Beta-Band EMG-EMG Coherence is Higher at Low Grip Forces in Carpal Tunnel Syndrome Patients

Tarkeshwar Singh, Peter J. Evans, MD, PhD, William H. Seitz, MD, Zong-Ming Li.
Cleveland Clinic, Cleveland, OH, USA.

Disclosures:
T. Singh: None. P.J. Evans: None. W.H. Seitz: None. Z. Li: None.

Introduction: Carpal tunnel syndrome (CTS) results from compression of the median nerve in the carpal tunnel. Previous studies in our laboratory which have simulated CTS like conditions with median nerve block have shown that force fluctuations increase significantly in a precision grasp. Such fluctuations could arise from integration of the descending neural drive with the noisy afferent signals. Other studies have shown elevated β-band corticomuscular coherence with more stable motor outputs and depressed β-band coherence when the motor output wasn’t steady. Therefore, we expected β-band EMG-EMG coherence to be lower in CTS patients. The specific purpose of this study was to investigate differences in EMG-EMG spectral coherence of the abductor pollicis brevis (APB) and first dorsal interosseous (FDI) muscles in an isometric precision pinch task between CTS patients and healthy controls. APB is innervated by the median nerve and FDI is innervated by the ulnar nerve. The compression of the median nerve in the carpal tunnel results in a slowing of the sensory conduction velocity that could result in augmented noise to the motoneuron pool involved in the precision task. Hence, our hypothesis was that EMG-EMG coherence between the two muscles would be lower in CTS patients compared to healthy controls.

Methods: Nine right-handed control subjects and seven patients diagnosed with CTS voluntarily participated in the study. All participants were right hand dominant. CTS subjects were diagnosed according to standard clinical guidelines. Control subjects did not previously report a history of disease, injury, or complications involving the hand or wrist. All participants consented to the study as per the approved protocols by the Cleveland Clinic Institutional Review Board. The exclusion criteria included for both the groups included: 1) history of electrodiagnostic test results indicating ulnar, radial, or proximal median neuropathy; 2) existence of a central nervous system disease (multiple sclerosis, motor neuron disease, myasthenia gravis, Parkinson’s disease, dystonia); 3) pregnancy; 4) history of trauma or surgical intervention to the hand/wrist; 5) rheumatoid arthritis or osteoarthritis of the hand/wrist; and 6) diabetes. The participants performed isometric force production tasks. The first set involved three isometric force production tasks with the thumb and index finger at 10% MVC, 40% MVC and at minimal force (Min-F) to ensure that the handle does not slip. The participants were given visual feedback of their force production on a computer screen. We collected EMG signals of the APB and FDI and computed EMG-EMG coherence in the β (15-30 Hz) and Y (30-60 Hz) frequency bands. Coherence values were Z-transformed by computing the arc hyperbolic tangent transformation.

Results: The maximum pinch force produced by the CTS patients was similar to controls (97.8 ± 9.3 N for controls and 95.9 ± 11.1 N for CTS). Consequently, there were no differences between the two groups for the average grip force applied at the 10% and 40% precision grip task. The coefficient of variation (CV) and standard deviation (STD) of the grip force was significantly higher for the CTS group compared to the control group for all the three grasp conditions (see Figure 1). For the MinF condition, coherence value in the β band, 0.32±0.06, was significantly higher (by ~250%) for the CTS group compared to the control group, 0.09±0.02 (p<0.05) (see Figure 2). Similarly, at the 10% force level, coherence value in the β band, 0.35±0.10, was significantly higher (by ~170%) for the CTS group compared to the control group, 0.13±0.02 (p<0.05). There were no differences in the Y band coherence for the low-force task. Unpaired t-tests showed no significant differences in EMG coherence in both the frequency bands between the two groups for the 40% force tasks.

Discussion: Contrary to our hypothesis, we found that EMG-EMG coherence tends to increase in CTS individuals. EMG synchrony in the β-band has been associated with the processing of sensory feedback and maintenance of steady force output. Therefore, higher β-band synchrony at low force levels for CTS patients suggests that the central nervous system increase the synchronous drive from the corticospinal system to the synergist muscles directly involved in the task. This increased synchrony may be a compensatory mechanism in response to diminished and delayed peripheral feedback due to the median nerve neuropathy.

Significance: The results of a higher β-band coherence between the intrinsic hand muscles in a precision pinch grasp associated with carpal tunnel syndrome suggest that higher β-band coherence facilitates sensorimotor integration to minimize the adverse effects of delayed sensory conduction in the median nerve associated with CTS.

Acknowledgments: NIH R01AR056964

Figure 1: The coefficient of variation (CV) of the grip force versus the average grip for the three conditions. The circles are for controls and the ‘*’ are for CTS patients. The black vertical line indicates the threshold for slippage assuming an average coefficient of friction of $\mu=0.9$. Note that CV of grip force is generally higher for the CTS patients.
Figure 2: The Z-transformed coherence values for the three conditions. The solid bars are for controls and the striped bars are for CTS patients.