Passive ankle exoskeletons influence the neural control of *triceps surae* during balance in a muscle-specific manner

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SUMMARY

The aim of this study was to determine how passive ankle exoskeletons alter the structure of the neural command during a range of balance tasks. We combined high-density electromyography with lower limb kinetic and kinematic measures in 20 participants to assess the changes in lower limb neural control and balance induced by passive exoskeleton assistance. Results are threefold. First, we found that the exoskeleton did not significantly alter balance performance. Second, we observed reduced muscle activation when wearing the exoskeleton only for *soleus*, but not the *gastrocnemii*. Third, we found a decrease in *soleus* motor unit discharge rate with exoskeleton assistance compared un-assisted balance. Together, these results demonstrate that passive exoskeleton assistance alters the *triceps surae* neural control in a muscle-specific manner during balance tasks.

INTRODUCTION

Understanding the interaction between device-assisted motor tasks and the user's underlying physiology is a key element to optimize the design of wearable assistive devices to augment or restore motions. Previous studies have revealed that exoskeletons can affect the neuromuscular control of lower limb muscles [1]. However, studies often record signals from only one synergist muscle [1] and used classic bipolar surface electromyography which may be prone to crosstalk [2]. The aim of this study was to determine the effect of passive ankle exoskeleton assistance on the neural control of the main lower limb muscles during balance.

METHODS

Twenty participants performed four balance tasks (standing eyes opened; standing eyes closed; standing on a foam surface with eyes closed; and single leg standing with eyes opened) without (NOEXO) and with (EXO) a custom-made bilateral passive ankle exoskeleton. For each trial, we measured the ground reaction force and center of pressure (COP) using an instrumented treadmill (FIT5, Bertec Inc, USA), lower limb kinematics using 3D motion capture (Miqus, Qualisys AB, Sweden) and the surface myoelectrical activity of the *tibialis anterior* (TA), *gastrocnemius lateralis* (GL), *gastrocnemius medialis* (GM) and *soleus* (SOL) muscles using high-density electromyography (Quattrocento, OT Bioelettronica, Italy). We decomposed the high-density electromyographic signals into motor unit activity and tracked the same active motor units between NOEXO and EXO conditions. Linear mixed effects models (R, V4.4.1, Austria) were used to determine the influence of task and exoskeleton assistance on COP path length, global muscle activation and motor unit discharge rates. For a sake of brevity, we present only the effect of exoskeleton assistance in this abstract.

RESULTS AND DISCUSSION

We did not observe an effect of the exoskeleton on COP path length (p=0.357), suggesting that assistance did not alter s balance performance. We observed an effect of exoskeleton on muscle activation only in SOL (p<0.001) such that activation was reduced in EXO compared to NOEXO. We were able to identify a substantial number of motor units for GM and SOL. We found that SOL discharge rates were significantly lower (all p<0.017) in EXO compared to NOEXO in all tasks except single leg standing (p=0.117; Figure 1). However, we did not find any condition effect on GM discharge rates (all p>0.116). The motor unit results are therefore consistent with the surface electromyography results and suggest that the exoskeleton selectively reduces the neural drive to the SOL, but not to the *gastrocnemii* when providing passive assistive the ankle joint.

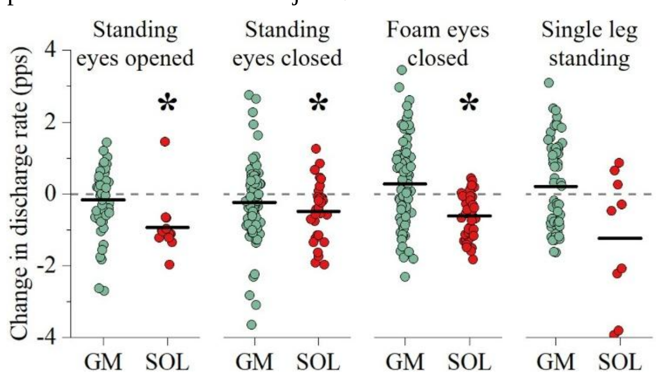

Figure 1: Change in discharge rate for GM and SOL motor units in EXO compared to NOEXO. Each circle represents a motor unit with the mean shown in black.

CONCLUSIONS

Our results demonstrate that passive ankle exoskeleton assistance reduces muscle activation and neural drive of some, but not all, plantarflexor muscles without altering balance performance. This muscle specificity should be considered to optimize the design of exoskeleton or the control of robotic assistive devices based on neurophysiological inputs.

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