Active ankle motion may result in changes to the talofibular interval in individuals with chronic ankle instability and ankle sprain copers: a preliminary study

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Introduction: Alterations in talocrural joint arthrokinematics related to repositioning of the talus or fibula following ankle sprain have been reported in radiological and clinical studies. It is unclear if these changes can result from normal active ankle motion. The study objective was to determine if active movement created changes in the sagittal plane talofibular interval in ankles with a history of lateral ankle sprain and instability.

Methods: Three subject groups [control ($n=17$), ankle sprain copers ($n=20$), and chronic ankle instability ($n=20$)] underwent ultrasound imaging of the anterolateral ankle gutter to identify the lateral malleolus and talus over three trials. Between trials, subjects actively plantar and dorsiflexed the ankle three times. The sagittal plane talofibular interval was assessed by measuring the anteroposterior distance (mm) between the lateral malleolus and talus from an ultrasound image. Between group and trial differences were analyzed with repeated measures analysis of variance and *post-hoc t*-tests.

Results: Fifty-seven subjects participated. A significant group-by-trial interaction was observed ($F_{4,108}=3.5$; $P=0.009$). The talofibular interval was increased in both copers [2.4 ± 3.6 mm; 95% confidence interval (CI): 0.73–4.1; $P=0.007$] and chronic ankle instability (4.1 ± 4.6 mm; 95% CI: 1.9–6.2; $P=0.001$) at trial 3 while no changes were observed in control ankle talar position (0.06 ± 2.8 mm; 95% CI: -1.5 – 1.4 ; $P=0.93$).

Discussion: The talofibular interval increased only in subjects with a history of lateral ankle sprain with large clinical effect sizes observed. These findings suggest that an alteration in the position of the talus or fibula occurred with non-weight bearing sagittal plane motion. These findings may have diagnostic and therapeutic implications for manual therapists.

Keywords: Arthrokinematics, Instability, Talocrural, Ultrasound

Introduction

Lateral ankle sprains account for a considerable number of athletic and military training injuries.^{1–3} The resulting pain, disability, and swelling can adversely impact joint health and may contribute to the onset of post-traumatic ankle osteoarthritis.⁴ Approximately 20–40% of individuals that suffer an ankle sprain may go on to suffer chronic ankle instability (CAI) characterized by recurrent instability symptoms, mechanical laxity, balance deficits, and

arthrokinematic changes.⁵ Cameron *et al.*⁶ found that the incidence rate of ankle sprain in members of the US military is 34.95 ankle sprains per 1000 person-years. Ankle sprain copers represent those 60–80% of ankle sprain sufferers who have sustained an ankle sprain, but recovered nearly completely and do not complain of symptoms of CAI.⁷ These ankle sprain copers demonstrate similar movement patterns to individuals with functional ankle instability and are suggested to be an appropriate comparison group to subjects with CAI as they have a history of ankle sprain; however, they do not report persistent ankle symptoms.⁷

The specific arthrokinematic changes of the talocrural joint resulting from lateral ankle sprains include a restriction in posterior talar glide possibly due to an

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anteriorly malpositioned talus^{8–11} or changes in the fibular position.¹² Clinicians have successfully treated impaired ankle motion using anteroposterior talar mobilizations along with ankle exercises and other manual therapy procedures.^{13–15} This evidence indicates that manual therapy procedures and ankle exercises may result in rapid treatment success potentially accompanied by clinically helpful changes in talar position,^{16,17} an effect that may also be associated with range of motion improvements, pain reductions, and improvements in self-reported function.^{8,18} Denegar *et al.*¹⁶ identified restricted posterior talar glide using a manual method of assessment in subjects with a history of lateral ankle sprain in the previous 6 months. Vicenzino *et al.*⁸ also identified restrictions in ankle dorsiflexion accompanied by restrictions in posterior talar glide in subjects with recurrent ankle sprain—an impairment that was subsequently improved following a mobilization with movement (MWM) manual therapy procedure. This evidence suggests that clinicians can detect arthrokinematic talocrural impairments and correct them within a treatment session.

