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The Effects of a Semi-Rigid Ankle Brace on a Simulated Isolated Subtalar Joint Instability

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ABSTRACT: Subtalar joint instability is hypothesized to occur after injuries to the calcaneofibular ligament (CFL) in isolation or in combination with the cervical and the talocalcaneal interosseous ligaments. A common treatment for hindfoot instability is the application of an ankle brace. However, the ability of an ankle brace to promote subtalar joint stability is not well established. We assessed the kinematics of the subtalar joint, ankle, and hindfoot in the presence of isolated subtalar instability, investigated the effect of bracing in a CFL deficient foot and with a total rupture of the intrinsic ligaments, and evaluated how maximum inversion range of motion is affected by the position of the ankle in the sagittal plane. Kinematics from nine cadaveric feet were collected with the foot placed in neutral, dorsiflexion, and plantar flexion. Motion was applied with and without a brace on an intact foot and after sequentially sectioning the CFL and the intrinsic ligaments. Isolated CFL sectioning increased ankle joint inversion, while sectioning the CFL and intrinsic ligaments affected subtalar joint stability. The brace limited inversion at the subtalar and ankle joints. Additionally, examining the foot in dorsiflexion reduced ankle and subtalar joint motion. © 2013 Orthopaedic Research Society. Published by Wiley Periodicals, Inc. J Orthop Res 31:1869–1875, 2013

Keywords: kinematics; inversion; instability; biomechanics; hindfoot

Lateral ankle sprain is one of the most common injuries with an estimated daily rate of 1 in 10,000 people in the United States[1] and was reported to account for 15% to 45% of sports-related injuries.[2] Approximately 74% of lateral ankle sprains result in chronic joint instability.[3] Among them, up to 75% are associated with subtalar joint instability.[4] The prevalence of subtalar instability in patients with a history of repetitive ankle sprains suggests a more thorough examination of the hindfoot (ankle and subtalar joint) may be required. During clinical examination, it is difficult to differentiate movement of the ankle and subtalar joints, which makes separating ankle and subtalar joint injury challenging. Moreover, the high inter-subject variability in the subtalar joint axis orientation affects the range of motion (ROM), making it difficult for clinicians to identify abnormal motion. Therefore, subtalar instability may not be adequately incorporated in the diagnosis.[5] Undiagnosed subtalar instability may further perpetuate mechanical and functional instabilities of the hindfoot, which may lead to long-term disability and degenerative joint conditions.[2,6–8] A step toward clinically detecting subtalar instability and differentiating it from ankle instability is to understand the 3D kinematics of the stable and unstable hindfoot. In vitro ankle kinematics has been studied extensively,[9–16] but few studies examined subtalar kinematics, especially cases of isolated subtalar instability.[17–20]

Forced inversion coupled with the ankle in neutral or dorsiflexion is believed to create subtalar instability by progressively injuring the calcaneofibular ligament (CFL), the cervical ligament, and the interosseous talocalcaneal ligament (ITCL).[21] However, involvement of the CFL in subtalar stability is controversial. Some authors[13,20,22–24] demonstrated that CFL rupture created subtalar instability while others[9–12,14,25] stated that it only affected ankle stability. Few studies[12,18,19,26,27] examined the effect of a total rupture of the intrinsic ligaments (cervical ligament and ITCL) on subtalar kinematics.

When evaluating subtalar stability, clinicians often position the ankle in dorsiflexion to lock the talus in the mortise and therefore limit ankle motion to detect excessive subtalar motion.[21,28,29] One method is to dorsiflex the foot at the mortise while applying a varus stress on the calcaneus.[29] Applying this technique in vitro would help in understanding the mechanism behind these clinical evaluation strategies.

