The influence of medial gastrocnemius fascicle length on the elasticity of the Achilles tendon and aponeurosis

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Summary

Stiffness is an important factor for muscle energetics. It influences maximal muscle force and rate of force development. The structure of the muscle in series has a direct effect on the tendon and aponeurosis compliance, yet interplay between tendinous tissue and muscle in series is not fully understood. Hence, we explored associations between ankle plantarflexion strength, medial gastrocnemius (MG) fascicle length and the elasticity of the MG muscle belly, MG aponeurosis and free Achilles tendon (AT). Tissue elasticity was assessed using shear wave elastography when relaxed. Bilateral data from 6 and 12 months were combined from patients with unilateral AT rupture. Longer fascicle length correlated with lower shear wave velocity (SWV) in the muscle belly and higher SWV in the aponeurosis. Greater MG aponeurosis and AT SWV were associated with higher plantar flexion maximal torque. Longer MG fascicles reflect a more compliant muscle and stiffer aponeurosis at rest.

Introduction

Force exerted by a muscle is transmitted readily through the surrounding collagen-rich connective tissues [1], including aponeurosis and free tendon, to reach the bone and facilitate locomotion. Regional stiffness in different components within the muscle-tendon unit can be altered by pathology such as Achilles tendon (AT) rupture [2] or immobilization [3]. Muscle structure has a direct influence on tendon and aponeurosis the stiffness [4], yet the interplay within the muscle-tendon unit is not well understood. Therefore, this study aimed to explore how the shear wave velocity (SWV) of the medial gastrocnemius (MG) muscle, MG aponeurosis and free AT are associated with MG fascicle length and isometric maximum voluntary torque (MVC).

Methods

Twenty-three participants (6f, 41±10.6 years, 178±9.6 cm, 87±17.4 kg) with unilateral AT rupture were recruited within a clinical cohort study (NoARK) [5]. MVC, SWV of the muscle belly and aponeurosis and fascicle length of the MG muscle were assessed at 6 and 12 months bilaterally. Elasticity of the AT was assessed 1.5 cm proximal to the superior calcaneal echo. Bilateral data from 6 and 12 months were combined to explore the associations, since there was no difference in the SWV between un-injured and injured limbs or between time points. Partial correlations controlled for age was used to explore associations between SWV, fascicle length and MVC.

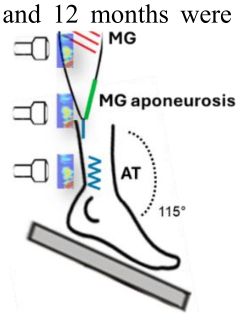

Figure 1: Schematic representation of the SWV measurement protocol.

Results and Discussion

Fascicle length correlated negatively with SWV of the muscle belly (r_p= -0.25 [-0.48 to 0.025]), and positively with aponeurosis SWV (r_p= 0.29 [0.06 to 0.50]) (Figure 2). MVC was positively correlated with SWV of the aponeurosis (r_p= 0.29 [0.10 to 0.46]), SWV of the AT (r_p= 0.30 [0.07 to 0.52]), and fascicle length (r_p= 0.66 [0.58 to 0.74]).

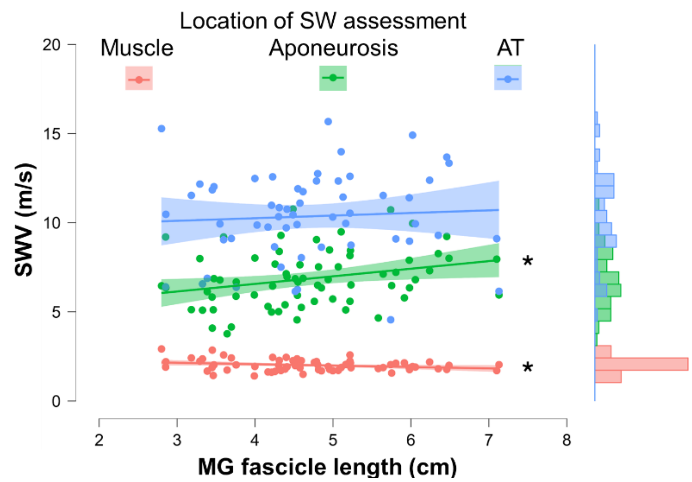

Figure 2: Scatterplots and regression lines of the correlations between SWV assessments and fascicle length of the MG muscle. * Significant correlation $p < 0.05$.

Conclusions

Consistent with our observation, there is evidence that longer fascicles in a given muscle are associated with lower passive tension at micro and macro levels of the muscle [6]. We found that plantar flexion maximum force production was positively associated with SWV of aponeurosis and tendon, which is reasonable considering the role of tendon stiffness in muscle force and rate of torque development [7].

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