The use of ultrasound in the evaluation of the anterior talofibular ligament (ATFL) and lateral talocrural joint has demonstrated good to excellent reliability in the measurement of the talus relative to the fibula during stress positions in control subjects and subjects with a history of ankle injury. This method has been used to identify laxity changes resulting from lateral ankle sprain injuries.^{19,20} Several authors have described the use of ultrasound at the ankle to help clinicians understand the techniques required to identify tendon and ligament injuries, in addition to changes in ankle laxity.^{21–24} Because of the orientation of the ultrasound probe in the transverse plane, changes in the talofibular interval can be evaluated and may represent changes in the sagittal plane position of the talus.^{20,25} Ultrasound imaging may reveal subtle changes in the talofibular interval that appear to be a result of injury to the anterior talofibular ligament.²⁶

The purpose of this study was to use ultrasound imaging to view the lateral talocrural joint and to measure the sagittal plane talofibular interval changes resulting from active ankle motion in ankles with a history of lateral ankle sprain and instability.

Methods

Participants

Control subjects, ankle sprain copers who have suffered one ankle sprain at some point during their lives, and subjects with CAI were considered for inclusion in the study. Potential subjects were contacted via flyers, emails, and public service announcements throughout our campus population. Subjects were included in the study based upon their answers to the Ankle Instability Instrument questionnaire.²⁷

Copers were those who answered ‘yes’ to a history of a lateral ankle sprain and whom reported that it had only occurred once and that it was greater than 1 year prior, but answered ‘no’ to questions 4 through 8 regarding instability symptoms. Subjects with CAI were those who answered ‘yes’ to a history of lateral ankle sprain and who reported two or more recurrent injuries and selected ‘yes’ for two or more questions regarding symptoms of instability. Subjects were excluded if they had a past history of ankle fracture, surgery, or had broken skin around the foot/ankle region. Control subjects were included if they answered ‘no’ to a history of previous ankle sprain. All participants signed an informed consent form approved by the University of Virginia Institutional Review Board for Human Subjects Research.

Instrumentation

Ultrasound (US) imaging was performed with a GE Logiqbook PRO (Westborough, MA, USA) portable US unit using a 38-mm linear array transducer probe operating at 8 MHz and scanning at a depth of 30 mm. Digital images were stored on the device’s hard drive and transferred to a flash drive in jpg format for later measurement. Measurements were performed using ImageJ software. ImageJ is a free public domain, Java-based image processing program that was developed by the National Institutes of Health (Bethesda, MD, USA).²⁸ The US image had a field of view of 13.3 × 10.8 cm in size and 521 × 412 pixels in resolution. A digital caliper was used to standardize the linear measurement to 13.8 pixels/mm for all images.

Procedures

Subjects provided demographic information on screening questionnaires. Height and mass were measured prior to data collection. US testing began with the subject in sidelying with the tested ankle resting upon a 50 × 50 × 12 cm box and in a neutral ankle dorsal and plantar flexed position (Fig. 1). The examiner was a physical therapist with 4 years experience in US imaging and board certified in orthopedic physical therapy. The examiner palpated the lateral malleolus and talus and then applied US conducting gel and the US transducer probe along the lateral ankle. The examiner oriented the lateral malleolus to the right side of the screen and identified the lateral talar cartilage and the neck of the talus where the ATFL attaches. After optimizing the image and centering the talofibular interval within the field of view, the examiner copied the image to file for storage and removed the probe. In order to make each image independent of the previous one, the subject was instructed to plantar and dorsiflex the ankle three times and then repositioned the ankle in neutral (0° plantar and dorsiflexion). The examiner reapplied the transducer probe, captured an image,

Figure 1 Ankle movements between imaging trials. The subject fully dorsiflexed, then plantarflexed the ankle three times before returning to the neutral position for the next imaging trial.

and removed the probe. The participant then performed a second bout of three repetitions, and returned to the neutral position where the examiner reapplied the probe, and captured the third image. Figure 2 depicts the sequence of three US images captured in the study as well as the relevant bony landmarks.

Blinded images were measured later using ImageJ software.²⁸ Each image was coded to blind group allocation, subject identification, and trial from the examiner. Digital calipers were used to measure the distance between the anterolateral aspect of the lateral malleolus to the talus just anterior to the lateral talar articular cartilage. These two bony landmarks appear hyperechoic under US and are discrete locations to select for the origin and insertion of the ATFL when using US imaging.²⁹ The talofibular interval is operationally defined as the anteroposterior distance between these two bony landmarks when measured on an US image taken in parallel with the length of the ATFL fibers. The examiner performed one measurement per image trial. Intratester reliability of these methods was established with the intraclass correlation coefficient of ($ICC_{3,1}$) 0.83 (95% CI: 0.63–0.93) for an average of measurements. Intertester reliability has been previously established.¹⁹ Data were stored in an MS Excel spreadsheet and later analyzed with SPSS v19.0 (Chicago, IL, USA). Results were considered significant at the $P < 0.05$ level.