Conservative treatment strategies for subtalar instability also require further investigation. The application of an ankle brace is commonly used after ankle or subtalar sprains.[30] The effect of braces, including their ability to reduce re-injury during athletic activities, was demonstrated in vivo.[31–38] Semi-rigid braces limit inversion/eversion while keeping normal sagittal motion at the hindfoot.[32,33,39] Additionally, ankle braces also reduced talar tilt and frontal plane motion in passive and rapidly induced inversion.[40,41] Despite these studies, limited evidence is available regarding the effects of ankle braces on subtalar instability. After total rupture of the lateral and intrinsic ligaments, the brace significantly restricted subtalar but not ankle inversion.[17] However, the effect of the brace after isolated CFL injury was not investigated and the applied moment was small compared to moments

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applied during dynamic motion that may be more closely associated with an ankle sprain.[42]

To assess the change in ankle and subtalar kinematics after ligamentous injury and to improve understanding of the stabilizing role of an ankle brace, we: (1) assessed kinematics of the subtalar joint, ankle joint, and hindfoot in the presence of isolated subtalar instability; (2) investigated the effect of bracing in a CFL deficient foot and with a total rupture of the intrinsic ligaments; and (3) evaluated how maximum inversion ROM of the ankle and subtalar joint is affected by the position of the ankle in the sagittal plane.

METHODS

Nine fresh-frozen cadaveric lower extremities (7 left, 2 right, age 66 ± 9 years, 3 female and 6 male) were sectioned 20 cm above the lateral malleolus. The hindfoot was examined manually by an athletic trainer to confirm that no instability or other pathology was present.

An incision placed on the lateral side of the ankle exposed the ligaments. The Achilles tendon was sectioned and sutured to a 22 N weight to approximate the tendon tension during a manual examination.[43] Each specimen was placed into a custom six degree-of-freedom positioning and loading device (Fig. 1).[15] The tibia and fibula were fixed using a clamp and stainless steel k-wires. A 22 N axial load was applied to the tibia to counterbalance the weight applied to the Achilles tendon. The calcaneus was fixed to the foot plate using bone screws. The foot plate was moved using a handle to apply forces. The trainer was instructed to move the hindfoot similar to what would occur during a clinical evaluation. A force/torque transducer (ATI mini45, ATI Industrial Automation, Apex, NC) was placed between the foot plate and the handle to record the applied moment.

Kinematic data were collected from the tibia, talus, and calcaneus with a six camera Motion Analysis Eagle System (Motion Analysis Corp., Santa Rosa, CA) in combination with the MotionMonitor (Innovative Sports Training, Chicago, IL). Custom-made sensors composed of four retroreflective markers each were screwed on the lateral side of the calcaneus, on the neck of the talus, and proximal end of the tibia. The talus sensor was placed anteromedially to keep the extensor retinaculum intact. The trainer re-evaluated the foot and ankle after screw insertion to ensure motion restrictions were not created. Line levels were attached to the foot plate and were used as guides to assure that the foot returned to a neutral position after each trial.

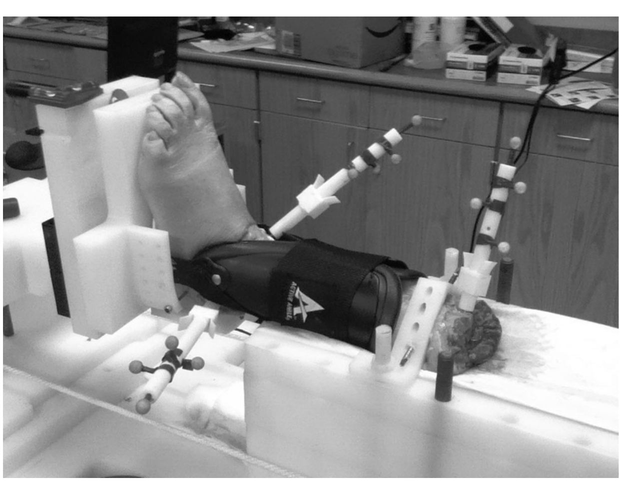

Figure 1. Cadaver foot attached to the 6DOF loading and positioning device. The semi-rigid ankle brace was fitted to the foot, and calcaneus, talus, and tibia marker clusters were screwed onto each bone.

