Cortico-Muscular Connectivity for Single and Two Degree-Of-Freedom Tasks
Jun Yao1, PhD, Ivy Wolfe1, SPT, Laura Anderson1, SPT, Katey Larson1, SPT, Ryan Sharkey 1, SPT, Carolina Carmona1, DPT, and Jules Dewald1, 2, 3, PT, PhD,
1Department of Physical Therapy & Human Movement Sciences, 2Department of Biomedical Engineering, and
3Department of Physical Medicine & Rehabilitation, Northwestern University, Chicago, IL

Introduction

Cortico-muscular connectivity (CMC) is critical for the quality of motor control. Able-bodied individuals can activate muscles/joints more or less independently, depending on the requirement of a motor task. The question then is whether the quality of CMC changes corresponding to the requirement for muscle selectivity. It has been shown that synchronized oscillation serves as one of the effective ways for the cortex to connect with target motor units. At the cellular level, each synapse and neuron has its own resonant frequency. Presynaptic inputs oscillating at the postsynaptic resonant frequency are more likely to cause a postsynaptic cell to fire. By using inputs of different frequencies, the presynaptic cell can selectively postsynaptic targets.

We therefore hypothesized that in able-bodied individuals the cortex connects with different muscles at more distinguished frequencies when higher muscle selectivity is required to guarantee a selective muscle activation.

Methods (Experimental protocol)

Subjects: 8 able-bodied subjects (4 young and 4 age-matched) and 1 stroke subject (FMA = 14/66).

Methods (Signal processing)

For each motor task, the coherence between EEGs and a target muscle (i.e., IDL or BIC) was analyzed. The CMC frequency distribution was then calculated as the number of EEG electrodes with significant coherence at a specific frequency.

Fig 1. Experiment setup. The forearm was casted and coupled with a metal ring attached to a load cell. The subject’s elbow is 90° flexed and the shoulder 80° abducted and about 40° flexed. The 160-channel EEG electrode montage is shown as well as the electrodes above and below the right eye that detect unwanted eye movements and blinks. EMGs were collected from intermediate deltoide (IDL) and biceps (BIC).

Results

Results (continued)

Fig 4. For 1 DOF task, the CMC frequency distributions for IDL and BIC overlap in both controls and the individual with stroke. This distribution widens in elderly able-bodied subjects and is even broader following stroke. During the 2 DOF task, a shift in the frequency distribution for both IDL and BIC and a reduction in their overlap were observed in all control subjects but not in the individual with stroke. A within-subject repeated measure (repeated on the tasks) reported a significant reduction (F=5.276, p<0.1) in the overlap of frequency distributions between CMC for IDL and BIC during 2DOF task as compared to 1DOF task.

Conclusion

In healthy subjects, CMC occurs at more selective frequencies during a 2 DOF task as compared to a 1 DOF task, suggesting a ‘fine-tuned’ communication with the desired muscles when high-level muscle coordination is required. The pilot data in the individual with stroke, however, demonstrated that such selectivity was lost.

Clinical Relevance

Understanding CMC in individuals with/out stroke could aid in the development of more effective therapies in the future: for example to use a brain stimulation method to change the resonant frequency of cortex, and thus enhancing the CMC.

Acknowledgments

Support: NIH Grant HD39343

References