Evaluation of the Anterior Talofibular Ligament via Stress Sonography in Asymptomatic and Symptomatic Populations

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Objectives—Sonography during externally applied stress has the potential to identify ligamentous instability, but diagnostic parameters for the most commonly sprained ankle ligament, the anterior talofibular ligament (ATFL), have not yet been established. The purpose of this study was to determine normative values of the change in the length of the ATFL in an asymptomatic population during manual stress sonography and to compare these values to those in patients with clinical findings of anterolateral ankle instability.

Methods—Sonography of the ATFL at rest and with maximally applied manual stress was performed bilaterally in 20 asymptomatic volunteers from each of three 10-year age groups from 20 to 50 years. Data were compared to those for 34 patients retrospectively identified who underwent stress sonography of the ATFL for clinical signs and symptoms of chronic anterolateral ankle instability.

Results—In the asymptomatic population (10 men and 10 women), for men, the mean change in ATFL length between stress and neutral positions was 0.44 mm (95% confidence interval [CI], 0.32–0.57 mm). For women, it was 0.43 mm (95% CI, 0.31–0.55 mm). The difference in laxity between sexes was not significant ($P = .85$). In the symptomatic population, the mean ATFL length difference between stress and neutral positions was 1.26 mm (95% CI, 0.97–1.55 mm). A *t* test comparing the mean change in ATFL length showed a statistically significant increase in laxity in the symptomatic group ($P < .0001$).

Conclusions—The normal ATFL shows minimal laxity in both men and women on stress sonography, with significantly greater laxity among patients with ankle instability. Given these findings, stress sonography may have an important role in the imaging diagnosis of anterolateral ankle instability.

Key Words—ankle instability; anterior talofibular ligament; extremities; musculoskeletal (diagnostic); normal ligamentous length; sonography

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Abbreviations
ATFL, anterior talofibular ligament; CI, confidence interval; MRI, magnetic resonance imaging

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In a review of 227 epidemiologic sports studies from 1977 to 2005, the ankle was the most commonly injured body site in 24 of 70 sports, with a sprain being the most common injury of the ankle.[1] In the United States, an estimated 2 million acute ankle sprains occur each year, resulting in an aggregate health care cost of $2 billion.[2,3] The most common mechanism of an ankle sprain is to the lateral ligamentous complex, caused by a combination of ankle inversion and adduction with the foot in plantar flexion.[4–7] The ligament most commonly involved is the anterior talofibular ligament

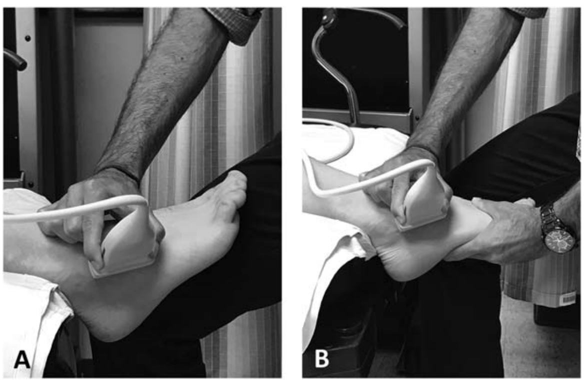
(ATFL), with the calcaneofibular ligament involved in a minority of the injuries.[8,9] Most ankle sprains are treated conservatively with nonsurgical management; however, up to 20% of people continue to have anterolateral instability.[10,11]

Stress sonography of the ankle is a real-time evaluation of the osseous and ligamentous anatomy of the lateral ankle ligamentous complex in maximal plantar flexion and talar tilt.[12–14] We hypothesized that this method may help identify patients with anterolateral ankle instability. The purpose of this investigation was to use sonography to measure the ATFL before and during manual stress to determine the change in ATFL length in an asymptomatic population. After determination of the normal change in ATFL length, we compared these values to those of patients who underwent stress sonography for clinically suspected chronic anterolateral instability.

Materials and Methods

We performed stress sonography of the ATFL of both ankles in asymptomatic volunteers between February and September 2015. Volunteers consisted of personnel working within the radiology department and were excluded if they had any history of a sprain, other trauma, or surgery to either ankle. Each participant provided written informed consent for this study, in accordance with the format recommended by our Institutional Review Board for the use of human subjects.

