MOTOR ADAPTATION TO A POWERED ANKLE-FOOT ORTHOSIS UNDER FOOT SWITCH CONTROL

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INTRODUCTION

Powered orthoses are an innovative way to study how humans adapt and change control strategies during walking. A previous study [1] using a powered ankle-foot orthosis (AFO) under proportional myoelectrical control (soleus EMG) to provide plantar flexion assistance found a decrease in soleus EMG amplitude without concomitant decreases in gastrocnemius EMG amplitude. We hypothesized that using foot switch control, in which the nervous system has no direct control over plantar flexion assistance, would result in simultaneous decreases in soleus, medial gastrocnemius, and lateral gastrocnemius EMG.

METHODS

Two healthy subjects (ages 23 and 24) participated in this study. The University of Michigan Institutional Review Board approved the study protocol and each subject gave informed consent. Each subject walked without an orthosis at a speed of 1.25 m/s on a treadmill and also while wearing a powered AFO as described by Gordon et al. [2] on the left leg. The powered AFOs used artificial plantar flexors (pneumatic muscles) that were controlled using an on/off (i.e., bang-bang) controller. The forefoot portion of a footswitch provided the signal to the controller to activate the artificial muscle. Each subject had two training sessions three days apart. A session consisted of walking without an AFO (no AFO) for 5 minutes, with a passive AFO (pre-passive AFO) for 10 minutes, with an active AFO (active AFO) for 30 minutes, and with a passive AFO (post-passive AFO) for 15 minutes. We collected and analyzed lower limb kinematics and electromyography (EMG) for 9 muscles (Motion Analysis system & Visual3D). We calculated average EMG RMS values normalized to the final minute of the pre-passive condition.

RESULTS AND DISCUSSION

The powered orthosis produced a peak plantar flexion torque of ~55 Nm, which resulted in increased plantar flexion from mid-stance through swing phase when wearing the powered AFO (Figure 1A). The subjects decreased soleus (SOL), medial gastrocnemius (MG), and lateral gastrocnemius (LG) muscle activation when the AFO was active (Figure 1B). During the last 10 minutes of the active AFO condition, EMG was reduced to ~77, 68, and 72% of pre-passive values for SOL, MG, and LG, respectively. When the powered AFO was turned off, SOL, MG, and LG EMG returned to ~100, 87, and 100% of pre-passive values. Both subjects were able to adapt to the powered AFO more quickly on the second day of training. As hypothesized, both subjects decreased muscle activity in all three triceps surae muscles (SOL, MG, LG) when walking with the powered AFO. However, even after two days of training, ankle kinematics were substantially different from passive AFO walking.

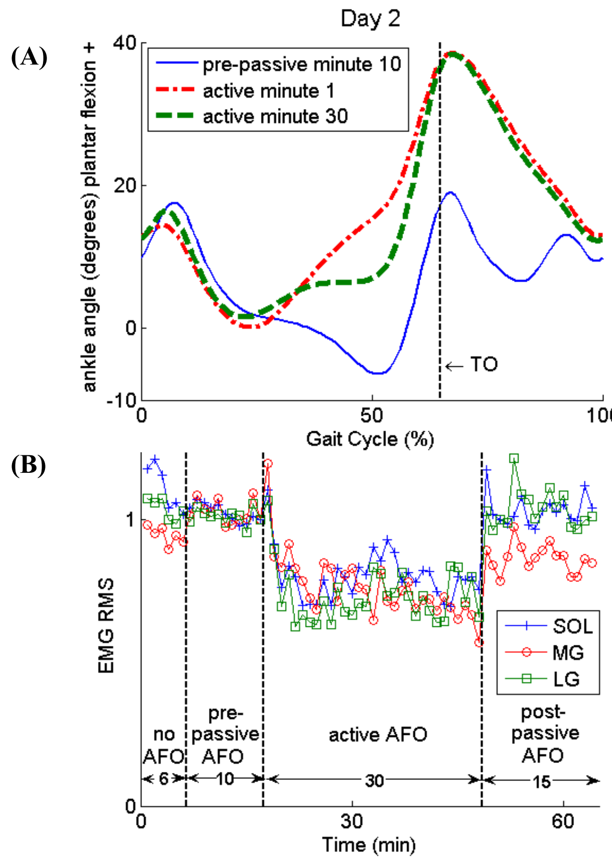

Figure 1: A) Ankle flexion versus gait cycle (left heel strike to left heel strike). Subjects walked with increased plantar flexion with the artificial plantar flexor powered ankle-foot orthosis (AFO). **B)** EMG RMS normalized to the last pre-passive minute versus time for soleus (SOL), medial gastrocnemius (MG), and lateral gastrocnemius (LG). With the powered AFO, subjects decreased muscle activity in SOL, MG, and LG simultaneously.

CONCLUSIONS

When a foot switch was used to control a plantar flexor-assist AFO instead of soleus EMG, muscle activity in all three triceps surae muscles (SOL, MG, LG) decreased synergistically. This study emphasizes that neural adaptations to a powered orthosis during gait depend on the type of controller used. Proportional myoelectric control [1] resulted in faster kinematic adaptation than foot switch control.

REFERENCES

1. Ferris, et al. *Proc 25th ASB*, San Diego, CA, 2001.
2. Gordon, et al. *Proc XXth ISB / 29th ASB*, in review, 2005.

ACKNOWLEDGEMENTS

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