Non-invasive insight into electrical activity of human muscles

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In vivo investigation of electrical activity of skeletal muscles provides a unique insight into control strategies of human movement and their adaptations to pain, fatigue, pathologies and skeletomuscular disorders. This analysis is classically performed by invasive needle-based muscle recordings, so called indwelling electromyograms (EMG). While acceptable in clinical practice, indwelling EMG recordings have obvious drawbacks in neurorehabilitation, ergonomics, examination of children and needle-intolerants patients and in many other applications.

Muscle activity can also be recorded with non-invasive electrodes placed on the surface of the skin above the muscle of interest. However, due to their low selectivity, surface EMG electrodes detect electrical activity of thousands of muscle fibers (Figure 1). The latter are organized into hundreds of motor units (MU) that activate and deactivate asynchronously, producing highly interferential surface EMG. The complexity of surface EMG is also the main reason for contradictory results reported in the literature and for the lack of standardisation in the field. In summary, surface EMG is easy to measure, but also very easy to misinterpret.

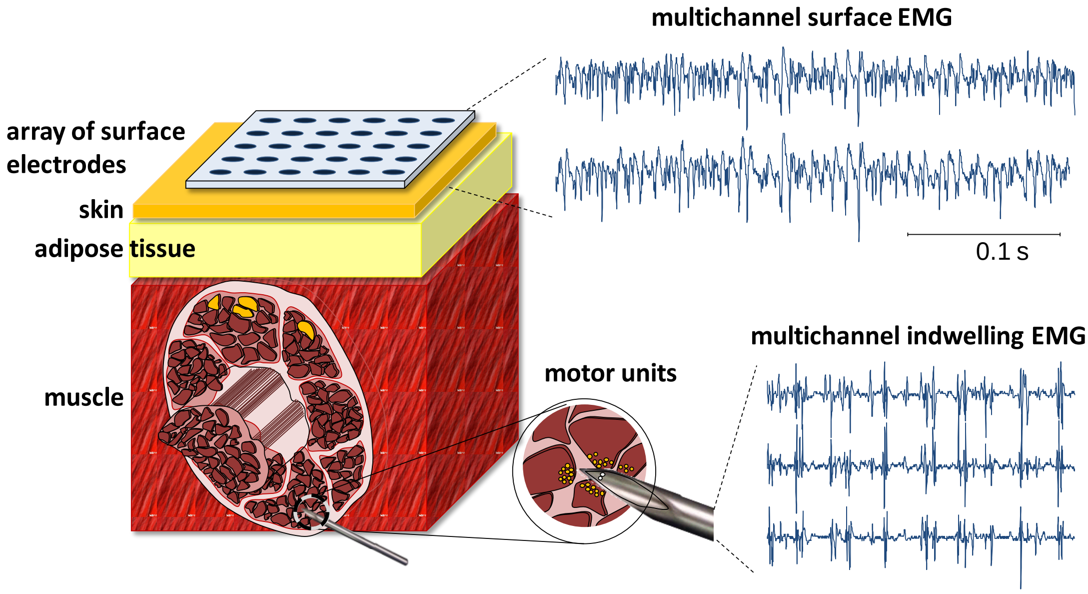

Figure 1: Non-invasive and invasive EMG acquisition by surface and needle electrodes, respectively, and corresponding surface and indwelling EMG signals. When compared to needles, surface electrodes detect contributions of many more motor units. This results in highly interferential EMG waveforms that are difficult to interpret.

We developed a world-wide recognized Convolution Kernel Compensation (CKC) computer algorithm [1] for fully automatic extraction of muscle control strategies from multichannel surface EMG. This method is asymptotically Bayesian optimal, insensitive to anatomy of skeletal muscles and identifies complete MU activation patterns (Figure 2), regardless the level of muscle contraction and MU synchronization. As such, it enables interpretation of surface EMG in terms of well-defined physiological parameters and, thus, eliminates controversies behind its interpretation.

Up to date, the CKC method has been validated in about 25 different muscles of more than 500 healthy persons and patients suffering from stroke, cerebral palsy, cleft lip, type II diabetes and delivery-related muscle trauma. It is also used as a fundamental research tool in EU projects TREMOR and NeuroTREMOR, supporting the assessment, diagnosis and suppression of Parkinsonian and essential tremor [2]. The latter are the most common movement disorders that affect about 5% of population above 60 years of age.

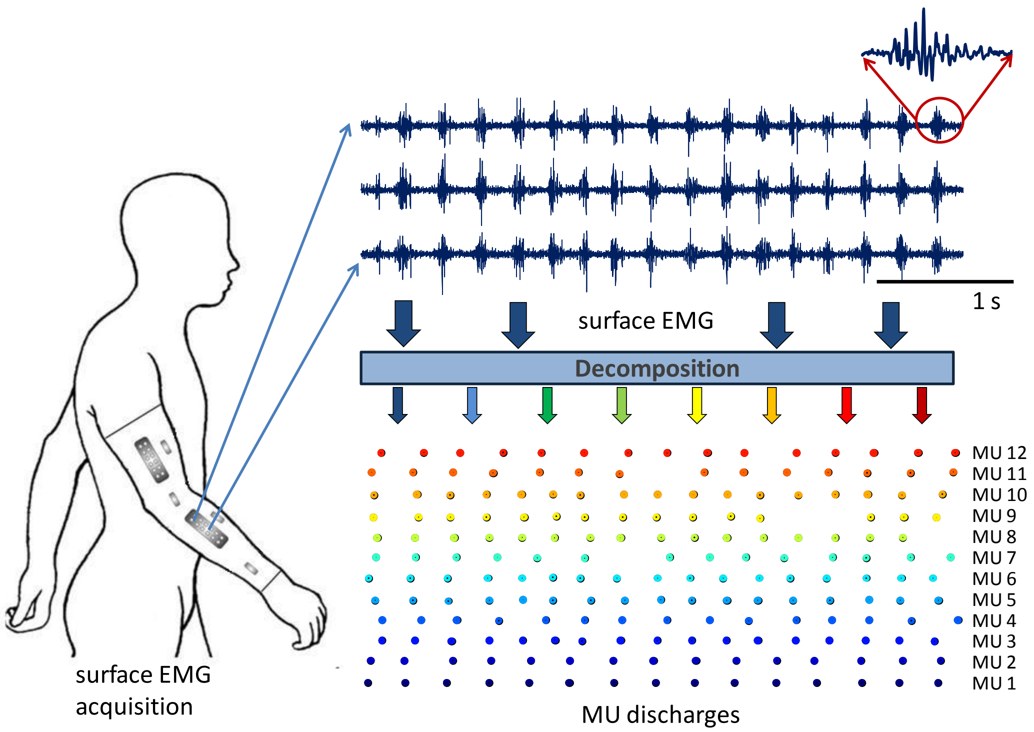

Figure 2: Surface EMG of wrist flexors acquired in a patient with Parkinsonian tremor and its CKC-based decomposition to contributions of twelve MUs. Time instants of MU activations are depicted by coloured dots; MU –motor unit

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[1] Holobar, A., and Zazula, D. (2007). Multichannel Blind Source Separation Using Convolution Kernel Compensation. Signal Processing, IEEE Transactions On *55*, 4487 –4496.

[2] Holobar, A., Glaser, V., Gallego, J.A., Dideriksen, J.L., and Farina, D. (2012). Non-invasive characterization of motor unit behaviour in pathological tremor. J Neural Eng 9(5):056011.