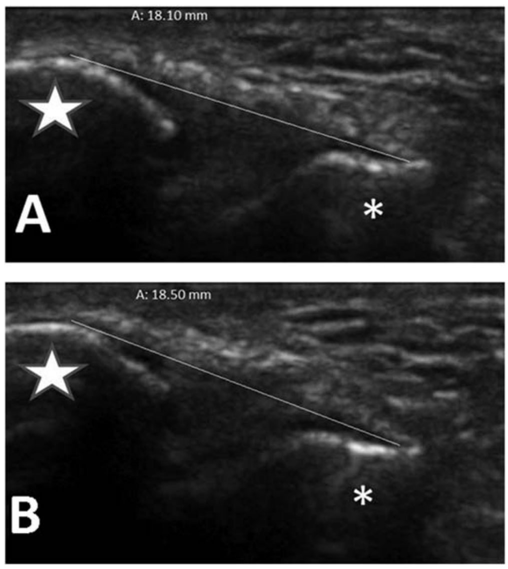
Figure 1. Transducer positioning in a 29-year-old man with no history of ankle trauma. **A**, Transducer and ankle positioning in the neutral position. **B**, Transducer and ankle positioning in plantar flexion and maximally applied manual talar tilt.



For this Institutional Review Board–approved and Health Insurance Portability and Accountability Act–compliant study, the participants were positioned supine with the ankle resting on a stretcher in the neutral position (Figure 1A). The fibers of the ATFL were identified at rest and with maximally applied manual stress using talar tilt with the foot held in plantar flexion (Figure 1B) and the bony attachments in view (Figure 2). The participants were imaged with a compact sonography unit (M-Turbo; SonoSite, Inc, Bothell, WA) using a 13–6-MHz multifrequency linear transducer and standard acoustic coupling gel. Each participant's ankle was imaged at rest then during stress 3 consecutive times for a total of 12 measurements per participant (6 per ankle) in the same session by an attending radiologist with more than 25 years of musculoskeletal sonography experience.

Images of the ATFL were saved to a hard drive, and the ligament was measured with electronic calipers by a radiology resident and attending physician working independently using ImageJ software (National Institutes of Health, Bethesda, MD). The measurements were saved in an Excel spreadsheet (Microsoft Corporation, Redmond WA) that categorized laterality, sex, and age. A

Figure 2. Sonography of the left ankle in a 33-year-old asymptomatic female volunteer. **A**, Sonogram of the fibrillar pattern of the anterior talofibular ligament and bony attachments at the talus (asterisk) and fibular tip (star) in the neutral position measuring 18.1 mm. **B**, Sonogram at the same level in maximally applied stress measuring 18.5 mm.



statistical analysis, including means for neutral and stress for each sex, a *t* test comparing ATFL length between sexes, and intraclass correlation coefficients between observers, was performed with SAS (Cary, NC) software.

We then retrospectively identified patients within our picture archiving and communication system between January 2008 and December 2016 who were referred to our outpatient musculoskeletal ultrasound clinic for the sonographic evaluation of chronic anterolateral ankle instability. Patients were referred to our clinic after being clinically evaluated and receiving a diagnosis of chronic ankle instability from the history and physical examination by foot and ankle surgeons. At our institution, stress sonography of the ATFL is routinely performed in the evaluation of ankle instability. Examinations were performed by 1 of 3 attending musculoskeletal radiologists using either a 12–5-MHz linear or 15–7-MHz compact linear transducer (iU22; Philips Healthcare, Bothell, WA). In cases of complete tears of the ATFL in which the fibers were indistinct or incompletely identified, the bony attachments of the ATFL at the anterolateral aspect of the lateral malleolus and peak of the bony acoustic landmark of the talus were used to determine the change in the talofibular interval.

A statistical analysis included means for neutral, stress, and the mean change between neutral and stress. A *t* test comparing the mean change in ATFL length between the symptomatic and asymptomatic groups was performed. A power analysis and effect size at a power of 0.8 and α of .05 was performed, using the means and standard deviations for both groups

