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Changes in Motor Unit Discharge Patterns Following Strength Training

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Previous work has found that only a few weeks of strength training is necessary to elicit increases in muscle strength. Further, it has been found that the increase in muscle strength seen after few training sessions is due primarily to neural adaptations, with only minor changes in the contractile element. However, the neural changes that underlie this increase in muscle force are still poorly understood. This knowledge would provide crucial insight regarding neural involvement in strength training. The study conducted by Del Vecchio et al. seeks to provide this critical information regarding these adaptations, at the motor unit level. Several groups have previously attempted to investigate these changes, though, the results were based on pooling data across subjects because of the limited number of motor units identified from each subject. More importantly, the identified motor units were not tracked at the same relative force levels, making it impossible to identify the specific adaptions taken place. Recent advancements in motor unit decomposition has afforded the ability to both decompose large number of motor units from a single muscle and track these motor units across multiple sessions. (Martinez-Valdes *et al.* 2017). Employing the newly developed methods, Del Vecchio et al. were able to reliably track the same motor units over the course of training, which allowed the comparison of motor unit properties at the level of individual subjects. The authors hypothesized that the increase in muscle force would be accompanied by adaptations in the discharge characteristics of the motor units.

In this study, 2560 motor units were identified from the tibialis anterior (TA) of twenty-eight young and healthy male subjects during trapezoidal dorsiflexion contractions. Subjects were split into an intervention and a control group, which matched for anthropometric characteristics, habitual levels of physical activity, and peak force with the dorsiflexor muscle. Subjects in the intervention group underwent 4 weeks of unilateral isometric

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strength training of the ankle dorsiflexors, while subjects in the control group simply maintained previous levels of physical activity. EMG signals were collected from the TA using high-density surface array electrodes (HDsEMG) and individual motor units were identified by a convolutive blind source separation method.

In total, 30% of the identified motor units were able to be tracked across sessions. The reliability of the tracking technique was based on average two-dimensional correlation value for the action-potential waveforms. Discharge times for motor units were used as triggers for extracting the action-potential waveforms.

The authors reported: (1) an increase in maximum voluntary force (MVF) in the intervention group, (2) a decrease in motor unit recruitment threshold (both in terms of absolute force levels and as a percentage of MVF), (3) a decrease in absolute motor unit derecruitment threshold, though no change was found in the relative motor unit derecruitment threshold, (4) an increased discharge rate during the plateau phase of the trapezoidal dorsiflexion ramps, yet no change in motor unit discharge rate at recruitment or derecruitment, and (5) an unchanged rate of change of discharge rate with respect to the change of force. These main findings suggest that the increase in muscle force seen following 4 weeks of strength training is primarily due to an increase in excitatory inputs to the motor neuron.

Del Vecchio et al. employed HDsEMG combined with a blind source separation signal decomposition algorithm to identify a robust number of motor units and more impressively, they were able to track them over multiple training sessions. By taking advantage of the latest technology, the authors were able to record and track activities from thousands of motor units, enabling to study synaptic control and intrinsic properties of motor neurons more in depth. They proposed that the changes in motor unit excitability after 4 weeks of strength training is attributable to changes in synaptic inputs from the motor cortex or to adaptations in intrinsic properties of motor neurons.

The authors suggested that because there is no difference in the relationship between discharge rate and force, the intrinsic properties of motor neurons were not changed after 4 weeks of training. Instead, they suggested the possibility of modulation of lower motor neurons by the cortex as the source of adaptation. While not directly addressed in this work, the data collected for this study may be analyzed to investigate the role of monoaminergic drive from the brainstem in the increased muscle force. The increased muscle excitation could be elicited through an increase in monoamine-regulated persistent inward currents (PICs). Motor unit recruitment hysteresis is often used to estimate the level of PICs and correspondingly the level of monoaminergic input to motor units (Johnson *et al.* 2017). The results show that although the motor unit recruitment thresholds significantly decreased, the motor unit de-recruitment thresholds were not decreased with respect to muscle force. These results suggest reduced motor unit hysteresis, with respect to torque, and may suggest that an increase neuromodulatory inputs from the brainstem did not contribute to the modulation of the spinal motor neuron excitability, however, a more formal investigation of this excitability with established methods (e.g. delta-F) would be necessary to understand any possible changes during strength training (Gorassini *et al.* 2002). Johnson et al. also showed that increased corticospinal input tends to compress motor unit recruitment range, which may result in lowered recruitment thresholds. Assessments of PIC level could provide support for the authors' idea that the motor cortex is responsible for any changes observed in motor neuron excitability. This is further supported by the relationship between change in force and change in motor unit discharge rate not being affected by strength training.

Current results suggest that the changes in spinal motor neuron excitability after 4 weeks of strength training is more attributable to changes in synaptic inputs from the cortex, rather than adaptations in intrinsic properties of motor neurons. An electroencephalography (EEG) study exploring changes in the motor cortex activity after strength training in aging population showed that after 5 weeks of training, high mental effort training significantly increased the motor activity-related cortical potential (MRCP). Although statistical significance was lacking (P = 0.061), they showed that conventional strength training increased MRCP as well (Jiang *et al.* 2016). These results further solidify the role of motor cortex in changes in excitatory inputs to the spinal motor neurons. Cortico-muscular coherence (CMC) is a technique to assess the coherence between EEG and EMG. Future studies that aim to relate the changes in motor unit discharge patterns reported by Del Vecchio et al. with cortical measures, such as CMC, may provide stronger evidence that increased excitatory inputs to the spinal motor neurons from the cortex are the major source of adaptation in increased muscle force. Further, the methods outlined in this study should be applied to more diverse population groups (women and older adults) to further generalize these results.

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