INTRODUCTION:
Tendon injuries are common, disabling, and can have a significant impact on healthcare costs and workplace productivity. Tendon injuries are often treated through conservative or surgical procedures, with tendon function typically assessed using measures of strength, joint range of motion, pain, and other subjective indicators of function. These measures provide only an indirect assessment of tendon function, and there are few techniques that provide a direct assessment of in-vivo tendon function. As part of our ongoing efforts to develop the necessary tools for measuring in-vivo tendon function, the purpose of this study was to assess the effect of ankle plantarflexion force on in-vivo Achilles tendon deformation. We hypothesized that tendon deformation would increase with plantarflexion force and that there would be no difference in tendon deformation between right and left Achilles tendons.

METHODS:
Following IRB approval and informed consent, eight male subjects (average age: 30.3 ± 3.7) agreed to participate in the study. All subjects had no history of Achilles tendon injury or chronic ankle injury.

Experimental Setup: Subjects were placed in a custom testing fixture that positioned their lower limb in 90° of knee flexion and 90° of ankle flexion. The subject’s foot rested against a footplate attached to a digital force gauge (Imada DPS-220, Deerfield, IL) (Fig. 1).

Testing Protocol: To simulate a single-leg heel raise, subjects were instructed to produce an isometric plantarflexion contraction against the footplate to force levels of 200 N, 400 N, and 600 N. During each test, dynamic ultrasound images of the Achilles tendon were collected with the ultrasound transducer manually positioned approximately 2-3 cm proximal to the tendon’s insertion on the calcaneus (Fig. 1). All ultrasound images were collected by one experienced technologist using a Logiq9 scanner with a 10 MHz linear array transducer (GE Medical Systems, Milwaukee, WI). The ultrasound images were acquired at 15 Hz with a spatial resolution of 0.051 mm per pixel. Three trials were conducted at each force level and both legs were tested, resulting in a total of 144 trials. Testing order – i.e., combinations of limb (left, right) and plantarflexion force (200 N, 400 N, 600 N) – was randomized.

Data Analysis: One-dimensional measures of tendon deformation were computed from the ultrasound images using texture correlation analysis. Texture correlation analysis, which has been previously validated for accuracy and reliability [1], measures tissue deformation by using a pattern-matching algorithm to track naturally occurring features or patterns within the tendon across the entire image sequence (typically 30 to 60 images). Using this approach, maximum tendon deformation was recorded from each trial.

Statistical Analysis: The effects of limb (left, right) and plantarflexion force (200 N, 400 N, 600 N) and their interaction on maximum tendon deformation were assessed with a repeated measures two-way ANOVA, force (200 N, 400 N, 600 N) and their interaction on maximum tendon deformation were assessed with a repeated measures two-way ANOVA, followed by a Fisher’s test with Bonferroni correction for multiple comparisons. Significance was set at p < 0.05.

RESULTS:
As expected, no statistically significant difference in deformation was detected between right and left Achilles tendons (p=0.16, Fig. 2). Although tendon deformation increased with plantarflexion force, this increase was not found to be statistically significant (p=0.36, Fig. 2).

DISCUSSION:
The most interesting observation from this study was that the Achilles tendon shortened during plantarflexion in 51% of the trials. Although this observation was surprising, it is consistent with previous studies that have shown negative strains or shortening of the gastrocnemius-soleus complex at the aponoeurosis during muscle contraction [2, 3]. Indeed, the gastrocnemius-soleus complex has been shown to exhibit compartmentalized activation [2] and shear strains have been implicated in the pathogenesis of Achilles tendinopathy [4], so it is entirely plausible that shortening of this small region of the Achilles tendon during plantarflexion may be a normal physiologic phenomena. Alternatively, these data may reflect experimental error due to manual positioning of the ultrasound transducer, out-of-plane tendon movement, or inadequate stabilization of the ankle during testing. Additional research is necessary to corroborate these findings.

Future efforts will focus on the development and validation of a technique for quantifying 3D, in-vivo tendon strains. This technique will be used to directly assess the effects of surgical and conservative treatment on in-vivo tendon function.

REFERENCES: