XXVI Congresso Brasileiro de Engenharia Biomédica

Armação de Búzios – RJ – Brasil

October 21st to 25th, 2018

Influences of muscle cross-sectional area morphology on the EMG generation

R G Molinari[1*] and L A Elias[1, 2]

[1]Neural Engineering Research Laboratory, Department of Biomedical Engineering, School of Electrical and Computer Engineering, University of Campinas, Campinas, Brazil

[2]Center for Biomedical Engineering, University of Campinas, Campinas, Brazil

**molinari@gmail.com*

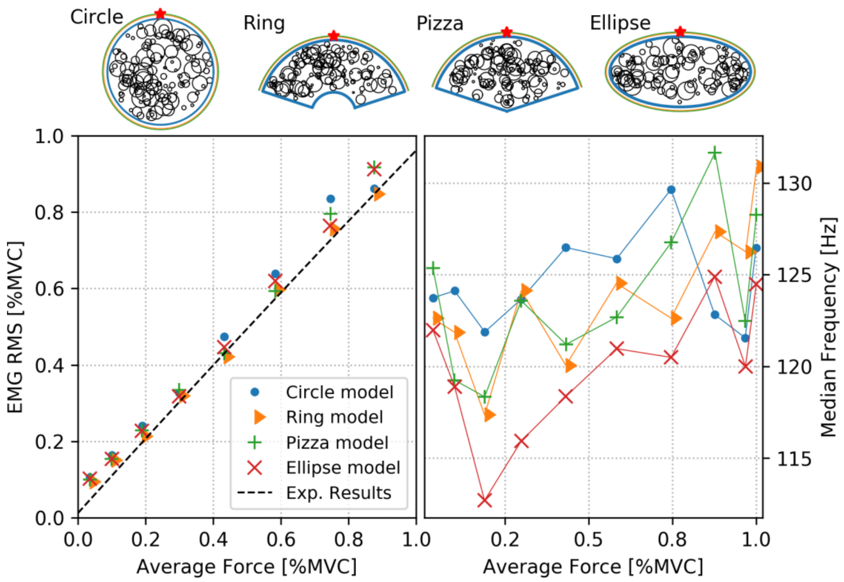
Background, Motivation and Objective. Computer simulations of surface myoelectric (EMG) signals have been used to investigate the relationship between the features of the EMG signal and the underlying physiological processes. Simulation of EMG is of paramount importance for research in motor control, biomedical signal processing, and electrophysiology. Phenomenological models have been frequently used to represent the surface EMG signal due to their computational efficiency and reduced number of free parameters. However, to the best of our knowledge, few studies evaluated the influence of different muscle cross-sectional area morphology on the simulated surface EMG signal. In the present study, the aim was to investigate the influence of muscle cross-sectional area morphology on the generation of the EMG signal and its time- and frequency-domain properties.

Methods. The neuromuscular model employed in the present study was based on those previously reported in the literature. The model encompasses a spike train generator and a population of muscle units. Each muscle unit generated a motor unit action potential (MUAP) and a twitch in response to a spike. The MUAP model was represented by first- and second-order Hermite-Rodriguez functions randomly attributed to each muscle unit. Motor unit territories were randomly distributed (uniform distribution) within the muscle cross-sectional area. MUAP attenuation due to the volume conductor was represented by an exponentially decaying function. Additionally, MUAP duration was increased as a linear function of the distance between motor unit territory and electrode location at the skin surface. Four different cross-sectional area morphologies (see Figure 1) were adopted to investigate their influence on EMG signal generation. Muscle twitch was represented by a second-order critically damped system. Surface EMG and muscle force were represented by the linear sum of all MUAP trains and muscle unit forces. The root mean square (RMS) and power spectral density (PSD) of the simulated EMG signal were computed. PSD was calculated using the Welch's periodogram method. In the present study, the amplitude and duration of MUAPs and muscle twitches were set based on experimental data from the first dorsal interosseous (FDI) muscle. Also, the number of motor units was 120, which is an estimate for the FDI muscle. Ten independent simulations (6s duration/simulation) were performed for each excitation level, which varied from 10% to 100%. A two-way (factors: force level and muscle morphology) analysis of variance (ANOVA) was performed to evaluate statistical differences between each condition. A significance level of 5% was adopted in the present study.

Results. Irrespective of muscle cross-sectional area morphology there was an increase in EMG amplitude (RMS) with the average force produced by the muscle model. There was a main effect for the morphology ($p = 0.007$), but there is no interaction between force intensity and cross-sectional morphology ($p = 0.406$). Tukey post hoc test showed that EMG RMS was significantly reduced for the ring morphology in comparison to the circle morphology ($p = 0.005$). The remaining comparisons did not present statistical difference. All force-EMG relations produced by the model were similar to the experimental data reported in the literature for the FDI muscle (see dashed line in the left graph in Figure 1), but the ring model best fitted the experimental data ($R^2 = 0.991$), while the circle model produced the poorest fit ($R^2 = 0.972$). As to the EMG median frequency (a spectral measure extracted from the PSD, see the right graph in Figure 1) there was an effect of the average muscle force ($p = 4 \cdot 10^{-6}$). Post hoc Tukey test revealed that the median frequency produced at 10% and 20% were different from the maximal muscle excitation (100%). Additionally, the median frequency at 20% was different from that at 70% and 80% of the maximal excitation. When the morphology was evaluated, the ANOVA revealed a significant main effect ($p = 2 \cdot 10^{-4}$). The median frequency was significantly lower ($p < 0.001$) when the morphology was an ellipse.

Discussion and Conclusions. The lower EMG RMS observed in the ring model and the lower median frequency observed in the ellipse model compared to the other models might be explained by a larger average distance between the MUs and the electrode at the skin surface, which produces a greater attenuation/widening of the MUAPs. The best linear fit of the force-EMG relation observed in the ring model suggests that this morphology is better to represent the FDI cross-sectional area morphology. Anatomical data from cadaver or in vivo imaging of the FDI would be important to validate this prediction. Therefore, with this study we showed that the morphology of the muscle cross-sectional area is an important factor to be considered when modelling the EMG signal generation. Further analyses should be performed to understand the interaction between muscle cross-sectional area morphology and MU distribution and their effects on the generation of the surface EMG signal.

Figure 1. Four different muscle cross-sectional area morphologies were adopted: circle, ring, pizza, and ellipse. The graph in the left shows the force-EMG relations. The black dashed line represents an estimated linear function for experimental data from the FDI muscle. The graph in the right shows the relation between the average force and the median frequency of the.



Acknowledgment. RGM received a scholarship from PIBIC/CNPq (#138498/2017-2). LAE is funded by CNPq (#409302/2016-3 and #312442/2017-3)

Keywords. Surface electromyography, Mathematical modelling, Motor unit, Muscle morphology.