Inversion and eversion were applied to the hindfoot with the foot in neutral, maximum dorsiflexion, and maximum plantarflexion. Motions were applied with and without a semi-rigid ankle brace with a hinge joint (Active Ankle T2, Cramer Products, Gardner, KS) on an intact hindfoot and after each ligament was sectioned. For each sagittal position and condition, the foot was moved to the end range of dorsi- or plantarflexion and inversion or eversion until no further motion at the joint could be observed. Ligamentous injury was created by sectioning the CFL in isolation and in combination with the intrinsic ligaments (i.e., the cervical ligament and ITCL).

Euler angles exported from the MotionMonitor were analyzed with a custom Matlab program (The Mathworks, Natick, MA). Hindfoot motion was the motion of the calcaneus relative to the tibia, ankle motion was the talus relative to the tibia, and subtalar motion was the calcaneus relative to the talus. Reference frames for the tibia, talus, and calcaneus were defined using ISB recommendations.[44] Rotations were calculated from neutral to maximum motion. Sensor data were exported from Motion Monitor using an X–Z′–Y″ Euler rotation sequence for the subtalar joint and a Z–X′–Y″ Euler sequence for the ankle and hindfoot joint.[12]

A two-way repeated measure ANOVA (condition × sagittal foot position) was used to investigate the interaction between the foot position in the sagittal plane and the maximum inversion and eversion rotation detected in each ligament and bracing condition. A separate two-way repeated measure ANOVA (ligament × bracing) was used to analyze the differences in moments applied around the inversion–eversion axis on the foot between each ligament sectioned (intact, CFL cut, CFL cut with the intrinsic ligaments) with and without a brace applied (bracing condition). In the presence of a significant interaction or main effect, Fisher's LSD and Cohen's *d* effect sizes were applied for post hoc comparisons. The significance level for all analyses was $\alpha = 0.05$ and an effect size greater than 0.8 were required for clinical relevance. Statistical analyses were conducted using SPSS (Version 20, SPSS Inc., Chicago, IL).

RESULTS

A significant 3.5° increase in inversion was found at the ankle after sectioning the CFL ($p = 0.002$) and 3° at the subtalar joint after sectioning the CFL, cervical ligament, and ITCL ($p = 0.007$). Using a brace significantly reduced ankle inversion by 3° after sectioning the CFL and reduced the subtalar joint inversion by 5° after all ligaments were cut. A significant decrease of 3.5° and 2.5° in inversion was found at the subtalar and ankle joint, respectively after placing the foot in dorsiflexion compared to neutral. Placing the foot in plantarflexion also decreased subtalar ROM by 2.5° in inversion and 3.4° in eversion compared to neutral.

No significant interactions were detected between foot conditions (i.e., intact, ligaments cut with and without brace applied) and foot sagittal position for all joints (Table 1A–C). Significant condition (Fig. 2A) and position (Fig. 3A) main effects were present for inversion at each

Table 1. Mean Rotation (Std Dev) of the Rotation Angle at the (A) Talocalcaneal Joint, (B) Talocrural Joint, and (C) Tibiocalcaneal Joint

