The Effects of Passive Ankle Exoskeleton on Ankle Muscle Reflex Onset Muscle Latency Responses

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Summary

This study examined the effects of a spring-loaded passive ankle exoskeleton (EXO) on ankle muscle reflex latencies and activation during balance perturbations. The EXO delayed tibialis anterior (TA) medium latency responses during forward surface translations (FT), potentially affecting reflexive control. It also reduced gastrocnemius medialis (GM) and lateralis (GL) activation during FT. While soleus (SOL) showed a trend toward later responses, no significant latency differences were found for GM and GL, or TA during backward surface translations (BT).

Introduction

EXOs are unpowered devices that provide mechanical assistance to muscles and joints at the ankle. These devices provide support by supplementing the strength of lower limb muscle contractions and have been shown to aid the wearer's postural stability and gait [1]. Previous studies have found that they can have non-intuitive effects on ankle muscle function and activation patterns [2, 3]. However, it is unclear if these effects are a result of interferences to the neuromuscular feedback mechanisms that influence these muscles' reflex responses and the corresponding standing balance [4]. This study aimed to investigate how donning an EXO affects short, medium and long latency muscle reflex responses during perturbations to standing balance. We hypothesised that the mechanical assistance provided would cause a delay in the onset of latency responses due to reduced muscle background activity.

Methods

Our ankle EXO was an ankle-foot orthosis with an extension spring to assist plantar flexion force, as per Farris et al. (2024) [5]. Data from 9 participants out of a planned 18 participants has been analysed. Each participant stood on a stationary instrumented treadmill (Motek) for 60 s whilst wearing a harness. At pseudo-random instants, the treadmill belts provided FT or BT, creating underfoot perturbations with an average velocity of 50 cm/s. During trials, surface EMG was used to record muscle activity from the SOL, GM and GL and the TA. This procedure was repeated for each of the following EXO conditions: (1) shoes only (No Exo), (2) a non-assistive EXO (No Spr) and (3) a fully assistive EXO (Exo). One-way repeated measures ANOVA and post-hoc t-tests ($p<0.05$) determined the effects the different EXO conditions had on the magnitude and onset of short (M1), medium (M2) and long (M3) latency reflex responses.

Results and Discussion

The BT and FT perturbations induced plantar flexion and dorsiflexion, respectively. No significant differences in muscle latency were found for GL, GM, or TA during BT perturbations ($p > 0.05$), while SOL showed a trend for later M2 responses with EXO ($p = 0.096$). For FT perturbations, GL, GM and SOL also showed no significant effects ($p = 0.131$), though TA exhibited significant differences reflex response time and magnitude (M2: $p = 0.014$; Fig 1) between EXO and No EXO, indicating potential delays in reflexive control that may impact postural stability. Regarding muscle response magnitude, no significant differences were noted for GL, GM, SOL, or TA during BT ($p = 0.109$). However, FT revealed significant differences for GL (M2: $p = 0.023$; M3: $p = 0.027$) and GM (M3: $p = 0.025$). Post-hoc analysis indicated greater muscle activation magnitudes with No Spr than No EXO ($p = 0.008$) and a trend toward decreased magnitudes with EXO ($p = 0.065$), supporting literature that suggests EXOs can reduce muscle force production.

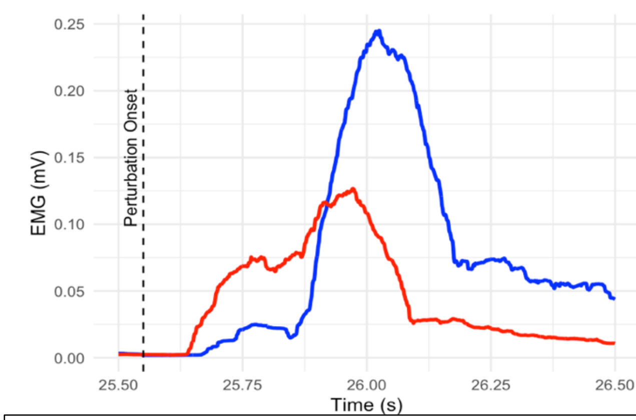

Figure 1: Mean TA EMG RMS response to FT perturbation with the Exo (blue trace) and No Exo (red trace). Dashed vertical is the perturbation onset.

Conclusions

Our findings suggest the EXOs may influence reflexive control in TA during perturbations and contribute to reduced muscle response magnitudes.

Acknowledgments

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References

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