Results

In the asymptomatic volunteers, the ATFL of both ankles was imaged sonographically in 10 men and 10 women from 3 different age groups (20–30, 30–40, and 40–50 years), for a total of 120 ankles. The age groups were chosen to reflect the demographics of patients who most commonly have ankle sprains.[15] The mean ATFL length of both right and left ankles for men at neutral was 19.13 mm (95% confidence interval [CI], 18.59–19.67 mm); at stress it was 19.57 mm (95% CI, 18.98–20.16 mm); and the difference was 0.44 mm (95% CI, 0.32–0.57 mm). The mean ATFL length of both right and left ankles for women at neutral was 17.12 mm (95% CI, 16.53–17.70 mm); at stress it was 17.55 mm (95% CI, 16.94–18.15 mm); and the difference was 0.43 mm (95% CI, 0.31–0.55 mm). The ATFL was longer in both neutral and stress positions in men compared to women ($P < .001$). Although static ligament lengths were longer on average in men, there was no significant change in length between the neutral and stress positions between sexes ($P = .85$; Table 1). Intraclass correlation coefficients for neutral and stress lengths were 0.67 and 0.73, indicating good reliability.[16] Averaging both right and left ankles of both sexes, the mean ATFL length at neutral was 18.12 mm (95% CI, 17.65–18.59 mm); at stress it was 18.56 mm (95% CI, 18.07–19.05 mm); and the difference between neutral and stress was 0.44 mm (95% CI, 0.35-0.52 mm; Table 2).

The symptomatic group initially consisted of a total of 48 patients. Fourteen patients were excluded because of a history of ankle surgery. Therefore, the ATFL was measured in 34 patients (20 women and 14 men) who underwent stress sonographic evaluations using talar tilt in plantar flexion (Figure 3). The age range of the group was 20 to 73 years with an average age of 42 years. Averaging both right and left ankles of both sexes in the population with symptoms of ankle instability, the mean ATFL length at neutral was 17.22 mm (95% CI; 16.34–18.10 mm); at stress it was 18.48 mm (95% CI, 17.54–19.43 mm); and the difference between neutral and stress was 1.26 mm (95% CI, 0.97–1.55 mm). A *t* test comparing the mean change in ATFL length for the symptomatic (mean, 1.26 mm; 95% CI, 0.97–1.55 mm) and asymptomatic (mean, 0.44 mm; 95% CI, 0.35–0.52 mm) populations showed a statistically significant difference between the groups ($P < .0001$; Table 3).

Table 1. Comparison of Mean ATFL Length at Neutral, Stress, and the Difference Between Neutral and Stress in Men and Women in the Asymptomatic Group With *P* Values (*t* Test)

	Men, mm	Women, mm	*P*
Neutral	19.13	17.12	<.001
Stress	19.57	17.55	<.001
Difference	0.44	0.43	.85

Table 2. Mean ATFL Length of Both Sexes in the Asymptomatic Group With 95% CIs

	Mean, mm	95% CI, mm
Neutral	18.12	17.65–18.59
Stress	18.56	18.07–19.05
Difference	0.44	0.35–0.52

This study showed an effect size of 0.6 at 80% power, with 34 patients in the symptomatic group and 60 participants in the asymptomatic group.

Discussion

Techniques for the clinical assessment of lateral ankle injuries include physical examination, radiography (including stress radiography), magnetic resonance imaging (MRI), arthrograms, arthrometry, and sonography (including stress sonography).[12] Physical examination maneuvers used for the detection of lateral ankle abnormalities are the anterior drawer, talar tilt, and inversion-eversion stress tests.[17–23] The physical examination is limited by subjectivity and difficulty discerning the degree of ligament stability as well as identifying specific ligament involvement.[24] Stress radiography for the assessment of mechanical ankle laxity has been shown to be unreliable.[18,25–32] Magnetic resonance imaging can show the site of ankle injury but is expensive and time-consuming and lacks the portability and availability of sonography. Oae et al[33] compared the arthroscopic appearance of 34 patients with acutely and chronically injured ATFLs to the sonographic appearance and found 91% accuracy, 100% sensitivity, and 33% specificity in identifying injured ligaments. It has been estimated that 25% to 40% of lateral ankle ligament injuries may be associated with prolonged disability, in most cases chronic pain or recurrent instability.[11] A review conducted by Rodriguez-Merchan[34] of the diagnosis and treatment of chronic ankle instability described low reliability of testing lateral ankle stability in a clinical setting. Also, Rodriguez-Merchan[34] stated that the sensitivity of MRI may be inadequate to detect lesions in patients with chronic ankle instability before surgery, thereby requiring arthroscopy in symptomatic patients with negative MRI results.