Statistical analysis

A 3×3 repeated measure analysis of variance was performed across the within subjects, repeated variable of trial at three levels (trials 1–3) and then across the

between subject variable of group also with three levels: control, copers, and CAI. Significant results were followed by paired t -tests. Cohen's d effect sizes (ES) were calculated based upon the control group standard deviation for within group changes across trials, and for between group changes at the third trial only. The Cohen's d ES differences used to characterize the effect of the change in talofibular interval and they can give an indication of the clinical meaningfulness of the change. Cohen's d is evaluated on a scale of $ES > 0.8$ =strong effect, potentially clinically meaningful, 0.5 – 0.8 =moderate, 0.2 – 0.5 =weak, and <0.2 =small effect.³⁰ This was a retrospective analysis and a *post-hoc* power analysis was performed in G*Power v3.1.5 to evaluate a repeated measure analysis of variance. In order to identify a moderate ES of 0.5 , a sample size of 57 was needed with a critical F value of 2.46 and a resulting power of 0.85 .

Results

Fifty-seven participants consented to the study and the demographics are listed in Table 1. A significant interaction was observed between trial and group ($F_{4,108} = 3.5$; $P = 0.009$) and a main effect for trial ($F_{2,108} = 15.9$; $P < 0.0001$) was identified. *Post-hoc* t -tests identified no differences across trials in the control group between trial 1 and trial 3 (0.06 ± 2.8 ; 95% CI: -1.5 – 1.4 ; $P = 0.93$); however, the talofibular interval of ankle sprain copers was greater at trial 3 than both trial 1 (2.4 ± 3.6 mm; $t_{19} = 3.01$; $P = 0.007$) and trial 2 (2.2 ± 3.3 mm; $t_{19} = 3.08$; $P = 0.006$). Similar results were identified in CAI with trial 3 significantly increased over trial 1 ($t_{19} = 4.01$; $P = 0.001$) and trial 2

Figure 2 Sequence of ultrasound (US) imaging of the anterolateral aspect of the ankle across the lateral malleolus (LM) to the talus (T). Each image was taken after the subject actively plantar flexed and dorsiflexed the ankle as shown in Fig. 1. The linear distance (mm) from the anterolateral aspect of the LM to the peak of the talus was the variable of interest.

Figure 3 Talar position change across repeated trials of sagittal plane ankle movement. The distance measured is between the anterolateral aspect of the lateral malleolus and the lateral talus. * $P < 0.05$ versus control at trial 1. † $P < 0.05$ versus trial 1. ‡ $P < 0.05$ versus trial 2.

($t_{19} = 3.35$; $P = 0.003$). Changes in talofibular interval are shown in Fig. 3.

The clinical ESs between groups and trials are shown in Table 2. Clinically meaningful changes in the talofibular interval are shown in both copers and CAI, particularly at trial 3. The CAI group demonstrated a Cohen's d ES difference at trial 3 that was significantly greater than the control group, but not the coper group.

Discussion

The key finding of this research is that ankle sprain copers and individuals with CAI may have transient changes in the talofibular interval resulting from active, sagittal plane motion of the ankle. These changes were not observed in control ankles. The talofibular interval in subjects with CAI was decreased after the trial 1 imaging compared to the control group. The interval then increased (from 2 to

Table 1 Subject demographics

	Control ($n = 17$, 11 males)	Coper ($n = 20$, 10 males)	CAI ($n = 20$, 9 males)
Age (years)	25.2 ± 5.1	22.3 ± 2.9	23.5 ± 4.2
Mass (kg)	78.0 ± 20.7	72.4 ± 14.3	74.8 ± 17.3
Height (cm)	174.6 ± 9.8	172.8 ± 11.3	174.6 ± 9.6
Time since last injury (months)	NA	58 ± 32	13 ± 15
Number of ankle sprains	0	1	6.9 ± 4.4

Notes: Values are mean $\pm$ SD.
CAI, chronic ankle instability.

