Plantarflexor Torque and Work is Positively Correlated with Medial Gastrocnemius Fascicle Length in Healthy Adults

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Summary

In this study, we determined the relationship between muscle architecture and peak torque and total work produced by the plantarflexors during maximal effort isokinetic contractions. We measured resting fascicle length and pennation angle and calculated muscle thickness in the medial gastrocnemius using ultrasound in healthy adult subjects (n = 12). Subjects performed maximal effort isokinetic contractions on an isokinetic dynamometer at 0, 30, 120 and 210 °/s. We calculated peak torque and total work at each velocity and used linear regression to examine the relationship relating fascicle length, pennation angle, and muscle thickness to peak torque and total work. We found that fascicle length was more strongly correlated with both peak torque and total work than pennation angle or muscle thickness. This provides experimental evidence linking resting muscle architecture to dynamic muscle performance in healthy adults which has been hitherto not experimentally demonstrated in existing literature.

Introduction

Plantarflexor kinetics is critical for ambulatory function in elite athletes, the elderly, and many patient populations. Despite the robust findings linking plantarflexor muscle structure with these populations[1], the link between plantarflexor fascicle length and ankle kinetics has not been established in the literature. Therefore, the purpose of this study was to determine the relationship between medial gastrocnemius architecture and plantarflexor function.

Methods

Twelve healthy adults performed maximal effort plantarflexor contractions at 0, 30, 120, and 210 °/s on an isokinetic dynamometer after providing written informed consent in this IRB approved study. We measured muscle architecture (fascicle length, pennation angle, and thickness) of the medial gastrocnemius muscle with the ankle in resting position of 16°[2] using ultrasound. We calculated peak torque and total work at each velocity. To determine the relationship between muscle architecture and plantarflexor function, we performed linear regression between the three architectural parameters and the two kinetic parameters. We hypothesized that (1) longer resting fascicles would generate higher peak torques and do more work (2) that fascicle length would have the strongest correlation to plantarflexor function.

Results and Discussion

Longer fascicles generated higher peak torque and did more total work (Figure 1, $R^2 > 0.41$, $p < 0.013$) across all velocity conditions. We found that resting fascicle length was more strongly correlated with both peak torque and total work than pennation angle and muscle thickness (Table 1). These experimental findings support our recent computational simulations[3]

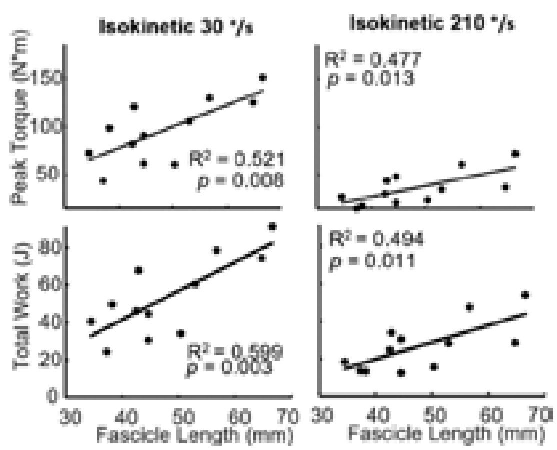

Figure 1: Peak plantarflexor torque (*top row*) and work (*bottom row*) are positively correlated with resting fascicle length at slow (30°/s) and fast (210°/s) rates of plantarflexion rotation.

Table 1: Regression Values comparing three resting architecture parameters to the two functional dynamic parameters. Bold shows p < 0.05.

	R^2 - Resting Fascicle Length				R^2 - Resting Pennation Angle				R^2 - Resting Muscle Thickness			
Angular Velocity (°/s)	0	30	120	210	0	30	120	210	0	30	120	210
Peak Torque	**0.325**	**0.521**	**0.415**	**0.477**	0.09	**0.339**	0.296	**0.417**	0.153	0.124	0.104	0.076
Total Work	**–**	**0.599**	**0.413**	**0.494**	–	0.326	0.255	**0.39**	–	0.172	0.117	0.089

that highlight the importance of plantarflexor fascicle length during single-leg heel raises—a clinical test of function in patients with Achilles tendon pathology.

Conclusions

These results link muscle architecture with dynamic muscle function in healthy young adults. Ongoing work is focused on understanding the implications of injury on muscle remodelling and long-term plantarflexor function.

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References

1. **Abe *et al*** (2000). *J Appl Physiol*, *88*, 811-6
2. **Zellers *et al*** (2018). *F and Ank Int 39*, 343-348
3. **Baxter *et al*** (2019). *J Biomech*, Online 29 January 2019