The Effect of Altered Hindfoot Kinematics on Syndesmotic Strain

Harold W. Gehring Center for Biomechanics and Implant Analysis, Beaumont Hospital, Royal Oak, MI
megates@umich.edu

**Introduction:** Syndesmotic integrity is necessary for normal ankle joint function. Alterations in the normal hindfoot kinematics may result in alteration of the distal tibiofibular relationship. Possible clinical implications involve ankle stability, syndesmotic injury and component loosening and subsidence following total ankle arthroplasty. Our goal was to determine if foot position and/or altered hindfoot kinematics affect syndesmotic strain in a cadaveric model.

**Materials and Methods:** Six fresh frozen cadaveric lower limbs (3 matched pairs) age 33-43 with no known ankle pathology were potted at the proximal tibia. Care was taken to avoid damage and not to obstruct the motion of the proximal tibiofibular joint or joint capsule. Simulated fusions were performed under fluoroscopic guidance using multiple divergent 2.0 mm Kirchner wires. Each specimen was tested in a six-degree of freedom pure moment testing fixture. The potted end of the specimen was rigidly fixed in the testing frame. The foot was allowed to rest on a flat wooden plate that prevented slippage during cyclic loading. Pure moments generated by two Enduratec SmartTest servo-pneumatic actuators (Bose Corporation, Eden Prairie, MN) and a closed-loop cable-pulley system moved the foot in both internal and external rotation. To simulate inversion or eversion, the foot bed was tilted and rigidly held at 9° from neutral. A mass pulley system was used to apply 700N compression along the axis of the tibia to simulate a single legged stance and an Achilles tendon tension of 500N to simulate gastrocnemius/soleus contraction throughout testing.

![Figure 1: (A) The specimen oriented in the six-degree of freedom apparatus. (B) Posterior view showing applied Achilles load.](image1)

The specimens were tested through 4 cycles of internal and external rotation to a specimen specific range of motion selected to produce a maximum torque of 25 Nm. Four conditions were tested: simulated combined subtalar/talonavicular fusion (ST+TN), subtalar fusion (ST), talonavicular fusion (TN) and unfused. Each condition was tested in the neutral coronal position and 9° of inversion and eversion. Infrared light emitting diode (irLED) marker arrays were used to track displacement across the syndesmosis, as an indicator of syndesmotic strain, as well as motion of the tibia, talus, calcaneus and footbed. Values were normalized to the unfused state in the neutral coronal position.

Mean displacements obtained for each testing condition were analyzed based on a Randomized Complete Block Design. The overall effect on syndesmotic displacement was analyzed using a main effects model with mean displacements. Statistical analysis was performed using The SAS System for Windows version 9.1.3, Service Pak 2.

**Results:** Subtalar motion was assessed as rotation about the axis of the tibia. There was a statistically significant reduction of subtalar motion between the unfused and ST, TN and ST + TN simulated fusion when the foot was inverted. A significant decrease in subtalar motion was also observed between the unfused condition in the flat position and the ST + TN simulated fusion in the flat position.

![Figure 2: Syndesmotic marker displacement along the ATIFL normalized to the unfused, flat condition](image2)

Evaluation of the mean values of syndesmotic displacement in Figure 2 reveals a trend towards greater displacement with the simulated ST and/or TN fusion in all three foot positions. Pair wise comparison showed a significant increase in syndesmotic displacement with inversion compared to flat foot position without fusion. In the flat foot position, ST + TN simulated fusion also significantly increased syndesmotic displacement compared to the unfused condition. A statistically significant difference was observed between inversion and eversion in all fusion conditions. ST also increased syndesmotic displacement with foot inversion compared with flat positioning.

Regardless of foot position, a main effects model using mean displacements showed that ST, TN and ST + TN all significantly increased syndesmotic displacement relative to the unfused, flat condition.

**Discussion:** Altered hindfoot kinematics through simulated fusion of the subtalar and/or talonavicular joints increases syndesmotic strain during physiologic loading. This effect is most pronounced when the foot is inverted. These observations may have clinical implications with respect to hindfoot position and syndesmotic injury patterns as well as implant survival and selection criteria in total ankle arthroplasty.

Small sample size and indirect rather than direct measurement of strain are two important limitations of this study. The use of syndesmotic displacement as an indicator of strain yields appropriate strain relationships between conditions but does not allow for accurate quantification. Future studies may avoid this potential inaccuracy by inserting placement markers directly into the tendon fibers.


**Acknowledgements:** The authors would like to thank DePuy for their funding of this study.