Simultaneous measurement of active potentials and bioimpedance during muscle movement

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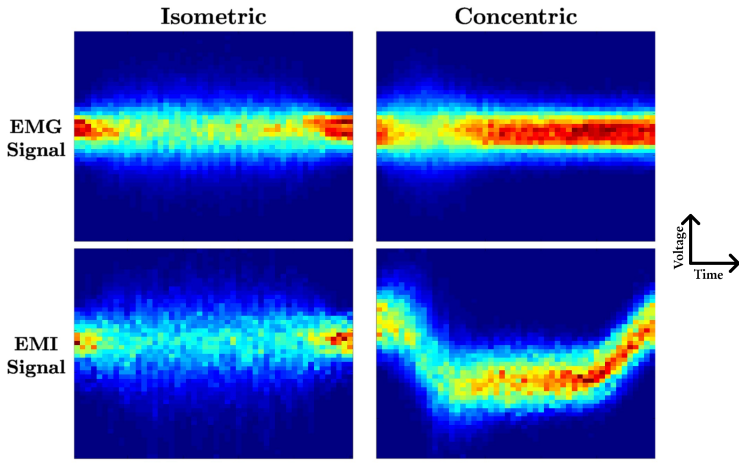
Numerous studies and applications have shown electromyographic signals (EMGs) as useful for controlling prostheses and ortheses. Their great utility stems from the degree of voluntary control a user can wield over these signals, even if limbs are missing, especially in the EMGs of skeletal muscles. Despite the success and utility of EMGs, a related signal---the electrical myoimpedance (EMI)---has been largely ignored. Previously this was due to the low-sensitivity of skin-based measurements and the undesirability of invasive methods, such as needles. But these are problems which can be overcome. Here, we demonstrate that non-invasive skin-based EMI measurements are possible and that they provide additional information which is not present in the EMG signal.

The EMG signal is a measurement of the voltage drop between two or more points. Since muscle contractions are caused by neuroeletric signals and produce voltage changes, EMG signals occur any time a muscle is contracted. In contrast, the EMI signal is a measurement of a muscle's resistance to an injected current flow at a particular frequency or set of frequencies. Since resistance is directly proportional to the current's path length and inversely proportional to its cross-sectional area, the EMI signal correlates to the geometry of the muscle. Therefore, it is expected to be sensitive to morphologic changes which occur during concentric contractions.

To test this, we developed a non-invasive procedure for making simultaneous skin-based measurements of EMG and EMI signals during both concentric and isometric contractions. A 1V signal was passed through a 100kΩ resistor to produce a small injection current for measuring the EMI. This signal, along with the EMG, was sampled using a two-electrode sensor. A Fourier transform was used to separate the EMI and EMG signals. To facilitate the correlation of signal features with muscle actions, a video camera was synchronized with the measurement system.

Fifty isometric and fifty concentric contractions were recorded, normalized, and co-registered resulting in the aggregated signal views shown below, where red indicates high-densities of measured points and light-blue indicates low-densities. The EMI signal shows stark differences depending on the contraction whereas the EMG signal does not. Low-density regions in both signals are caused by high-amplitude signals, but such regions cannot be used to differentiate between types of contractions using the EMG signal because they are wholly dependent on the length of a contraction, be it concentric or isometric.



From this, we conclude that the EMI and EMG signals can be differentiated and that the EMI signal carries additional information about a muscle's state which may have potential as a control channel for prostheses.