The Talocrural and Subtalar Helical Axes are not fixed during Plantarflexion

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INTRODUCTION

In an attempt to understand the etiology of ankle joint injury and degeneration, numerous models of this joint have been created as a means to estimate ankle joint forces. Due to a lack of non-invasive *in vivo* measurement techniques, the kinematics required to drive these models have typically been acquired in cadavers or using external markers to infer internal bone motion. This has left some uncertainty as to the validity of the two most common model simplifications (assuming that the talocrural joint is a locked joint or that both joints are simple hinge joints). Thus, the purpose of this study was to quantify the 3D finite helical axis of the subtalar and talocrural joints non-invasively *in vivo* during plantarflexion, in order to test if the above assumptions were true.

METHODS

Four healthy male subjects participated in this IRB approved study. In total data for 6 ankles were collected (age=26.2±5.0 years, mass=79.5±11.6 kg, height=173.6±1.3cm). Subjects were placed supine in a 1.5T MR imager (LX; GE Medical Systems, Milwaukee, WI, USA) after obtaining informed consent.

A specialized ankle loading device, which allowed 3 degrees of rotational freedom at the ball of the foot, was used to apply load during plantarflexion. Time permitting, both ankles were studied. Plantarflexion (PF) was defined as the rotation of the calcaneus about the tibial medial-lateral (M-L) axis. Zero degrees PF was defined as when the long axis of the tibia was perpendicular to the plantar surface of the foot. While subjects cyclically plantarflexed and dorsiflexed their ankle at 35 cycles/min, aided by an auditory metronome, fast-PC MR images (anatomic and x, y, and z velocity images, temporal resolution=72 ms, imaging time=2:48) were collected. The imaging parameters were consistent with prior studies [1]. The sagittal-oblique imaging plane contained the soleus musculotendon junction, tibia, calcaneus, and talus. The 3D time dependent attitude of the tibia, talus and calcaneus was derived through integration of the velocity data [2]. From these data the FHA was determined. Since it is undefined as the angular velocity goes to zero, the FHA was not reported for angular velocities less than 0.25 rad/s. For clarity, on PF is being reported.

RESULTS AND DISCUSSION

The subtalar joint rotation for all subjects occurred primarily about the medial-lateral axis (Fig 1B&C) during plantar-flexion. Yet the FHA was not oriented solely in the M-L direction and rotation of subtalar FHA with minimal displacement during plantarflexion was seen across all subjects. The lateral side of the FHA began PF angled towards the anterior and inferior direction and as the ankle plantarflexed it rotated posteriorly and superiorly. One

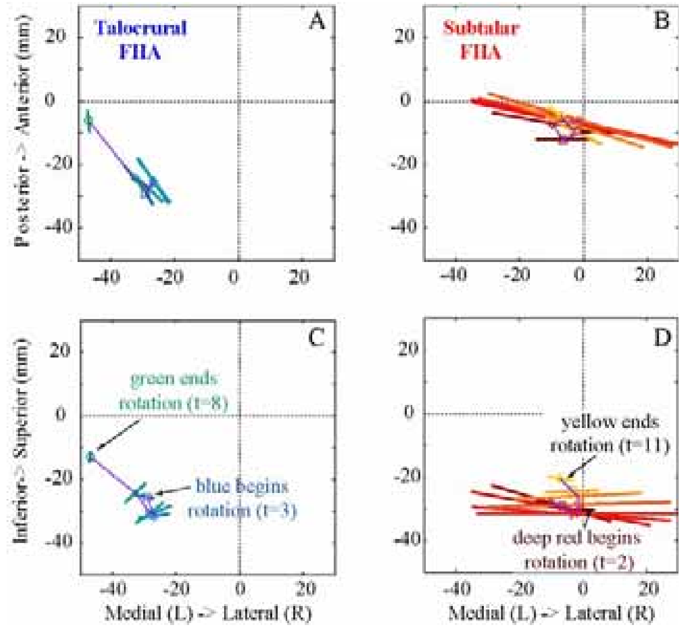

Figure 1: ***3D Talocrural (A&C) and Subtalar (B&D) FHAs During Plantarflexion for subject 9821R***. All FHA's are plotted relative to the tibial coordinate system. The talocrural joint changes from blue to green and the subtalar FHA changes from deep red to yellow as the ankle plantarflexes. **A&B.** a view from above the ankle (AP vs. ML) **C&D.** a frontal view (IS vs. ML). The length of the FHA indicates the magnitude of the angular velocity. The center of the FHA is the closest point the the talar origin (A&C) or the tibial origin (B&D). PF angle for this subject ranged from 1.9° to 39.4°.

exception was seen in one subject, where lateral side of the FHA pointed posteriorly and inferiorly at the beginning of PF and rotated further posteriorly and superiorly. The talocrural FHA was directed primarily in the anterior-posterior direction (Fig 1A&C). The amount of angulation in the M-L and superior-inferior directions did change during PF, but was variable across subjects. The angular velocity of the talocrural joint was smaller than that of the subtalar joint.

The data from this study clearly indicate that neither joint is a simple hinge joint, nor is the talocrural joint a locked joint. One interesting kinematic result of the latter is that inversion occurs about the talocrural joint, while eversion occurs about the subtalar joint during plantarflexion. Thus, the eversion that is seen externally is much smaller than that which is occurring at the subtalar joint. The tendency of the subtalar and talocrural joints to rotate and translate will impact the calculation of tendon and ligament moment arms and, thus, alter the moment producing capabilities of the force generating structures at the ankle joint. Therefore, future modeling studies should investigate the sensitivity of the model outputs to variations in the FHA direction and location.

REFERENCES

[1] Rebmann and Sheehan *JMRI* **17** 206-213, (2003)
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