	Intact		CFL Cut		CFL + Cevical + ITCLcut	
	Barefoot	Bracing	Barefoot	Bracing	Barefoot	Bracing
(A) Subtalar						
Inv (°)	13.46 (3.48)	10.20(2.22)	15.18 (3.81)	10.11(2.37)	17.73(4.29)	12.55(3.21)
Ev (°)	8.55 (3.74)	6.05 (3.48)	9.52 (3.94)	7.02 (2.99)	9.12 (3.43)	8.6 (3.43)
DF + Inv (°)	10.31 (2.91)	7.74 (2.60)	11.78 (4.39)	7.68 (1.41)	12.42 (3.82)	8.53 (3.17)
DF + Ev (°)	8.18 (1.84)	5.32 (2.30)	8.18 (3.30)	7.17 (2.68)	10.31 (2.57)	8.28 (2.88)
PF + Inv (°)	12.16 (2.94)	7.28 (3.84)	12.83 (2.38)	7.91 (2.38)	14.88 (4.11)	8.91 (2.56)
PF + Ev (°)	4.31 (1.73)	3.90 (1.36)	5.40 (2.39)	3.99 (1.47)	5.57 (1.70)	5.08 (2.05)
(B) Ankle joint						
Inv (°)	3.43 (3.08)	2.34 (2.36)	8.22 (4.68)	4.42 (4.02)	8.64 (5.44)	4.61 (3.53)
Ev (°)	1.91 (1.12)	1.48 (0.89)	1.83 (1.43)	1.47 (1.62)	1.81 (0.79)	1.49 (0.87)
DF + Inv (°)	1.85 (1.56)	0.95 (0.93)	4.81 (2.90)	2.25 (2.04)	5.24 (4.62)	1.73 (1.65)
DF + Ev (°)	1.04 (0.85)	1.20 (0.70)	1.06 (0.45)	1.31 (0.84)	1.52 (0.62)	1.08 (0.89)
PF + Inv (°)	3.35 (1.72)	2.17 (1.90)	6.16 (3.52)	3.48 (2.09)	6.12 (3.75)	3.77 (2.75)
PF + Ev (°)	2.04 (1.54)	1.54 (1.00)	2.67 (2.37)	1.91 (1.36)	2.16 (1.34)	1.71 (0.77)
(C) Hindfoot						
Inv (°)	16.65 (3.63)	12.39(3.93)	23.29 (6.12)	14.60(5.56)	26.28 (6.48)	17.11(5.45)
Ev (°)	10.25 (4.01)	6.96 (3.28)	11.09 (3.16)	8.21 (3.23)	10.47 (3.14)	9.44 (3.15)
DF + Inv	11.68 (2.41)	7.71 (2.09)	16.42 (5.10)	9.73 (2.77)	17.55 (3.98)	10.11(2.69)
DF + Ev	8.29 (2.61)	5.84 (1.87)	8.93 (3.26)	8.05 (3.50)	11.05 (3.26)	8.92 (3.28)
PF + Inv	15.54 (4.17)	9.31 (5.01)	19.00 (5.57)	11.40(4.08)	20.98 (7.69)	12.54(4.70)
PF + Ev	6.14 (2.44)	5.33 (1.35)	7.70 (3.17)	5.66 (2.19)	7.27 (2.11)	6.58 (1.88)

Inv, inversion; Ev, eversion; DF, dorsiflexion; PF, plantarflexion.

joint ($p \leq 0.009$). Significant condition (Fig. 2B) and position (Fig. 3B) main effects were also detected in eversion at the subtalar joint and hindfoot ($p < 0.001$). Isolated CFL injury significantly affected ankle motion ($p = 0.002$, $d = 2.03$) (Fig. 2A). Combined injury of the CFL with the intrinsic ligaments significantly increased subtalar inversion ($p = 0.007$, $d = 1.00$).

The brace significantly limited inversion in the intact condition ($p = 0.001$, $d = 1.66$ for the subtalar joint and $p < 0.001$, $d = 1.69$ for the hindfoot), after the CFL was sectioned ($p = 0.002$, $d = 2.02$ for the subtalar joint; $p = 0.001$, $d = 1.02$ for the ankle joint; $p = 0.001$, $d = 1.76$ for the hindfoot) and after the CFL and intrinsic ligaments were sectioned ($p < 0.001$, $d = 1.71$ for the subtalar joint; $p = 0.001$, $d = 1.01$ for the ankle joint; $p < 0.001$, $d = 1.72$ for the hindfoot) (Fig. 2).

