CAN THE USE OF A HIGH DENSITY EMG SYSTEM IMPROVE A BIOMECHANICAL MODEL FOR PREDICTING ANKLE PLANTAR FLEXORS FORCE?

[1] Liliam F. Oliveira, [2]Taian M. M. Vieira, [3]Luciano L. Menegaldo, [2]Roberto Merletti
[1]Physical Education and Sports School, Federal University of Rio de Janeiro, RJ, Brazil
[2]Laboratorio de Ingegneria del Sistema Neuromuscolare, Politecnico di Torino, Italy; [3]Military Institute of Engineering, RJ, Brazil; email: liliam@eefd.ufrj.br, web: www.eefd.ufrj.br

INTRODUCTION

EMG-driven models are widely used for predicting muscle forces, in a forward dynamic approach. The model input is often the neural command and can be obtained from electromyograms (EMG). The use of single differential configuration may hinder force prediction due to the small detection area covered by a couple of electrodes [1,2]. A grid of densely spaced monopolar electrodes, named high-density EMG (HD_EMG) [2], maps the myoelectrical activation over a wide superficial area on the skin, providing better spatial representation of the neuromuscular activity. This study aims to investigate if the use of HD-EMG can improve the estimation of the plantar flexors force with a Hill-type mechanical model.

METHODS

Ten male subjects laid prone over a bed, with the knee extended and the right ankle at neutral (90^o) position and with the joint rotation axis coaxial to a torque meter axis. Ultrasound scanning was applied to assist in the positioning of the detection system on the *gastrocnemius medialis* (**gm**), *gastrocnemius lateralis* (**gl**) and *soleus* (**sol)** muscles (Figure 1). The protocol consisted of two 5 s maximal voluntary contractions (MVC) followed by one isometric contraction at 60% MVC and lasting 10 s. Feedback display of actual torque output and rest periods of 2 min between trials were provided. Torque signal and surface HD-EMG (monopolar configuration) were synchronously recorded from **gm**, **gl** and **sol** muscles. For each muscle, the EMGs were processed in two ways. 1) **HD (**high-density): The envelopes of single differential EMGs, pertaining to pairs of electrodes disposed along each columns of the matrix, were averaged into a single envelope. 2) **BP** (bipolar): One single differential signal were digitally obtained between two selected electrodes, separated by 2.4 cm, to simulate the conventional bipolar configuration according to recommendations for the triceps surae muscles [3]. In both conditions, the resulting envelope was normalized and fed in the model as the excitation signal for each muscle. A Hill-type model with parallel elastic and damping elements was applied to estimate muscle force twice (with signals from **HD** and **BP**) [4,5]. The total torque was computed by summing up each simulated force multiplied by the moment arm of each muscle around the ankle joint [5]. The difference between simulated and measured torque was calculated as the mean square error between the two curves, normalized with respect to the maximum measured torque (%RMSE). A non parametric Wilcoxon test was applied to assess significant differences of the RMSE(%) between **HD** and **BD** methods. Significance level was set to 5 %.

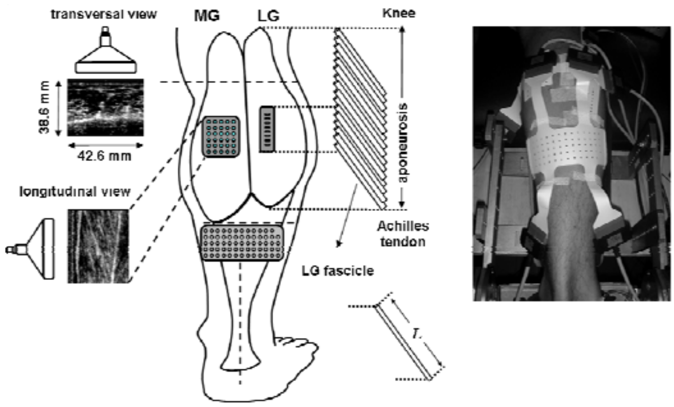

Figure 1: Schematics of electrodes positioning on the skin. **gm**: 6x5 electrodes array, 8mm IED; **gl**: 8x1 electrode arrays 5mm IED and **sol:** 5x13 electrodes array, 8mm IED.

RESULTS AND DISCUSSION

The mean RMSE(%) values were: 25.7 ± 9.9 with the **BP** signals and 21.6 ± 10.2* with the **HD** signals (*$p<0.05$), showing that the HD-EMG reduced the torque estimation error by approximately 16%. The use of spatially distributed electrodes, likely covering different motor units, has shown to improve the estimation of the muscle force in some EMG-force studies, without concerning to Hill-type muscle models [1,6], as for example, a 30% improvement of force estimation for the *triceps brachii* muscle during three different contractions levels [1]. Considering the averaged envelope from the matrix of electrodes as representative of the underlying muscle activity could have represented a limitation. Other processing methods, as maximal centroide amplitude and cluster analysis together with improvements of the model formulation may enhance the muscle activation level and force estimations. The HD-EMG significantly improved the plantar flexors force estimation for the specific task tested.

REFERENCES

1. Staudenmann D. et *J. Electromyog. Kinesiol* 15:1-11, 2005
2. Merletti R, et al, *J. Electromyog. Kinesiol* 18: 879-890, 2008.
3. Freriks B. et al., *European recommendations for surface electromyography – SENIAM Project*., 1999
4. Zajac, F.E., *Critical Rev. Biomed Eng.*17:359-411, 1989.
5. Menegaldo L.L. et al *J.Biomech.* 37:1447-1453, 2004.
6. Clancy E. et al. *IEEE Trans. Biomed.Eng.,* 42:203-211, 1995.