Table 2 Clinical ESs of changes in talofibular interval across trials and between groups

Comparison	Cohen's d ES	95% CI	Std error of ES estimate
Trial 3–trial 1 (control)	0.03	–0.59 to 0.65	0.32
Trial 3–trial 1 (coper)	0.80	0.15 to 1.44	0.33
Trial 3–trial 1 (CAI)	1.99	1.23 to 2.75	0.39
CAI–control (trial 3)	0.85	0.18 to 1.54	0.34
CAI–coper (trial 3)	0.51	–0.12 to 1.14	0.32
Coper–control (trial 3)	0.24	–0.40 to 0.89	0.33

Note: CAI, chronic ankle instability; CI, confidence interval; ES, effect size.

over 4 mm) on subsequent sets of the active range of motion (AROM) activity. This represents a large ES change from the first trial, as well as in comparison to that of the control group. These preliminary findings may have important implications for anteroposterior talar mobilizations and intervention studies seeking to improve arthrokinematics in subjects with restricted posterior talar glide, changes in fibular position, and ankle dorsiflexion deficits.

Denegar *et al.*¹⁶ identified restrictions in posterior talar glide range of motion following lateral ankle sprain. Vicenzino *et al.*⁸ similarly identified talocrural joint restrictions in sagittal plane movement in participants with a history of recurrent lateral ankle injury and were able to apply manual therapy techniques to the talocrural joint resulting in immediate improvements in posterior talar glide and ankle dorsiflexion range of motion. Our study identified a relative increase in the talofibular interval after AROM exercise which suggests that acute changes in talar, or fibular, position may occur with minor joint movements and that transient changes may be dependent upon the activity that the individual (or clinician) performs immediately prior to motion testing.

Unlike Vicenzino *et al.*,⁸ we did not apply manual therapy techniques to the talus, as this was not the primary aim of our study. Whitman *et al.*¹³ applied manual therapy to the talocrural joint, gave general ankle mobility exercises, and demonstrated rapid improvements in self-reported function. These findings are supported by those of Landrum *et al.*¹⁵ who identified immediate increases in ankle dorsiflexion following anteroposterior talar mobilization. Although not applied for therapeutic purposes, our copers and CAI subjects performed AROM exercise between US imaging trials and changes in the talofibular interval were observed, suggestive of a change in the talofibular position in the sagittal plane. It is unclear if an anteroposterior talar mobilization would have resulted in further changes or if the changes in the talofibular interval would have been accompanied by changes in ankle dorsiflexion. Bleakley *et al.*¹⁸ found that talar anteroposterior mobilization applied following lateral ankle sprain is moderately effective for restoration of ankle dorsiflexion. US imaging may aid clinicians in the evaluation of talocrural joint positional relationships before and after the application of manual therapy, particularly when using bony landmarks to image the position of the talus,^{23,29} either with or without the application of ankle joint stress.^{19,20} Future investigations should consider repeated imaging trials before and after manual therapy or with therapeutic movements such as MWMs designed to improve talocrural arthrokinematics.¹⁷

Subjects with CAI demonstrated a diminished talofibular interval followed by a pattern of increasing