Positioning the foot in maximum dorsiflexion significantly reduced subtalar ($p = 0.003$, $d = 1.37$), ankle ($p = 0.002$, $d = 0.84$), and hindfoot ($p = 0.001$, $d = 1.72$) inversion compared to neutral. Having the foot in plantarflexion while applying inversion–eversion significantly reduced subtalar ($p = 0.004$, $d = 1$ for inversion and $p = 0.003$, $d = 1.4$ for eversion) and hindfoot ranges of motion ($p = 0.005$, $d = 1.2$ for eversion) compared to neutral (Fig. 3).

No significant interaction for the applied moment was found between the ligaments (intact, CFL cut and CFL, cervical, and ITCL cut) and bracing condition (with and without brace) for inversion and eversion and all sagittal foot positions (Table 2). A simple main effect was found on bracing in all foot positions for inversion ($p \leq 0.001$) and eversion ($p \leq 0.003$), meaning that moments applied on the foot wearing a brace were significantly higher.

DISCUSSION

Our first purpose was to assess the kinematics of the subtalar joint, ankle joint, and hindfoot (i.e., calcaneus relative to the tibia) in the presence of isolated subtalar instability created by sectioning the CFL in isolation and in combination with the cervical and ITCL. The CFL is the main stabilizer of the subtalar joint[13,20,22,24] and an important structure in maintaining subtalar stability. However, some studies concluded that CFL rupture does not affect the stability between the talus and calcaneus, but increased ankle motion.[9–12,14,25] All of the studies that concluded that CFL rupture affected ankle stability previously damaged the anterior talofibular ligament (ATFL), which is known as the main stabilizer of the ankle. We confirmed that tear of the CFL alone, leaving the ATFL intact, increases inversion at the ankle but not at the subtalar joint. In neutral position, a 140% increase in laxity was found at the ankle after sectioning the CFL. These results were similar to previous studies that found a 128%,[14] 150%,[12] and 168%[10] increase in inversion after sectioning the ATFL and CFL. Only one study[17] looked at the effect of isolated CFL sectioning on the ankle and found an average of 283% increase in maximum inversion in a closed kinetic chain device.[17] Our and other studies[10,12,14] used an open kinetic chain device, which may account

