NEURAL COUPLING BETWEEN THE UPPER AND LOWER LIMBS IN INDIVIDUALS WITH INCOMPLETE SPINAL CORD INJURY

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INTRODUCTION

Growing evidence suggests that there are spinal connections between upper limb motor neurons and lower limb motor neurons in humans that facilitate coordinated interlimb movements (Zehr and Duysens, 2004). Upper limb muscle activation has been shown to facilitate lower limb muscle activation during passive locomotor-like movements of the lower limbs in neurologically intact individuals (Ferris et al 2006; Huang & Ferris, 2004; Kao & Ferris, 2005).

The purpose of this study was to examine neural coupling between the upper and lower limbs in individuals with incomplete spinal cord injury. We wanted to determine if a) upper (or lower) limb muscle activation facilitates lower (or upper) limb muscle activation during passive locomotor-like movement of the lower (or upper) limbs, and b) maximal effort simultaneous upper and lower limb muscle activation results in greater muscle activation compared to maximal effort upper limb only or lower limb only muscle activation.

METHODS AND PROCEDURES

Ten individuals with incomplete spinal cord injury (ASIA C & D) performed recumbent stepping (Fig.1) using four different combinations of upper and lower limb effort (active-A, passive-P). For active effort, we instructed subjects to use maximal effort. For passive effort, we instructed subjects to relax and exert minimal effort. The four conditions were: passive upper & passive lower (PU-PL), passive upper & active lower (PU-AL), active upper & passive lower (AU-PL), and active upper & active lower (AU-AL). Velcro gloves, pedal straps, and a torso strap secured subject’s hands, feet, and torso to the handles, pedals, and seat, respectively. The stepping frequency was 1.25 Hz.

We collected electromyography (EMG) and joint kinematic data from upper and lower limbs. We calculated limb forces from load cells on the handles and pedals. For each condition and muscle, we calculated the root-mean-square (RMS) EMG. We normalized RMS amplitudes to the AU-PL data for the upper limb muscles and to the PU-AL data for the lower limbs. We used an ANOVA with Tukey-Kramer post-hoc tests to determine differences between pairs of conditions.

Figure 1: Recumbent stepping machine with real-time computer-controlled resistance and force and position sensors (modified TRS 4000, NuStep Inc, Ann Arbor, MI).
RESULTS

Upper limb exertion resulted in greater muscle activation of passive lower limb muscles (Fig. 2 *). AU-PL RMS amplitudes were significantly greater than PU-PL amplitudes for the right vastus medialis, the left and right medial hamstrings, and the left and right tibialis anterior. The effect was large enough that AU-PL amplitudes were not significantly different from AU-AL for the left medial hamstrings, both tibialis anterior, and left soleus (Fig. 2 ‡). Similarly, lower limb exertion resulted in greater muscle activation of passive upper limb muscles (Fig. 2 *). PU-AL amplitudes were significantly higher than PU-PL amplitudes for the left and right anterior deltoid, the right posterior deltoid, and the left and right biceps.

During simultaneous upper and lower limb exertion, EMG amplitudes were not significantly different compared to just upper limb exertion or just lower limb exertion. The right anterior deltoid was the only exception (Fig. 2, **AU-AL < AU-PL).

DISCUSSION

Upper limb exertion does not facilitate lower limb muscle activation during maximal effort tasks in individuals with incomplete spinal cord injury. There was no additive interlimb effect on recruitment. However, therapeutic exercise and activities of daily living are often performed at submaximal levels. Our results do not rule out the possibility that upper limb exertion provides an excitatory effect on lower limb muscles during submaximal exercise. Transcranial magnetic stimulation (TMS) could be used to determine if there is an excitatory interlimb coupling during submaximal muscle activation that results in less supraspinal descending neural drive to the lower limbs with upper limb exertion.

SUMMARY

These results suggest that neural coupling between upper limbs and lower limbs is bidirectional during locomotor-like movements in individuals with incomplete spinal cord injury. At maximal levels, there is no facilitation of muscle activation.

REFERENCES


ACKNOWLEDGEMENTS

Supported by grants from NIH (F31 NS056504) and PVA SCRF (2293-01).