

# FOOT DEFORMITIES RESULTING FROM FORCES APPLIED TO THE TENDONS OF EXTRINSIC FOOT MUSCLES IN A CADAVER MODEL

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## INTRODUCTION

Various gait abnormalities result from inappropriate activations of extrinsic foot muscles whose principle actions are documented in standard anatomy texts. When the muscles act in combination with one another, however, decisions regarding which muscle to treat surgically become more complicated. The ability to predict the effects of spastic muscle synergies would have a profound impact on treatment decisions, but it is currently very difficult to determine these actions *in vivo*. The purpose of this study was to examine the degree of the three most common spastic foot deformities in the presence of varying levels of force applied to the tendons of the tibialis anterior, tibialis posterior, and to the Achilles tendon in a cadaver model.

## METHODS

The soft tissues of six adult cadaver foot specimens (3 M, 3 F; 3 R, 3 L) were dissected 3 cm above the ankle, leaving the tendons of all extrinsic foot muscles intact. The tibia and fibula were sectioned 23 cm above the plantar surface of the foot.

Each specimen was rigidly mounted in an aluminum frame by fixing the proximal end of the tibia and allowing the foot to hang below with the tibia vertical. Steel cables were attached to the tendons of tibialis

anterior and tibialis posterior and to the Achilles tendon using custom-designed clamps and sutures. The cables were routed around pulleys mounted in the frame that simulated physiological lines of action. Each cable was attached serially to a linear spring scale and an elastic cord that could be stretched and secured to prescribe individual tendon tensions.

A five-camera motion analysis system (Vicon 370; Oxford, UK) was used to record the locations of markers rigidly attached to the foot. Marker triads were fixed to the inferior aspect of the calcaneus and the medial aspect of the first metatarsal head using wood screws. An additional marker triad was attached to the aluminum frame. Homogeneous transformations between coordinate systems defined by the marker triads were decomposed into Euler angles (Craig, 1986). These Euler angles were taken to represent (a) hindfoot varus/valgus, measured with respect to ground; (b) forefoot supination/pronation, measured relative to the hindfoot; and (c) forefoot abduction/adduction, also measured relative to the hindfoot. Calculations of joint angles from marker coordinates were performed using custom-written routines in MATLAB (Mathworks; Natick, MA).

Eight loading patterns were applied in a random order to the tendons of each specimen. The loading patterns were

achieved by systematically loading or unloading the three tendons of interest. The Achilles tendon was either unloaded or loaded to 100 N and tibialis anterior and tibialis posterior were either unloaded or loaded to 50 N. A greater force was applied to the Achilles tendon to reflect the larger cross sectional area of the triceps surae. One-way, repeated-measures analyses of variance (ANOVA) were performed to determine if significant differences in foot angles resulted from the eight loading scenarios. Each ANOVA was followed by Tukey mean comparison tests between individual patterns. The level of statistical significance was set at  $\alpha = 0.05$ .

## RESULTS

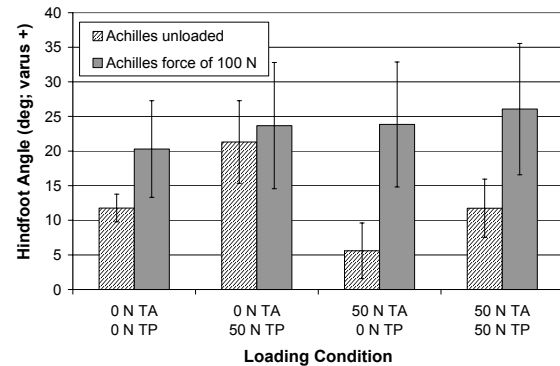
Loading of the Achilles tendon was associated with levels of hindfoot varus that were significantly greater than the unloaded case (all  $p \leq 0.003$ ) regardless of the tibialis anterior and tibialis posterior tensions (Figure 1). Tibialis posterior acting alone similarly contributed to hindfoot varus ( $p < 0.001$ ) but tibialis anterior acting alone did not produce a significant difference in hindfoot varus ( $p = 0.257$ ).

Tibialis anterior and tibialis posterior, acting either alone or in concert, produced significant forefoot supination relative to the unloaded case (all  $p < 0.001$ ) (Figure 2). Addition of Achilles tendon tension did not significantly alter forefoot supination in any case (all  $p \geq 0.464$ ). Only minimal changes in forefoot abduction-adduction were noted in any loading scenario.

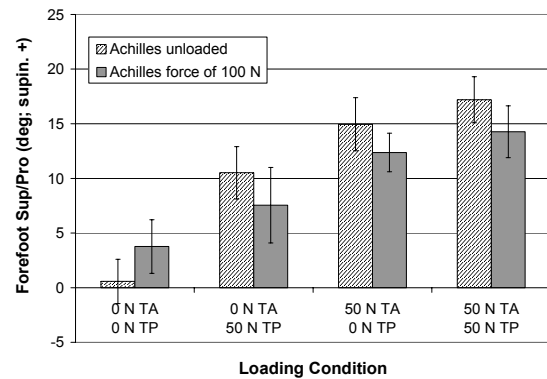
## DISCUSSION

These results suggest that forces transmitted by the Achilles tendon may be instrumental in producing hindfoot varus. Hindfoot varus may also result from the actions of tibialis

posterior, but this effect may be masked by plantarflexor overactivity. Our results also suggest that clinicians should consider the function of tibialis posterior, as well as that of tibialis anterior, when treating patients with excessive forefoot supination. Future work will examine the effects of additional muscles that have the potential to affect foot postures, such as the peroneals.



**Figure 1.** Mean ( $n = 6$ ) hindfoot varus-valgus angle for all specimens at each loading condition. Error bars indicate plus and minus one standard deviation.



**Figure 2.** Mean ( $n = 6$ ) forefoot supination-pronation angle for all specimens at each loading condition. Error bars indicate plus and minus one standard deviation.

## REFERENCES

Craig, J.J. (1986) *Introduction to Robotics: Mechanics and Control*. Addison Wesley

## ACKNOWLEDGMENTS

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