INTRODUCTION: Contracture of the tendoachilles has been implicated as a causative factor in plantar fasciitis. The positive clinical effect of tendoachilles stretching as a treatment regimen supports this theory. It has been hypothesized that tendoachilles stretching in plantar fasciitis promotes healing of microtears in the plantar fascia, presumably by reducing the stress exerted by the tendoachilles. The relationship between the tendoachilles and the plantar fascia has been described anatomically and clinically; however, the biomechanical relationship has not been defined. The purpose of this study was to measure the biomechanical relationship between the tendoachilles, the plantar fascia, and the metatarsophalangeal joint dorsiflexion angle.

MATERIALS AND METHODS: Eight cadaveric lower extremity specimens were obtained (age range 60-76 years). Each specimen was sectioned at the proximal third of the tibia and fibula. A circular external fixator was used to mount each specimen with three 5 mm diameter half-pins placed in the mid-portion of the tibia in divergent planes. Two half-pins were placed at the level of the distal tibia. The foot was stabilized using two additional pins drilled into the medial cuneiform and cuboid bones. The ankle was placed in a neutral position to simulate maximum tendoachilles and plantar fascia strain at 45° of the gait cycle. Sixteen gauge wire was woven into the tendoachilles and the wire was attached to the upper movable cross-head of the testing machine. The proximal phalanges of the toes were transfixed with a tensioned, 1.8 mm diameter wire and half-ring to allow fixed metatarsophalangeal positioning at 0°, 15°, 30°, and 45° of dorsiflexion relative to the horizontal axis. The fixator frame and specimen were mounted to the base of an MTS servohydraulic testing machine base (MTS, Minneapolis, MN). A precalibrated strain-gauged extensometer was attached in the mid-portion of the plantar fascia on the inferior aspect and parallel with the longitudinal axis of the tissue fibers. Mounting hooks and fine suture were used to secure the device to the plantar fascia. The metatarsophalangeal angle was set at 0°, and a tensile force of up to 500 N was applied to the tendoachilles at a displacement rate of 1 cm/sec. This tensile force produced tensile strain (or stretching) of the plantar fascia. Simultaneous tendoachilles tensile force data and plantar fascia tensile strain data were acquired at 0.05 second intervals using onboard software (MTS Testware SX, Minneapolis, MN). Following the completion of five identical test cycles at 0°, the test was then repeated five times each at metatarsophalangeal dorsiflexion angles of 15°, 30°, and 45°. Five data sets were obtained for each of the four metatarsophalangeal joint dorsiflexion angles tested in order to check for reproducibility. At the completion of the series of experiments, the lower limb specimen was removed from the fixator and a 50 mm length of the plantar fascia was carefully dissected out; the proximal and distal transverse sections of this length of the fascia corresponded to the attachment points of the extensometer. The cross-sectional area of the plantar fascia at the proximal and distal sections were then carefully measured. Assumption linearity: Modulus (E) = Stress divided by Strain. Stress = E x Strain. Stress = Force (F) divided by Cross-sectional Area. F divided by A = E x Strain. F = E x Strain x A. E and A are constants for each plantar fascia. The force in the plantar fascia was calculated using the strain data. E was assumed to be 585 x 10⁶ N/m² and A varied for each specimen (average value of A = 24.02 mm² with a standard deviation of 5.81 mm²).

RESULTS: - Graphs of tensile force in the tendoachilles against the average calculated values of tensile force generated in the plantar fascia for the eight specimens were drawn. The tightening effect of toe dorsiflexion on the plantar fascia is illustrated as a shift along the x-axis for a zero value of tendoachilles force. This demonstrates the windlass effect on plantar fascia tensile force in the absence of tendoachilles force. The subsequent application of up to 500 N of tendoachilles force to the tendoachilles produced proportional increases in plantar fascia tensile force for each of the four toe dorsiflexion angles. For example, 500 N produced 314 N tension in the plantar fascia at 0° of toe dorsiflexion, and 511 N at 45° of toe dorsiflexion, a 1.6 times (511/316) increase.

DISCUSSION: The main result is the defined biomechanical relationship between the force in the tendoachilles and the force generated in the plantar fascia, and how this relationship is affected by the metatarsophalangeal joint dorsiflexion angle. Morton described pathologic contracture of the gastrocnemius-solens muscle complex as it related to disorders in the foot, including longitudinal arch strain. He implicated high heel shoes as a causative factor; presumably high heel shoes, over time, produce an effective shortening of the tendoachilles. This also could result in extra stress being placed on the plantar fascia when shoes with elevated heels are substituted for shoes with lower heels, or bare feet. This is supported by the clinical observation that pain in individuals with plantar fasciitis is often greatest upon waking in the morning and walking barefoot. The results of the present study support the theory that stretching of the tendoachilles and the postural calf musculature could have a positive effect on plantar fasciitis. Both clinical and experimental studies have identified significant negative functional and morphologic changes in the foot and longitudinal arch as a result of surgical plantar fascia release for plantar fasciitis, despite the favorable results reported with respect to symptomatic pain relief. This study defines the biomechanical relationship between the tendoachilles and the plantar fascia, and indicates that plantar fascia release disrupts an important mechanism necessary for normal foot function.

CONCLUSION: There is a biomechanical relationship between the tendoachilles and the plantar fascia, and this relationship is affected by the metatarsophalangeal joint dorsiflexion angle.