AGE-RELATED REDUCTIONS IN ACHILLES TENDON STIFFNESS PERSIST AT MATCHED TRICEPS SURAE ACTIVATIONS

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Introduction

Ankle muscle-tendon unit (MTU) stiffness is thought to arise from a combination of activation-independent (*i.e.*, Achilles tendon) and activation-dependent components (*i.e.*, muscle). Indeed, we have shown that MTU stiffness is regulated via activation-dependent changes in triceps surae length-tension behavior [1]. This neuromechanical behavior is critical to help explain clinically-relevant declines in ankle power output during walking – for example those due to aging. Historically, most human subject comparisons have shown *in vivo* evidence of reduced Achilles tendon stiffness (k_{AT}) with age [2]. However, these previous studies may have inadvertently compared k_{AT} between young and older adults at different regions on their respective tendon length-tension curves. Indeed, tendon length-tension relations are nonlinear at lower tissue strains and the effective stiffness "seen" by muscle can vary as a function of activation – something overlooked in our previous theoretical considerations of muscle-tendon interaction dynamics. Thus, it is unknown how aging effects on the effective stiffness of the Achilles tendon varies as a function of triceps surae activation. The purpose of this study was to quantify age-related differences in apparent K_{AT} across a broad range of matched muscle activations prescribed using electromyographic biofeedback. We hypothesized that (1) young and older adults would exhibit greater k_{AT} at higher triceps surae activations – consistent with a shift from the nonlinear to the linear region of their tendon length-tension curves, and (2) older adults would exhibit lesser k_{AT} compared to young adults at matched activations.

Methods

Thus far, 15 young adults (8F/7M, 23±4 yrs, 1.7±0.09 m, 72.9±14.2 kg) and 13 older adults (7F/6M, 71±5 yrs, 1.7±0.07 m, 71.3±12.0 kg) performed passive ankle rotation and a series of isokinetic plantarflexion contractions while using biofeedback to match targets representing 25 and 75% of their maximum voluntary isometric contraction (MVIC) triceps surae activation. Specifically, participants performed isokinetic eccentric contractions at 20°/s from 30° plantarflexion to maximum dorsiflexion. Ultrasound imaging captured displacement of the gastrocnemius muscle-tendon junction (MTJ) and surface electromyography measured muscle activation. Achilles tendon force was estimated by dividing ankle torque by subject-specific Achilles tendon moment arm. Achilles tendon stiffness was then calculated as the slope of the relation between tendon force and tendon elongation, from 20-80% of each subjects' dorsiflexion range of motion (i.e. starting from a neutral ankle angle). A mixed ANOVA compared Achilles tendon stiffness across activation levels, and between young and older adults (p<0.05).

Results and Discussion

We found a significant interaction between activation level and age (p=0.045), a significant main effect of activation level (p<0.001), and a significant main effect of age (p=0.028) on k_{AT}. First, consistent with our first hypothesis, Achilles tendon stiffness increased with muscle activation in both young and older adults. We interpret these data to suggest that the non-linear region of the tendon length-tension relation is functionally meaningful not only at negligible levels of muscle activation, but across a broad range relevant to daily activities such as walking. In addition, and consistent with our second hypothesis, older adults displayed lesser Achilles tendon stiffness than young adults. Pairwise comparisons revealed that this effect was activation-dependent and specific to passive rotation (-56%, p=0.045) and 75% MVIC activation (-63%, p=0.005). These results confirm prior reports that older adults exhibit lesser k_{AT} stiffness compared to young but add that this difference: (i) exists during passive rotation and (ii) persists despite matched activations at those representative of walking.

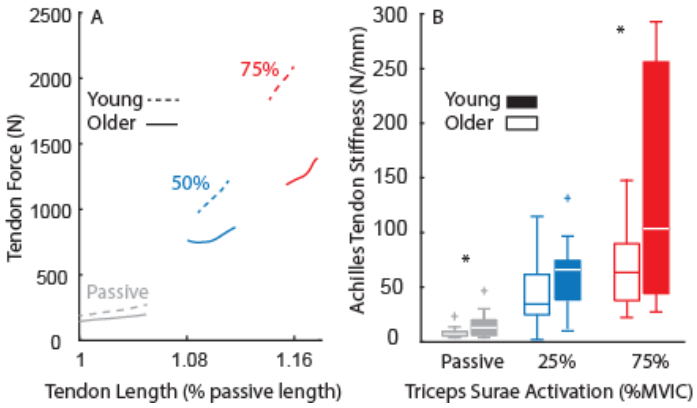

Figure 1. (A) Tendon force-length relations and (B) Achilles tendon stiffness across 0, 25, and 75% MVIC triceps surae activation in young (dashed line/filled box) and older adults (sold line/open box). Asterisks (*) indicate significant age effects.

Significance

Our results suggest that the effective tendon stiffness "seen" by the triceps surae muscles varies across a functionally-relevant range of activations and that age-related reductions in Achilles tendon stiffness persist even at matched muscle activations. These findings have functional implications for the origins of neuromechanical deficits in ankle push-off power observed in older adults. Indeed, in support of our recently published hypothesis [3], reduced Achilles tendon stiffness may precipitate an unfavorable cascade of muscle dysfunction.

Acknowledgments

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References

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