EFFECT OF A SEMI-RIGID ANKLE STABILIZER ON A SIMULATED ISOLATED SUBTALAR JOINT INSTABILITY

[1]Julie Choisne, [2]Matthew Hoch, [1]Sebastian Bawab, and [1]Stacie I. Ringleb
[1]Mechanical and Aerospace Engineering, Old Dominion University, Norfolk, VA, USA
[2] School of Physical Therapy and Athletic Training, Old Dominion University, Norfolk, VA, USA
email: SRingleb@odu.edu

INTRODUCTION

Subtalar joint stability can be affected after ligamentous injuries such as an acute ankle sprain. The calcaneofibular ligament and the combination of the cervical and interosseous talocalcaneal ligament (ITCL), known as the intrinsic ligaments, are the main stabilizers of the subtalar joint [1]. Clinical diagnosis of subtalar joint instability usually involves manually applying inversion while holding the foot in a dorsiflexion position to lock the talus in the ankle mortise to limit ankle joint motion. Currently, it is unclear if this evaluation technique of isolating the subtalar joint to test for subtalar instability is valid. A common non-operative treatment for hindfoot instability is the application of an ankle brace. While the main function of ankle bracing is to limit motion at the ankle joint, the ability of braces to promote stability in the presence of subtalar instability is not well established.

The purpose of this study was to 1) assess the kinematics of the subtalar joint, ankle joint, and hindfoot in the presence of isolated subtalar instability; 2) investigate the effect of bracing in a CFL deficient foot and with a total rupture of the intrinsic ligaments and 3) evaluate how maximum inversion range of motion of the ankle and subtalar joints is affected by the position of the ankle in the sagittal plane.

METHODS

Nine fresh-frozen cadaveric lower extremities were obtained and sectioned at the midpoint of the shank (7 left, 2 right; mean age 66 years; 3 female, 6 male). Each specimen was placed into a custom six degree-of-freedom positioning and loading device [2]. Kinematic data were collected from the tibia, talus and calcaneus with a 6 camera Motion Analysis Eagle System (Motion Analysis Corporation, Santa Rosa, CA) in combination with the MotionMonitor (Innovative Sports Training, Chicago, IL).

Inversion/eversion at the subtalar joint, the ankle joint and the hindfoot joint (tibia-calcaneus) with the foot placed in neutral position, dorsiflexion and plantarflexion were reported using Euler angles [3]. Motion was applied with and without an ankle brace (Active Ankle T2, Cramer Products, Gardner, KS) on an intact hindfoot and after sectioning the calcaneofibular ligament (CFL) alone and in combination with the intrinsic ligaments (i.e., the cervical ligament and the interosseous talocalcaneal). The ankle brace (represented in Figure 1) consisted of a semi-rigid brace with a hinge joint at the ankle. For each motion and condition, the foot was manipulated to the end range of motion.

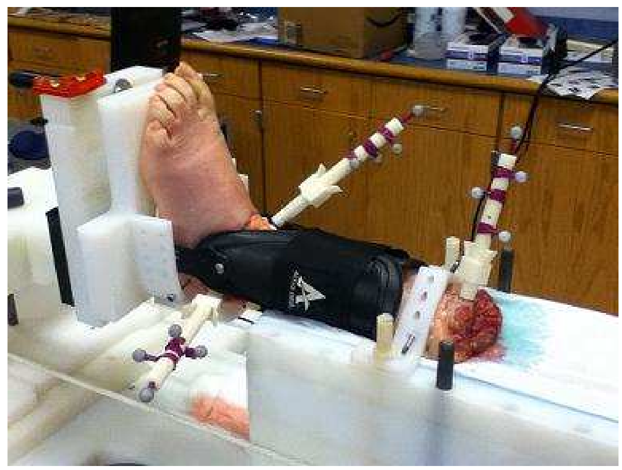

Figure 1: Cadaver foot in the ankle brace with the calcaneus, talus and tibia marker clusters.

Euler angles were exported directly from the MotionMonitor and analyzed with a custom program written in Matlab (The Mathworks, Natick, MA). A within-subjects repeated measure ANOVA ($\alpha=0.05$) with a LSD post hoc was used to analyze the differences in ligament condition and bracing using SPSS (SPSS Inc., Chicago, IL). The changes in the Euler angles were considered significant if $p<0.05$ and Cohen's effect size $d>0.8$. Differences in maximum inversion and eversion between each foot position in the sagittal plane were also assessed using 2 way repeated measure ANOVA (condition*motion) with a Bonferroni correction.

RESULTS AND DISCUSSION

A significant condition effect was detected for all repeated measures ANOVAs ($p<0.05$) except for the ankle joint eversion in all three foot positions. Specifically, subtalar joint inversion significantly increased after sectioning the CFL and the intrinsic ligaments when the foot was in neutral flexion (Table 1a). Ankle inversion increased after sectioning the CFL in isolation and in combination with the intrinsic ligaments in the neutral, dorsiflexed, and plantar flexed positions (Table 1b). Hindfoot inversion increased in all conditions except following isolated CFL sectioning in the plantarflexed position. Eversion was generally unaffected by ligament sectioning at any joint or position.

After creating instability, the use of a semi-rigid ankle brace significantly limited inversion motion in all joints and for all foot positions. Eversion was generally unaffected by bracing.

The position of the foot in the sagittal plane, while applying inversion /eversion, did affect the maximum range of motion over all conditions for all joints ($p<0.05$). Dorsiflexing the foot significantly reduced the inversion range of motion in the ankle ($p=0.006$) and subtalar joint ($p=0.01$). It was predicted that ankle motion would be affected by dorsiflexing the foot but not for the subtalar joint. Holding the foot in plantarflexion reduces inversion and eversion significantly in the subtalar joint ($p=0.011$ and $p=0.009$ respectively) but not the ankle.

Sectioning the CFL, described as the most important ligament in subtalar stability [1], did not significantly increase subtalar joint motion. On the contrary, the ankle joint was mostly affected by sectioning of the CFL, which has shown to stabilize the ankle along with the ATFL. The significant increase in inversion at the ankle when the CFL was sectioned and the foot was plantarflexed showed an increase in ankle instability, which is surprising because the CFL has been described as being slack in plantarflexion [5].

The use of an ankle brace restored intact mobility for all joints. The use of a semi-rigid brace is suited to limit motion in the presence of subtalar joint instability.

Dorsiflexing the foot reduced the range of motion at the ankle, as predicted, but it also reduced subtalar motion. In fact, subtalar instability was not detected, only ankle inversion was affected by deficiencies of the ligament even though the talus was locked in the ankle mortises. Sectioning the CFL might have changed the position of the fibula and thus unlocking the talus from the lateral side.

CONCLUSIONS

Creating instability at the subtalar joint mostly affected the ankle joint inversion motion. The use of a semi-rigid ankle brace helped in limiting inversion at the subtalar and ankle joint whether the foot was placed in neutral, dorsiflexed or plantarflexed position. Holding the foot in dorsiflexion reduces ankle joint and subtalar joint inversion.

ACKNOWLEDGEMENTS

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Table 1: Mean (standard deviation) of the rotation angle at the A) Talocalcaneal joint, B) Talocrural joint, C) Tibiocalcaneal joint. (DF = Dorsiflexion, PF = Plantarflexion)

A)

Subtalar joint	Intact		CFL cut		CFL + cervical +ITCL cut	
	Barefoot	Bracing	Barefoot	Bracing	Barefoot	Bracing
Inversion (°)	13.46 (3.48)	10.20* (2.22)	15.18 (3.81)	10.11* (2.37)	17.73§ (4.29)	12.55* (3.21)
Eversion (°)	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+Inversion (°)	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+Eversion (°)	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+Inversion (°)	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+Eversion (°)	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	Intact		CFL cut		CFL + cervical +ITCL cut	
	Barefoot	Bracing	Barefoot	Bracing	Barefoot	Bracing
Inversion (°)	3.43 (3.08)	2.34 (2.36)	8.22¤ (4.68)	4.42* (4.02)	8.64§ (5.44)	4.61* (3.53)
Eversion (°)	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+Inversion (°)	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+Eversion (°)	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+Inversion (°)	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+Eversion (°)	2.04 (1.54)	1.54 (1.00)	2.67 (2.37)	1.91 (1.36)	2.16 (1.34)	1.71 (0.77)

* Significant difference between barefoot and bracing condition

¤ Significant difference between intact and calcaneofibular ligament (CFL) cut

§ Significant difference between intact and CFL, cervical and interosseous talocalcaneal ligament (ITCL) cut