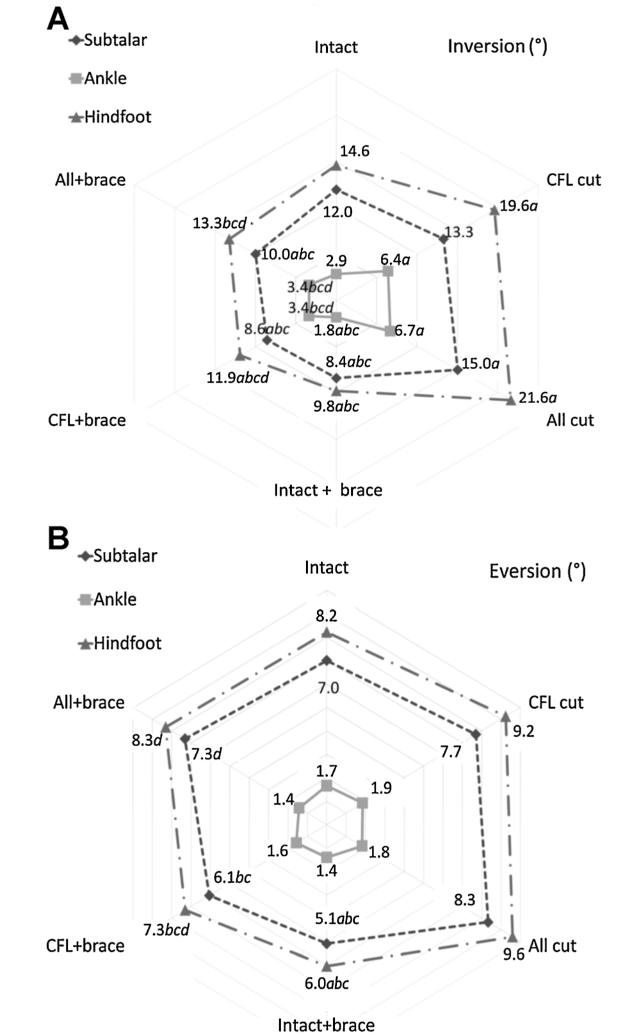

Figure 2. (A) Inversion and (B) Eversion ROM at the subtalar, ankle, and hindfoot for the intact, CFL cut, CFL + cervical + ITCL cut conditions with and without an ankle brace independently of sagittal foot position. [a]Significantly different from intact. [b]Significantly different from CFL. [c]Significantly different from all cut. [d]Significant difference between brace conditions (compared to intact with brace).

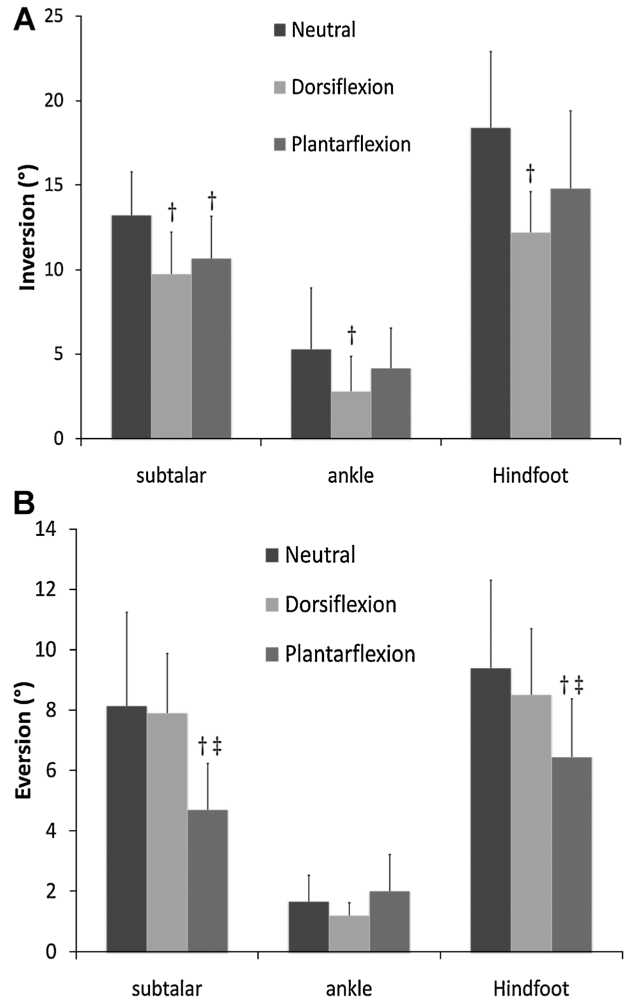

Figure 3. (A) Inversion and (B) Eversion ROM at the subtalar joint, the ankle joint, and hindfoot with the foot in neutral position, maximum dorsiflexion, and maximum plantarflexion. [†]Significantly different from neutral and [‡]significantly different from dorsiflexion.

for the differences. Subtalar stability was unaffected by CFL sectioning, which contradicts previous studies that reported higher subtalar tilt on roentgenograms[13] and x-rays,[22] but did not demonstrate it with statistics or reported increases. Two studies[20,24] demonstrated significant increases in subtalar inversion after CFL sectioning; however, their inversion increment was considered clinically insignificant because the increase was <2°. Ankle inversion increased 160% between intact and CFL cut in dorsiflexion, while it only increased 85% in plantarflexion. Similarly, the ankle-subtalar joint complex was most stable in plantarflexion after the CFL was sectioned in a previous study.[9] Based on the results of our study, it appears injury to the CFL increases ankle inversion and creates a more unstable hindfoot in dorsiflexion.

