Gait Speed and Tibialis Anterior Eccentric Contraction During the Swing Phase

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Summary

We investigated the behaviour of the tibialis anterior (TA) muscle during overground walking, with a particular focus on the swing phase. Thirty healthy participants (15 female; age: 25.25 ± 2.63 years) completed ten barefoot walking trials along a 5-metre path under 11 different speed conditions. To track participant movements, a motion capture system was employed alongside two force plates. Bilateral muscle activation was recorded, and TA movements in both legs were monitored via B-mode ultrasound. Joint kinematics and kinetics were computed through inverse kinematics and dynamics with subject-specific model scaling. Notably, ultrasound analysis revealed that as walking speed increased, the duration of eccentric contraction during the early swing phase was prolonged, while the subsequent concentric contraction was significantly reduced. This speed-dependent behaviour underscores how the TA harnesses the tendon's elastic recoil properties, playing a crucial role in enhancing walking efficiency under dynamic conditions.

Introduction

The TA plays a crucial role during the swing phase of human gait. As the primary dorsiflexor, it prevents foot drop, making it a key focus in rehabilitation for patients with neurological disorders. Despite its recognised importance, many aspects of the TA's role during gait remain unclear. In this study, we non-invasively investigate changes in tibialis anterior behaviour across various walking speeds, aiming to deepen our understanding of its function under different dynamic conditions.

Methods

Thirty healthy participants (15 male, 15 female; age: 25.25 ± 2.63 years) completed 11 walking conditions on a 5-meter path: 8 metronome-guided (60–130 bpm, 10 bpm increments) and 3 self-paced (slow, normal, fast). Conditions were randomized and repeated up to 10 times. Motion capture (100 Hz) and ground reaction forces (2 kHz) were collected via Vicon and AMTI force plates. EMG (2 kHz) from eight muscles (bilateral TA, soleus, medial and lateral gastrocnemius) was recorded with a Delsys system. TA fascicle length and pennation angle were measured via B-mode ultrasound (60 Hz) with probes on the mid-belly. Joint kinematics and kinetics were computed in OpenSim 4.5 using subject-specific models from static trials. Fascicle tracking from ultrasound was analyzed via a semi-automated method. All collected data were synchronized through an external trigger signal and processed in MATLAB.

Results and Discussion

The TA showed eccentric contraction during early swing, consistent with previous studies [1]. Additionally, increasing walking speed prolonged the duration of this eccentric contraction, supporting prior findings that link fascicle length changes to the TA's energy-efficient behaviour during the swing phase [2].

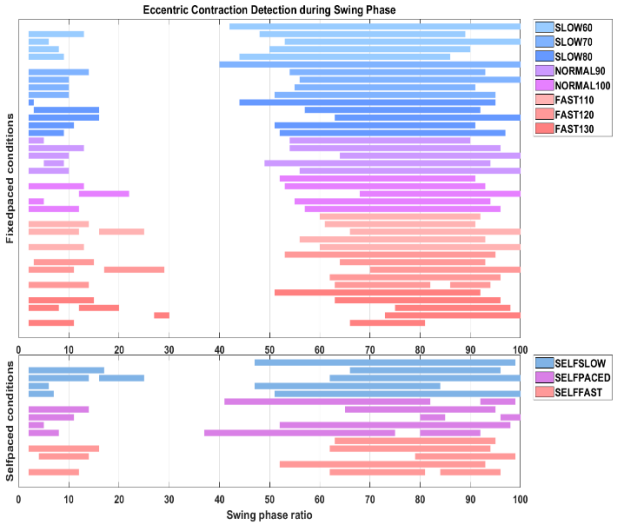

Figure 1: Detection of eccentric contraction during the swing phase based on fascicle length observations.

Additionally, fascicle length change during the subsequent concentric contraction did not increase. It appears to be influenced by the preceding eccentric contraction and further supports the notion that the TA's behaviour contributes to enhancing walking efficiency.

Conclusions

During the early swing phase, tibialis anterior (TA) eccentric contraction lengthens with increasing speed, hinting at its role in energy-efficient walking. This behaviour may align with previously proposed mechanisms like tendon elastic recoil or titin's function. Further exploration could offer valuable insights for gait rehabilitation strategies.

Acknowledgments

This work was financially supported by the Biotechnology and Biological Sciences Research Council (grant no. BB/S003762/1 to S.-H.Y.)

References

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