length of 7.4 mm (range 6–12 mm) from unstressed to stressed conditions and further demonstrated a 90.6% agreement between US and intraoperative findings.11 We used a 3-image US sequence and used the mean talofibular interval measurements for analysis. Hubbard and Cordova2 also identified significant anterior laxity in acute ankle injuries over an 8-week time period that did not improve using an instrumented ankle arthrometer. Our subjects were similar to those of Hubbard and Cordova in that they were evaluated in the acute phase of the injury and self-reported similar reductions in disability.2 Although self-reported function improved at the 6-week follow-up, increases in the talofibular interval suggestive of a decrease in ATFL integrity were still observed. It is unclear if further time or treatment would effectively reduce the talofibular interval and restore joint stability to a preinjury level or level similar to that of the contralateral, uninjured ankle.

The 4.8-mm difference between the neutral and anterior-drawer conditions in the involved ankle exceeded the threshold suggested by Gould et al,27 who indicated that elongation of the ATFL >4 mm would result in “ligament failure.” Increases of 2.0 mm28 to 3.9 mm29 of anterior laxity have been shown with cadaveric ATFL-sectioning experiments, and the results of the current in vivo study exceeded those findings. The anterior-drawer talofibular interval difference in the involved limb reduced...
to 4.03 mm between the neutral and anterior-drawer conditions at week 6, indicating that considerable laxity is present acutely and persists as the talocrural-joint capsule undergoes healing in the weeks after a lateral ankle sprain.

Inversion stress resulted in significant talofibular interval changes in both the uninjured and involved ankles, with injured ankles demonstrating the greatest lengthening by a margin of 2.27 mm at baseline compared with the uninjured ankle inversion. The ankle was approximately 15° plantar flexed and inverted to a tolerable end range of motion. The plantar-flexed position is known to produce higher levels of ATFL strain, particularly when combined with inversion. The anatomic orientation of the ATFL shows how the ATFL functions to restrict plantar flexion and inversion and how it is vulnerable during a forced inversion of the ankle. This study employed US at this end range of motion to image the ATFL during positions where it is vulnerable to injury. The increased talofibular interval observed is likely due to the plantar-flexed positioning combined with the internal rotation of the talus, a motion that the ATFL should restrain when intact.

Significant improvements in self-reported function were seen in both activities of daily living and sports performance. Similar improvements in self-reported function at 6 weeks were also observed by Gerber et al. with 95% of subjects returning to full function; however, at 6 months, 40% of those subjects reported residual symptoms and functional deficits. Rapid self-reported improvements over the first 6 weeks after ankle sprain may precede medium- to long-term residual impairments that could contribute to chronic ankle instability. One impairment may be a persistent and abnormal talocrural-joint laxity that may predispose an individual to recurrent injury and symptoms.

Clinicians seeking to develop rehabilitation programs to protect healing ligaments and improve talocrural stability may consider restricting full plantar flexion and inversion to reduce tension on the ATFL as healing occurs. Therapeutic interventions for ankle rehabilitation may consider the use of stress US to measure the talofibular interval to determine the response to treatment. This investigation was limited in that it was a single-plane imaging study through the ATFL to identify changes in talofibular orientation that may indicate reductions in ATFL integrity, leading to increases in talar motion. We did not attempt to qualitatively identify changes in ligament, as this was not the aim of the study, and we chose a quantitative approach to measure talocrural laxity instead. We did not assess subtalar-joint stability and we chose a quantitative approach to measure talocrural-joint integrity that allows a bilateral comparison, as well as between stressed and unstressed conditions. This study improves the clinical understanding of the acute effects of ATFL injury on talocrural-joint stability and the healing response over 6 weeks.

Acknowledgments

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense. Funding for this study was provided by the Retired Army Medical Specialist Corps Association (RAMSCA).

References

8. Bleakley CM, O’Connor S, Tully MA, Rocke LG, Macauley DC, McDonough SM. The PRICE study (protection rest ice compression elevation): design of a randomised


