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A computer simulation study on the influence of motor unit regionalization on the generation of surface myoelectric signals

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Abstract

The present study aims to analyze the influence of motor unit regionalization within the muscle cross-sectional area on time- and frequency-domain properties of surface myoelectric EMG signal. Computer simulations were performed using a phenomenological model of the neuromuscular system. Different contraction intensities were simulated, and the RMS and median frequency of the EMG were calculated for different muscle cross-sectional area morphologies. The level of MU regionalization was adjusted in the model. Results showed that experimental force-EMG relations could be appropriately simulated by the model, irrespective of the muscle cross-sectional area morphology and the level of MU regionalization. However, the best fit between simulation and experimental data is influenced by the level of MU regionalization.

Key words:

Surface electromyography, Mathematical modelling, motor unit.

Introduction

Several physiological processes and anatomical properties influence the generation of surface myoelectric (EMG) signals. Mathematical modeling and computer simulations can be used as an aid to better understand how each factor would affect time- and frequency-domain properties of the EMG signal. We recently showed that muscle cross-sectional area morphology could affect both the force-EMG relation and the median frequency of the EMG. However, little is known about the influence of MU distribution within muscle cross-sectional area on the generation of surface EMG. Some anatomical data have shown that MUs have a degree of regionalization within the muscle cross-sectional area[1]. Therefore, the present study aimed at analyzing the influence of the level of MU regionalization on the generation of the EMG.

Results and Discussion

Computer simulations were performed using a phenomenological model of the neuromuscular system. Surface EMG signals were generated for different muscle cross-sectional area morphologies (circle, ring, pizza, and ellipse) and regionalization levels (no regionalization, medium level of regionalization, and high level of regionalization). The method for MU regionalization was based on a previous study[2]. Force-EMG relations were computed for each condition, and the best fit between the simulation outcomes and an experimental data[3] was calculated using the coefficient of determination (R^2).

Table 1 shows the R^2 obtained for each condition. Without MU regionalization, the ring morphology produced the best fit to the experimental data. However, when a medium and a high level of regionalization was considered in the model, the pizza morphology produced the best fits.

Figure 1 shows the effects of the level of MU regionalization on the force-EMG relation and the median frequency of the EMG for the ring morphology. As the regionalization level increased (i.e., high-threshold MUs mostly located at the surface of the muscle) the EMG RMS at high-intensity contractions increased as well. Additionally, the median frequency of the EMG power spectrum at low-intensity contractions was lower when the level of regionalization was higher.

Table 1. Coefficients of determinations (R^2) between computer simulations and experimental data for different muscle cross-sectional area morphologies and regionalization levels.

Muscle Morphology	No	Medium	High
Circle	0.972	0.929	0.966
Ring	0.991	0.984	0.972
Pizza	0.981	0.990	0.990
Ellipse	0.985	0.991	0.941

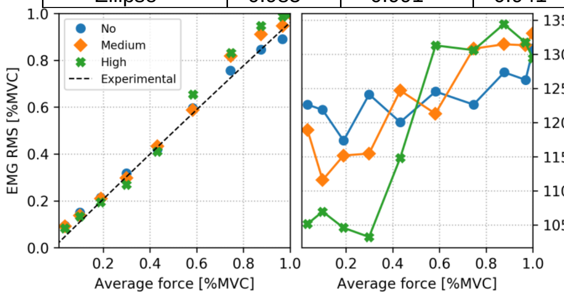

Figure 1. Left: Force-EMG relations for ring morphology. The black dashed line represents experimental data from the FDI. Right: Median frequency of the EMG PSD.

Conclusions

Here we showed that MU regionalization is an essential factor to be considered when modeling the surface EMG signal generation. Both time- and frequency-domain properties of the EMG are influenced by the level of regionalization of the MUs within the muscle cross-sectional area.

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[1] Johnson M. A.; Polgar J.; Weightman D.; Appleton D. Data on the Distribution of Fibre Types in Thirty-six Human Muscles An Autopsy Study. *Journal of the neurological Sciences, 18, pg. 111-129*. **1973**. doi: 10.1016/0022-510X(73)90023-3

[2] Carriou V.; Laforêt J.; Boudaoud S.; Al Harrach M. Realistic motor unit placement in a cylindrical HD-sEMG generation model. *Conf Proc IEEE Eng Med Biol Soc. pg.1704-1707*, **2016.** doi: 10.1109/EMBC.2016.7591044.

[3] Lawrence J. H.; C. J. De Luca. Myoelectric signal versus force relationship in different human muscles. *Journal of applied Physiology v54-6, pg.* 1653-1659, **1983**. doi: 10.1152/jappl.1983.54.6.1653

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