Additional injury created at the cervical ligament and ITCL significantly increased subtalar motion. The ITCL is found in the sinus tarsi and provides strong stabilization for the subtalar joint.[5,12,18,19,26,27,45,46] Discrepancy exists in the literature about the percentage of inversion increase after sectioning the ITCL. After applying inversion to the foot, increases in subtalar motion ranging from 24% to 94%[12,20] were found in previous studies, with various ligaments sectioned in combination with the ITCL. We found a 32% increase in subtalar inversion compared to intact with the ankle in the neutral sagittal plane position. Similarly a 45% increase in subtalar inversion was measured after sectioning the CFL, the cervical ligament, and the ITCL.[17] Sectioning the entire ITCL is difficult as it is a dense, broad, flat ligament with a bilaminar bundle that crosses the sinus tarsi obliquely and laterally,[45] which combined with differences in the ligaments that were sectioned may account for the differences in the literature on the rotational increase after ITCL sectioning.

Our second purpose was to investigate the effect of ankle braces on a CFL deficient foot and with a total

Table 2. Mean Moment (Std Dev) Applied to the Foot

	Intact		CFL Cut		CFL+Cevical + ITCLcut	
Moment (N.m)	Barefoot	Bracing	Barefoot	Bracing	Barefoot	Bracing
Inversion	5.74 (1.52)	7.75 (1.91)	5.29 (1.30)	7.14 (1.26)	6.42 (1.21)	7.55 (1.90)
Eversion	6.76 (1.57)	7.53 (1.20)	6.83 (1.66)	8.58 (1.77)	7.18 (1.78)	8.42 (1.51)
DF + Inversion	5.45 (1.61)	6.84 (0.75)	5.48 (1.59)	6.38 (0.84)	4.62 (1.36)	7.36 (1.64)
DF + Eversion	6.45 (1.5)	7.78 (2.10)	5.61 (1.94)	9.57 (2.16)	6.25 (1.66)	9.25 (2.18)
PF + Inversion	6.11 (1.66)	6.59 (1.19)	6.00 (1.36)	7.31 (1.71)	5.77 (1.16)	6.68 (1.65)
PF + Eversion	5.64 (0.83)	6.74 (1.38)	5.89 (1.26)	7.22 (1.29)	6.00 (0.66)	7.60 (1.75)

DF, dorsiflexion; PF, plantarflexion.

rupture of the intrinsic ligaments. The use of a semi-rigid ankle brace reduced inversion ROM for all joints. The angle of rotation at the hindfoot decreased 26%, 34%, and 40% when the intact foot was in neutral, dorsi-, and plantarflexion, respectively. When the effects of five semi-rigid braces were examined in volunteers wearing athletic shoes in inversion, a 57% decrease in inversion was observed at the hindfoot.[41] Another in vivo study[34] measured a 48% decrease with a shoe alone and with a semi-rigid brace. Wearing a shoe with an ankle brace decreased the inversion ROM by 20% compared to barefoot,[35] which may explain the large differences with this study. Additionally, a 28% decrease using a semi-rigid brace in a simulated barefoot condition was observed,[35] which is closer to our results. Cadaver studies displayed a significant restriction in motion by using ankle stabilizer devices after ligament injuries. For example, a significant decrease in talar tilt and anterior drawer was measured after applying a brace on specimen with ATFL and CFL deficiencies.[40] The range of inversion of three braces was evaluated on intact feet in vitro.[32] All three significantly reduced the inversion rotation, and positioning the foot in 20° plantarflexion decreased inversion compared to neutral. We observed a similar pattern with increased restriction of hindfoot inversion with the foot positioned in plantarflexion and smaller inversion stability with the foot in neutral.

