INVESTIGATING CHANGES IN ACHILLES TENDON LOAD DURING WALKING WITH EXOSUIT ASSISTANCE

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Summary

We investigated the use of shear wave tensiometry to detect modulation of Achilles tendon loading induced via exosuit assistance. Tendon shear wave speed, and hence tendon loading, exhibited systematic variations with walking speed, load carriage, and the timing of active ankle exosuit assistance.

Introduction

Exosuit effectiveness is often assessed based on metabolic cost reduction and decreased ankle torque, which imply energy savings and injury risk mitigation, respectively. However, metabolic measurements reveal only gross changes. Additionally, ankle torque reduction, estimated from inverse dynamics or EMG, relies on many assumptions to resolve the underlying tissue loads. We recently introduced shear wave tensiometry (SWT), which uses shear wave speed as a metric of tendon tissue loading [4]. This study investigated the potential for using SWT to detect changes in tendon loading induced via exosuit assistance.

Methods

One healthy male adult walked on a treadmill while wearing an active bilateral ankle exosuit [2]. The exosuit was similar in principle to [3], but unlike previous versions, the exosuit applied a pure ankle plantarflexion assistance without additional hip flexion assistance. Bowden cables transmitted assistive forces from an offboard actuation system to the exosuit. Achilles tendon shear wave speed was continuously measured via a tensiometer consisting of a piezoelectric actuator and two accelerometers [4]. Squared wave speed was used as an indicator of tendon loading [4].

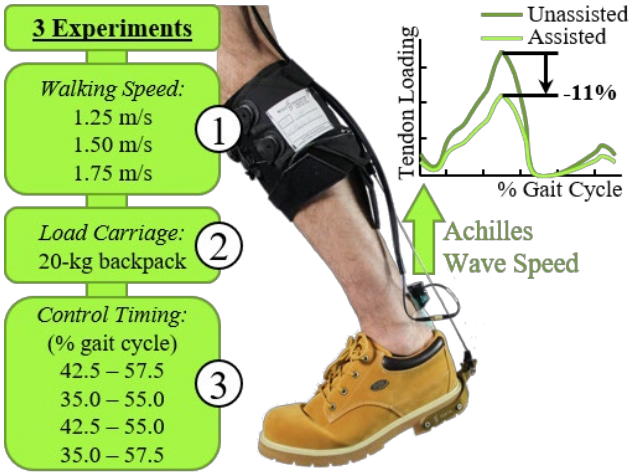

Figure 1: An active ankle exosuit and a tensiometer.

The subject performed three sets of treadmill walking tasks: 1) Walking at different speeds (1.25, 1.50, 1.75 m/s) with and without exosuit assistance (300-N tension). 2) Load carriage walking (20-kg backpack) with and without exosuit assistance (300-N tension). 3) Walking at 1.5 m/s as the timing of exosuit assistance was manipulated (Fig. 1).

Results and Discussion

Achilles tendon loading increased with walking speed and load carriage, as expected biomechanically (Fig. 2). With exosuit assistance, peak tendon loading was reduced by 11-15% during normal walking and by 5% during load carriage walking. The timing of exosuit assistance had a substantial effect on tendon loads. Relatively small changes (2.5% of gait cycle) in the onset/offset of assistance caused tendon loading to vary from a 11% reduction to a 6% increase. These results indicate that tendon loading, directly measured via SWT, is highly sensitive to exosuit assistance.

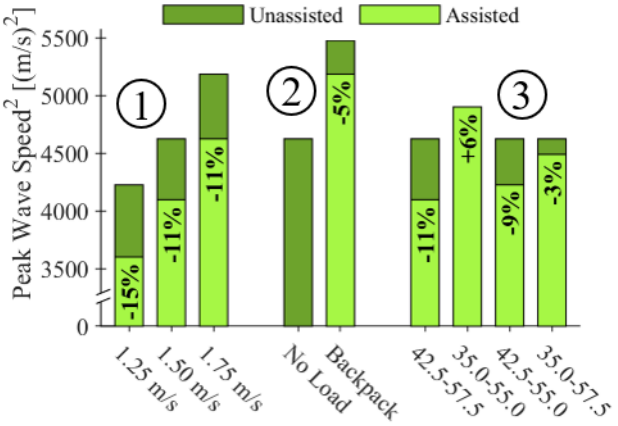

Figure 2: Squared wave speed was used to assess change in tendon loading with exosuit assistance during: (1) normal walking at 3 speeds, (2) load carriage, (3) 1.5 m/s walking with altered timing.

Conclusions

SWT can detect modulations in tendon loading resulting from exosuit assistance. Further work could use SWT to evaluate exosuit effectiveness and inform future designs.

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References

[1] Zhang J. et al. (2017). *Science*, **356**: 1280-1284.
[2] Lee S et al. (2018), ICRA. 2812-2819.
[3] Lee S et al. (2016), ICRA. 3509-3515.
[4] Martin JA. (2018) *Nat. Commun.* **9**: 1592.