The results of this study show that lengths of the ATFL in both neutral and stressed positions can be effectively measured with manual stress sonography. The ATFL is slightly longer in men, and the average normal elongation by manual stress is 0.4 mm in both men and women, which is very small in relation to the ligament length. This finding is in accordance with the findings of Jeys et al,[35] which indicated that normal ankle ligament changes with motion are less than 5%. The mean neutral ATFL length for both men and women of 18.12 mm in our study is within the range of the reported value of 17.81 ± 3.05 mm as measured in osteoligamentous preparations of 20 cadaveric ankles by Siegler et al.[36] Additionally, the mean length of the ATFL for both men and women in our study aligns with the value of 16.1 ± 3.63 mm as measured sonographically in 10 ankles by Brasseur et al.[37] de Asla et al[38] reported in vivo ATFL length changes in healthy ankles from 16 mm at neutral to 20.8 mm during an active ankle plantar flexion and supination motion using a dual-orthogonal fluoroscopic and MRI technique. The average in vivo length of the ATFL was 15.8 ± 2.9 mm. The difference between the mean change score in our study (0.4 mm) versus that described by de Asla et al[38]

Figure 3. Sonography of the left ankle in a 46-year-old woman presenting with anterolateral ankle pain and instability after a remote ankle injury. **A**, Sonogram of the anterior talofibular ligament at the bony attachments at the talus (asterisk) and fibular tip (star) in the neutral position measuring 19.6 mm. **B**, Sonogram in maximally applied stress measuring 22.3 mm.

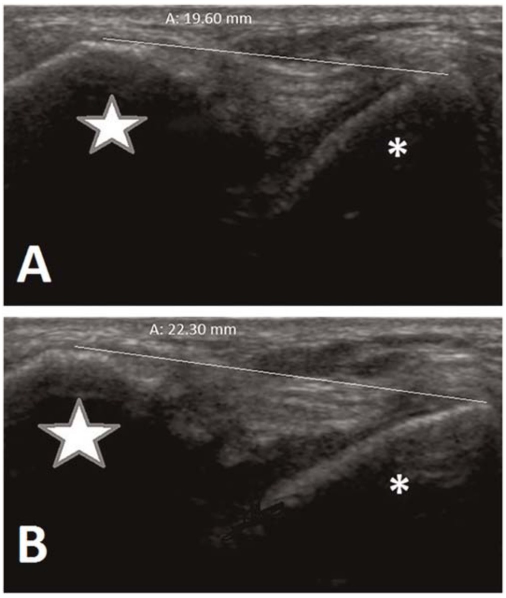


Table 3. Comparison of Mean ATFL Length at Neutral, Stress, and the Difference Between Neutral and Stress in the Symptomatic and Asymptomatic Groups With *P* Values (*t* Test)

	Asymptomatic, mm	Symptomatic, mm	*P*
Neutral	18.12	17.22	.07
Stress	18.56	18.48	.88
Difference	0.44	1.26	<.0001

via a combined MRI and fluoroscopic technique could be due to differences in the superior resolution offered by sonography as well as differences in stress techniques.

Croy et al[39] conducted a similar investigation that measured the percentage of change in the ATFL at neutral, mechanical inversion, and anterior drawer stress in healthy patients compared to patients with a history of ankle sprain. The average ATFL lengths between sexes in the asymptomatic population of our study at neutral (18.12 mm) and stress (18.6 mm) are within the ranges reported by Croy et al[39] for neutral (18.6 ± 1.5 mm) and stress (18.7 ± 1.9 mm with anterior drawer stress and 19.9 ± 2.3 mm with inversion stress). We showed a statistically significant difference and moderately large effect size when comparing the change of the ATFL length in asymptomatic participants to patients with anterolateral ankle instability. In this study, the mean change in ATFL length (1.26 mm) was nearly 3 times the mean change in length between neutral and stress in the asymptomatic population (0.44 mm). This change is a significant difference that could be used in the evaluation of patients with ankle instability. The findings in this study are in concordance with those of Croy et al,[39] which concluded that the percentage of change in ATFL length with mechanical anterior drawer and inversion stress was statistically significantly greater than in healthy individuals.

A potential limitation of this study was that the exact force applied during manual stress was not measured; however, maximally applied stress in plantar flexion and talar tilt is reproducible and closely resembles a clinical environment. Another limitation was a selection bias due to the retrospective identification of the symptomatic cohort. Also, the clinical details of the symptomatic patients were not available; thus, neither the diagnostic criteria nor exact chronicities of their injuries were defined. Furthermore, the patient population referred to our diagnostic musculoskeletal ultrasound clinic may not be widely generalizable.

In conclusion, we have used stress sonography to establish normal values for ATFL laxity and have shown significantly increased laxity among patients with clinical anterolateral ankle instability. Future studies should include a prospective analysis of imaging characteristics such as ATFL caliber and thickness, presence or absence of fiber disruption, and echogenicity, taken together with stress sonography to evaluate patients with chronic anterolateral ankle instability.

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