Applying the brace to the CFL deficient ankle significantly reduced inversion ROM. The brace restricted motion 46% in neutral, 53% in dorsiflexion, and 43% in plantarflexion. The largest increase in ankle inversion occurred when the foot was in dorsiflexion, which is also the position where greatest restriction of ankle motion took place. This suggests that the brace has the most potential to restrict motion where the instability is the greatest. The semi-rigid brace significantly restrained inversion at the subtalar joint as well. A 30, 36, and 34% decrease in rotation was found after applying a brace with intact, CFL cut, and all ligaments cut, respectively. In another study, a 34% decrease in subtalar inversion after applying the brace on a ligamentous deficient foot (CFL, cervical ligament, and ITCL) was observed[17] along with a non-significant 39% decrease in ankle inversion between the ligamentous deficient foot and after applying a brace, while we found a significant 49% decrease.

Our third purpose was to evaluate how maximum inversion ROMs of the ankle and subtalar joints are affected by ankle position in the sagittal plane. Twenty-six percent, 48%, and 34% decreases in the subtalar joint, ankle joint, and hindfoot inversion ROM were found after the foot was placed in dorsiflexion. Half of ankle motion was reduced, meaning that having the foot in maximum dorsiflexion limits ankle motion independently of the foot condition. Dorsiflexion is therefore a good sagittal position to isolate motion at the subtalar joint. With the foot held in plantarflexion, subtalar joint and hindfoot inversion and eversion ROM were significantly reduced. Plantarflexion did not affect ankle ROM because the ATFL intact helps stabilize the ankle in maximum plantarflexion.[13] Isolated CFL injury created a more unstable ankle in dorsiflexion than in neutral or plantarflexion. Due to its oblique posterior orientation, the CFL stabilizes the talus in dorsiflexion while approaching a right angle with the ATFL.[4]

This study advances our knowledge of the pathomechanics, evaluation and treatment of subtalar joint instabilities. The presence of detectable subtalar instability suggests likely injury to the CFL and intrinsic ligaments. The presence of an isolated CFL tear created minimal changes in subtalar stability. Also, placing the foot in maximal dorsiflexion ROM and providing a manual stress test to the hindfoot can reduce ankle motion, which may permit easy detection of subtalar instability during clinical evaluation. Future research should determine the sensitivity and specificity of this method. Finally, braces designed to restore or maintain ankle stability can also be beneficial in the presence of subtalar instability. We focused on a semi-rigid brace, but future studies should determine if lace-up braces demonstrate similar capabilities at the subtalar joint.

Limitations of our study include the cadaveric nature used to reproduce physiological conditions. For example, the end ROM will be different from a living person that will stop the examiner because of the pain. Moreover, after applying a 3.4 N m inversion moment on cadaver feet and on living individuals through an MRI a 3° higher range of inversion was noticed in vitro at the ankle with a similar subtalar joint rotation.[47] Another limitation was the use of an open kinetic chain device. People wear ankle braces in a closed kinetic chain condition and therefore might demonstrate different ROM. A future study should look at the differences in kinematics using a closed kinetic chain apparatus. Also, our study looked at the passive inversion/eversion ROM while braces are used in more dynamic conditions; therefore, future studies should examine more dynamically induced inversion motion to determine if these results are replicated when functional conditions are simulated.

We demonstrated that ankle stability is affected by sectioning the CFL while subtalar motion did not significantly change. Additional sectioning of the cervical ligament and ITCL did not increase ankle motion, but significantly increased subtalar joint inversion. Half of ankle inversion motion was reduced by placing the foot in maximum dorsiflexion; therefore, this method could be used to evaluate subtalar motion in clinical settings to facilitate detecting instability. After CFL injury alone or when combined with intrinsic ligaments, semi-rigid ankle braces limit inversion ROM at the ankle, and subtalar joints, which may be beneficial for clinical populations that exhibit these impairments.

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