The impact of tendon lengthening following Achilles tendon repair on foot kinetics, a finite element analysis

Hamed Malakoutikhah, Erdogan Madenci, L. Daniel Latt
University of Arizona, Tucson, AZ
hamedmalak@arizona.edu

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INTRODUCTION: Triceps surae muscle force is transferred through the Achilles tendon to the calcaneus and from the calcaneus to the plantar fascia and then to the metatarsal heads and the toes which exert force on the ground. Achilles tendon ruptures occur in tendons that have reached a critical point of intrasubstance degeneration. The Achilles tendon almost always heals but frequently lengthens during the healing process, leading to an alteration in the triceps surae force production profile. We hypothesized that Achilles tendon overlengthening has implications not only for force generation but likely has many other impacts throughout the foot. The goal of this work was to evaluate the effect of a lengthened Achilles tendon following tendon repair on the kinetics of the foot.

METHODS: A validated finite element model of the foot was used to compare foot biomechanics between the foot with a functional and non-functional Achilles tendon. The model of the foot constructed from CT scan images of a female cadaveric foot weighing 60 kg included all 28 bones, 72 ligaments, cartilage, and an encapsulating soft tissue. The model was loaded with 0.5 body weight applied at the center of mass and 0.25 body weight applied to the Achilles tendon simulating quiet stance. The tendon forces were applied using force vectors in the direction of their lines of action. The foot with a non-functional Achilles tendon was created by unloading the Achilles tendon since triceps surae muscle shortening due to tendon lengthening significantly decreases force production. The force transmitted through the joints, force in the ligaments, and plantar pressure were determined for both the foot with a functional and non-functional Achilles tendon.

RESULTS: We found that the force transmitted through all the joints decreased when the Achilles tendon force was removed (Figure 1a). In addition, removing the Achilles tendon decreased the force within the plantar fascia, long and short plantar ligaments, and deep deltoid ligament, while it increased the force within the spring and superficial deltoid ligaments (Figure 1b). The plantar fascia experienced the greatest reduction in ligament force after unloading of the Achilles tendon (from 93 N to 26 N). Moreover, the maximum plantar pressure in the heel fat pad increased from 164 kPa to 231 kPa when the Achilles tendon was removed.

DISCUSSION: The varying changes in the force in the ligaments and joints due to Achilles lengthening suggest that Achilles tendon rupture with sequent healing with overlengthening can alter the force distribution throughout the entire foot. A major implication of this work is that in treating Achilles ruptures, an extended period of protection with heel wedges beyond the customary six weeks may be needed to prevent over lengthening of the Achilles. Moreover, this study supports the efficiency of surgical lengthening of the Achilles in the treatment of diabetic forefoot foot ulcers by shifting the plantar pressure towards the calcaneus.

SIGNIFICANCE/CLINICAL RELEVANCE: The results of this study will help inform surgical decision making for the treatment of Achilles tendon ruptures by adding evidence supporting the need to restore Achilles tendon length.

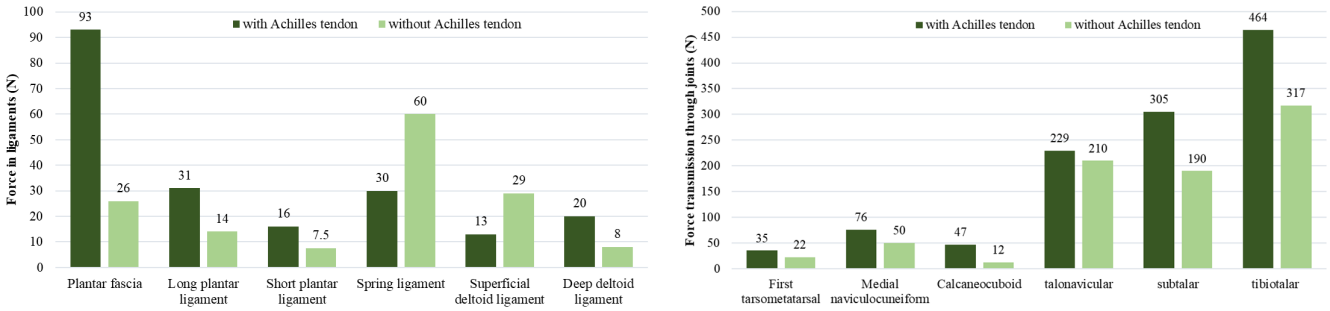

Figure 1. Comparison of the force (a) transmitted through the joints, and (b) within the ligaments, between the foot with and without the Achilles tendon