SHORT INTER-ELECTRODE DISTANCES UNDERMINE THE SENSITIVITY OF SURFACE ELECTROMYOGRAMS

Taian Vieira (1,2), Alberto Botter (1,2), Kohei Watanabe (3), Andrew Vigotsky(4)

1. LISiN-DET, Politecnico di Torino, Italy; 2. PoliTo^{BIO}Med Lab, Politecnico di Torino, Italy; 3. Laboratory of Neuromuscular Biomechanics, Chukyo University, Japan; 4. Departments of Biomedical Engineering and Statistics, Northwestern University, United States

Introduction

With surface electromyography (sEMG), there is an inherent tradeoff between sensitivity and specificity. While specificity is generally acknowledged in the sEMG literature (e.g., crosstalk), only recently has the sensitivity been systematically studied (1, 2). The existence of Type II errors in surface EMG has been formalized (3), but their practical importance has not yet been documented. Specifically, of broad biomechanical interest, how much does sensitivity affect inferences regarding muscle excitation when using bipolar sEMG?

Methods

In this study, we used a dense array of surface electrodes to systematically assess this issue for two muscle geometries. With this array, we were able to compute bipolar EMGs for progressively greater inter-electrode distances (IEDs)—from 5 mm to 50 mm, with greater IEDs having greater spatial sensitivity—with all pairs of electrodes being centered roughly at the same skin region over biceps brachii (BB; Figure 1) and gastrocnemius medialis (GM) of 20 healthy subjects. Using these signals, we investigated how much the onset of muscle excitation, the quality of surface EMGs (signal-to-noise ratio; SNR), and the coherence between EMG and joint moment were affected by IED. Non-parametric statistics and a Bayesian hierarchical model were used to test the hypothesis that excessively reducing IEDs limits the biomechanical and physiological validity of sEMG signals.

Results

Our results revealed a significant influence of IED on the onset of muscle excitation, quality of the detected signals (SNR), and the association between EMG amplitude and joint torque. The greater the IED, the more sensitive the bipolar signal was to changes in joint torque. In contrast, IEDs shorter than 30 mm resulted in EMG descriptors of dubious validity: physiologically unplausible onset values, spuriously low SNR values, and weaker EMG-force associations.

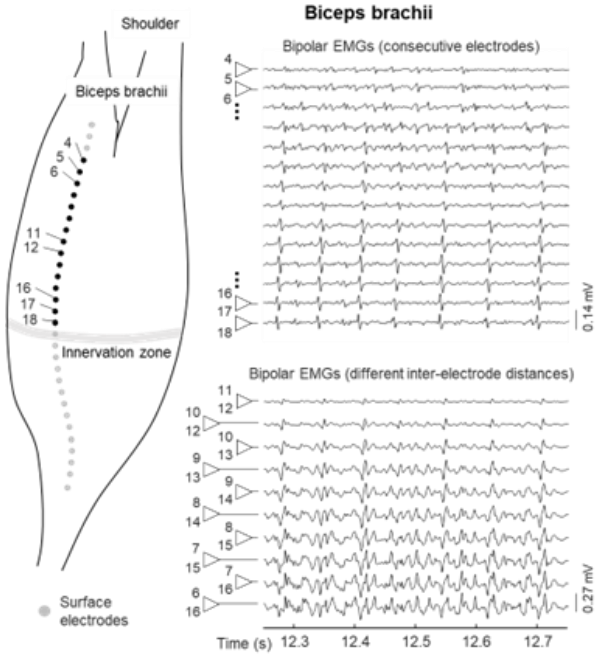

Figure 1: Inter-electrode distance (IED) and surface EMGs. Bipolar EMGs detected by 15, consecutive pairs of surface electrodes (IED = 5 mm) from the biceps brachii muscle are shown on top biceps brachii. Bipolar EMGs detected for progressively greater IED are shown at the bottom, from 5 mm to 50 mm.

Conclusion

Inter-electrode distance imposes a biophysical constraint on EMG sensitivity. Short IEDs yield EMG descriptors of dubious physiological validity, including the inflation of Type II errors. Owing to sEMG's ubiquitous use, our findings are of general biomechanical and physiological interest. We propose a potentially valid procedure for defining the most appropriate IED to help balance sensitivity and specificity in single bipolar sEMG recordings.

References

1. Vieira et al, Sci Rep 7: 1–11, 2017.
2. Munneke et al, J Electromyogr Kinesiol 40: 23–31, 2018.
3. Vieira and Botter, Exerc Sport Sci Rev 49: 23–34, 2021.