interval changes with AROM exercise. The most significant change occurred after the second trial, similar to that of copers. Single ankle sprains, or recurrent lateral ankle instability leads to injuries of the ATFL and alterations in talocrural and subtalar joint arthrokinematics¹⁶ that have also been shown following periods of ankle immobilization.¹⁵ The talus is unique in that it has only ligamentous attachments and may more freely move within the talocrural joint following ligamentous injury. The role of the ATFL is to restrict end range plantarflexion and to stabilize the talus.³¹ Subjects with CAI have demonstrated an anteriorly positioned talus using magnetic resonance imaging and radiographic methods. Caputo *et al.*⁹ identified a 0.9 ± 0.5 mm relative anterior talar position accompanied by 5.7° of talar internal rotation in subjects with CAI when compared to a contralateral control ankle with a Cohen's d ES of 0.90 (95% CI: -0.07 – 1.87 ; SEM of ES 0.49) using a sagittal plane talar measurement. In our study, there was a talofibular interval change of 4.1 mm from trial 1 to trial 3 in subjects with CAI, a change that was statistically and potentially clinically significant. Although not different from CAI, ankle sprain copers demonstrated changes in the talofibular interval of 2.4 mm whereas no movement-related changes were observed in control subjects. Moreover, our CAI subjects demonstrated a trial 3 mean difference from control subjects of 1.8 mm, a finding that supports those of Wikstrom and Hubbard¹¹ who identified a 1.04 mm anteriorly displaced talus in CAI ankles. Similar to the current study and Caputo *et al.*,⁹ the ES calculated from Wikstrom and Hubbard¹¹ was 0.84 (95% CI: 0.0 – 1.67 ; SEM of ES 0.43).¹¹ Hubbard and Hertel³² also identified radiographic changes in fibular position in relation to the tibia; however, we did not evaluate the fibular position and instead used the fibula as a fixed reference point on which to base changes in the talofibular interval. Unlike Caputo *et al.*⁹ and Wikstrom and Hubbard,¹¹ our study was the first to use US imaging to characterize the talofibular interval changes resulting from a history of ankle sprain, most notably in CAI. This was supported by Hubbard *et al.*¹⁰ who reported a significant increase in overall anteroposterior talocrural displacement in ankles with functional ankle instability compared to an uninvolved ankle. Our results may be affected by changes in talar translation and talar rotation due to the selection of lateral bony landmarks as well as by fibular position. However, US does not expose the subject to ionizing radiation and allows the examiner to capture multiple sagittal plane images and subsequently perform measurements between landmarks on the lateral malleolus and talus with freely available software.³³

The purpose of this study was to measure changes in talar position resulting from AROM exercise. The hypothesis of the study was that there are no differences in neutral talar position between the three groups. We identified potentially meaningful changes in the talofibular interval resulting from ankle motion that have been previously identified in subjects with a history of lateral ankle sprain injury resulting from three to six repetitions of ankle plantar and dorsiflexion. Our results differ from previous studies in that we quantified changes in the talofibular interval within a single testing session, findings that may improve understanding of the transient nature of talocrural joint arthrokinematics after injury. The differences found after trial 2 suggest that, in subjects with a history of CAI, and relatively low amounts of AROM may result in alterations in the talofibular position. In contrast to studies that show rapid changes in ankle arthrokinematics with anteroposterior talocrural mobilizations, our study demonstrated changes in the talofibular interval resulting from alterations in sagittal plane talar and/or fibular position, or transverse plane talar rotation as a result of AROM exercise. Further research should consider using a three-image US sequence followed by ankle movement and reimaging to further investigate the changes in talar position resulting from either active or passive movement of the talocrural joint.

Evaluation of the ESs between groups at trial 3 suggests that there were no statistically significant differences between the two groups with a history of lateral ankle sprain and control subjects, nor between copers and subjects with CAI. This is following an apparent change in anterior talar position that was at least weak, and possibly clinically meaningful when evaluating the point estimate from trial 1 to trial 3. Ankle sprain copers are similar to control subjects in that they do not report symptoms of instability or reductions in self-reported function. However, this group appears to be similar to subjects with CAI in regards to excessive joint play, as evidenced by an anterior talar reposition resulting from active motion. These findings support the use of ankle sprain copers as an appropriate comparison group to those with ankle instability for future studies.

Limitations

Our study did not include manual therapy intervention to correct the apparent change in talar position, nor were ankle dorsiflexion measurements obtained to determine if talofibular changes resulted in an impairment. The US method of using the fibula as a fixed reference point to discern changes in talofibular interval cannot capture changes which occur in the sagittal or transverse plane position of the fibula itself. Improvements upon this technique may include

similar measurements of the tibiotalar interval using the tibia as a fixed reference point. US imaging of the talofibular interval provides a narrow view of talocrural arthrokinematics in a single plane. We also did not use radiographs to evaluate changes in talar position, a method that has been used to demonstrate increased anterior talar translation in CAI.¹¹ Future investigations should attempt to establish single measurement reliability *a priori* and use multiple images and calculate the mean talofibular interval between AROM to further evaluate the changes resulting from movement, or from manual therapy intervention.

Conclusion

Individuals with CAI and ankle sprain copers demonstrated a sagittal plane talofibular interval that changed significantly with simple AROM exercise. Changes in anteroposterior talar position, talar rotation, or fibular position may have all contributed to the findings observed in this study.

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