BIDIRECTIONAL NEURAL COUPLING BETWEEN UPPER AND LOWER LIMBS

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INTRODUCTION

Humans have neural connections between their upper limbs and lower limbs that influence muscle activation patterns. For example, during human walking upper limb muscles are activated to swing the arms in coordination with lower limb movement (Hinrichs 1990). In addition, upper limb muscle activation can facilitate lower limb muscle activation during passive locomotor-like movements of the lower limbs (Ferris et al 2006; Huang & Ferris 2004).

The purposes of this study were to determine a) if lower limb muscle activation facilitates upper limb muscle activation during passive locomotor-like movement of the upper limbs, and b) if simultaneous upper and lower limb muscle activation results in a change in electromyography (EMG) amplitude compared to just upper or just lower limb muscle activation in healthy subjects. Based on our previous work, we hypothesized that lower limb activation would increase muscle activation in the passive upper limbs. We also hypothesized that simultaneous maximum upper limb and lower limb activation would result in decreased muscle recruitment compared to independent maximum upper limb or lower limb activation. This is contrary to what we have demonstrated for passive limb movement but it is in agreement with other studies showing a bilateral deficit with simultaneous activation of the upper limbs (Ohtsuki 1983).

METHODS

Six healthy subjects performed recumbent stepping (Figure 1) using four different combinations of upper and lower limb effort (active-A or passive-P).

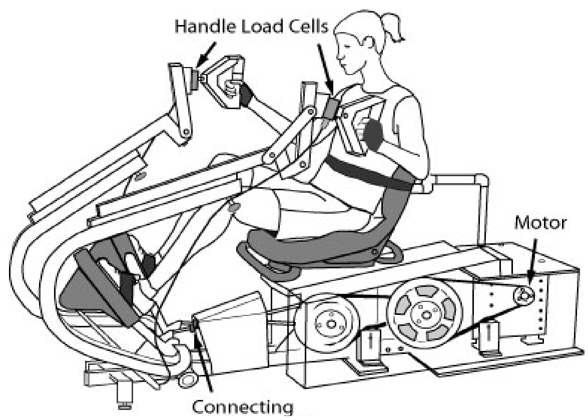

Figure 1: Recumbent stepping machine with real-time computer controlled resistance and force and position sensors. (Modified from TRS 4000, NuStep Inc, Ann Arbor, MI). The machine provided smooth consistent stepping regardless of subject effort through a custom designed position control of a prescribed sine wave stepping profile.

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 a) passive upper & passive lower, PU-PL b) passive upper & active lower, PU-AL c) active upper & passive lower, AU-PL, d) active upper & active lower, AU-AL. Velcro gloves and pedal straps secured subject's hands and feet to the handles and pedals, respectively. A torso strap helped minimize torso movement. The stepping frequency was 75 BPM, 1.25 Hz. After each trial, subjects rested for at least 30 seconds.

We collected EMG and joint kinematics 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 for the three strides with the greatest subject work. We normalized the RMS amplitudes to the maximum AU-PL RMS EMG for the upper limb muscles and likewise, to the maximum PU-AL RMS EMG for the lower limbs for each subject. To determine differences between conditions for each muscle, we used a repeated measures ANOVA and Tukey-Kramer Honestly Significant Difference (HSD) post-hoc tests.

RESULTS AND DISCUSSION

Lower limb muscle activation resulted in greater muscle activation of passive upper limb muscles (Fig. 2A *conditions). PU-AL RMS amplitudes were significantly greater than PU-PL amplitudes for the anterior deltoid, posterior deltoid, biceps, and triceps muscles. Similarly, upper limb muscle activation facilitated muscle activation of passive lower limbs (Fig. 2B * conditions). AU-PL amplitudes were significantly higher than PU-PL amplitudes for the vastus medialis, medial hamstrings, and tibialis anterior muscles. During simultaneous upper and lower limb muscle activation, EMG amplitudes were significantly lower compared to just upper limb activation or just lower limb activation for the posterior deltoid, vastus medialis, tibialis anterior, and soleus muscles (Fig 2, **conditions)

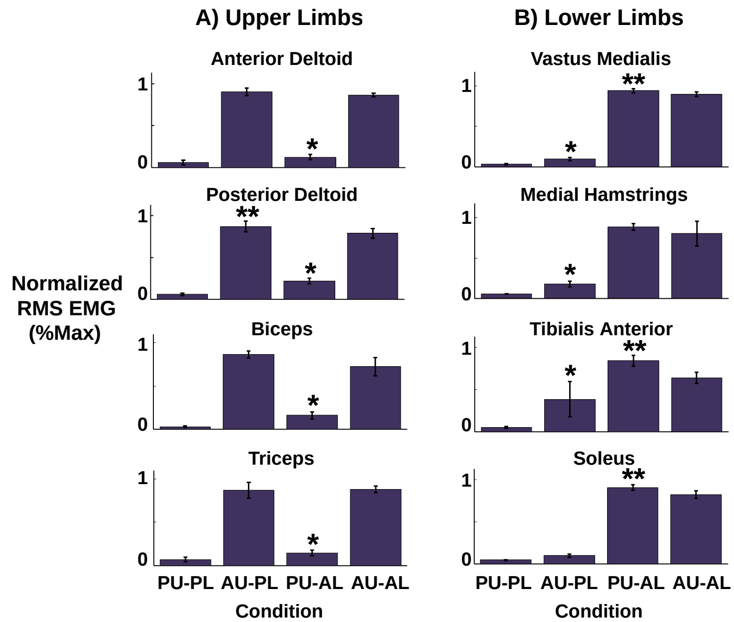

Figure 2: Averaged normalized RMS EMG with standard error bars for all subjects and strides. *Significantly different from PU-PL condition. **Significantly different from AU-AL condition.

SUMMARY / CONCLUSIONS

These results suggest that neural coupling between upper limbs and lower limbs is bidirectional during locomotor-like movements in healthy subjects. This bidirectional neural coupling facilitates muscle activation of passive limbs but hinders muscle activation of active limbs. Bidirectional upper-lower neural coupling could have implications for rehabilitation of interlimb coordination after neurological injury.

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