IMPROVING EMG BASED MUSCLE FORCE ESTIMATION USING PRINCIPAL COMPONENT ANALYSIS ON A HIGH-DENSITY EMG ARRAY

Didier Staudenmann, Idsart Kingma, Andreas Daffertshofer, Dick F. Stegeman and Jaap H. van Dieën
Institute for Fundamental and Clinical Human Movement Sciences, Faculty of Human Movement Sciences, Vrije Universiteit, Amterdam, The Netherlands; d.staudenmann@fbw.vu.nl

INTRODUCTION

The reliability of EMG amplitude measurements when predicting muscle activation is an important issue in EMG based force estimation. Theoretically, two important factors influence the EMG signal. First, the location of the electrode arrangement in relation to the muscle fibre architecture and second, the amount of detected motor units (MUs), contributing to both the EMG and the muscle force. High-density EMG arrays allow the collection of monopolar signal to which also deep MUs are contributing. Principle component analysis (PCA) is a method to classify multidimensional datasets and to detect redundant information [1].

The aim of this experimental study is to analyze whether PCA techniques can improve force estimation from EMG collected with a high-density array.

METHODS

Eleven healthy subjects (age 28.3 ± 4.7 years) performed isometric block-shaped extensions (Figure 1, left panel) with the right-arm at different conditions: Three elbow angles (60°, 90° and 130°) and three levels of maximum voluntary contractions (20%, 50% and 80% MVC). During efforts subjects had online feedback of the contraction level.

Surface EMG of the triceps brachii and force output were measured simultaneously. The EMG was measured with an active monopolar electrode array of 13×10 electrodes (BioSemi, biomedical instrumentation, Amsterdam, NL) [2].

EMG based force estimation from monopolar signals (1), PCA (low eigenvalues) (2) optimally aligned bipolar electrodes (3), Laplacian configuration (5) and conventional bipolar electrodes (5) were compared.

To quantify force estimation quality over the entire contraction pattern (Figure 1) we computed the root mean square difference (RMSD) between normalized EMG and normalized arm extension force.

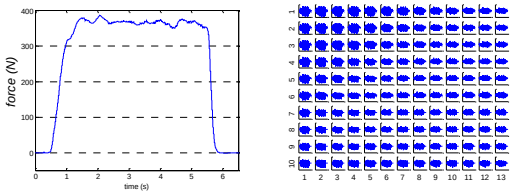


Figure 1: Left panel: Block-shaped contraction pattern with a mean force over the plateau of 370 N. Right panel: raw monopolar 13×10 EMG-signals (at 130° / 80% MVC).

To asses to what extent minor force fluctuations over the plateau were predicted we calculated the correlation coefficient between estimated and measured force.

RESULTS AND DISCUSSION

The EMG processing procedures (Table 1) significantly affected RMSD and correlation (both: $p<0.01$). The two highest RMSD was found for the conventional bipolar electrodes (5) and the monopolar signals (1). PCA reduced RMSD by about 40% compared to conventional bipolar electrodes (5) and by about 12% compared to optimally aligned electrodes (3). In addition, the highest correlations over the plateau were obtained with the PCA procedure.

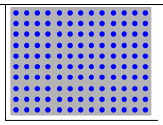
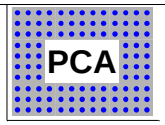
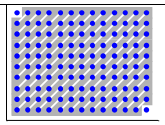
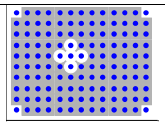
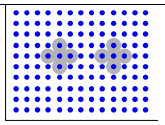
CONCLUSIONS

High-density EMG is a powerful tool for the prediction of force output of a muscle but its value depends strongly on the EMG signal procedures. PCA can be used as an alternative to spatial filtering with different electrode configurations (3-5). Apparently, any order of spatially filtering electrodes (3-5) suffers from a biased choice of the configuration direction relative to the direction of the underlying muscle fibers. PCA appears to be a valuable tool, extracting the physiologically relevant information independent from the muscle structure and thereby improving the quality of muscle force estimation.

REFERENCES

1. Daffertshofer A, et al. *Clin Biomech* **19**, 415-428, 2004
2. Blok J.H, et al. *Rev Sci Instrum* **73**, 1887-1897, 2002

Table 1: Five EMG procedures (1-5) are shown in the upper row. Small dots represent electrodes, grey surface shows the section of the 13×10 array used and white colors the nature of the electrode configuration (3-5). RMSD over the entire contraction pattern and correlation over the plateau between EMG procedures and the force are shown in the lowest rows.

EMG procedure	1	2	3	4	5
					
RMSD (%)	16.6 ± 2.7	10.8 ± 2.1	12.2 ± 2.1	15.1 ± 5.1	17.9 ± 2.6
Correlation (r)	0.3 ± 0.2	0.5 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.3