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Decomposition of HD-sEMG signals using CCA for muscle resilience evaluation

Chawki Nasrallah * (1)

Déborah Rubstein Crespin (1)

Kiyoka Kinugawa (2)

Sofiane Boudaoud (1)

1 – Université de Technologie de Compiègne,
Laboratoire de Biomécanique et de Bioingénierie
UMR CNRS 7338, Compiègne, France

2 - Sorbonne Université, CNRS, UMR Biological
Adaptation and Aging, AP-HP, Charles Foix
Hospital, Functional Exploration Unit for Older
Patients, F-94200 Ivry-sur-Seine, France

*Corresponding author. Email:
chawki.nasrallah@utc.fr

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1. Introduction

Muscle resilience is a concept recently introduced to evaluate functional recovery capacities after physical damage period (Yoo, J.-I. et al. 2020). This study explores the ability of monitoring muscle resilience by analyzing HD-sEMG signals after hip fracture surgery (FESF) of two elderly subjects. HD-sEMG technique is a new one that allows us to measure the electrical activity of the muscle using more than two electrodes (32 in this study) in order to study its spatial distribution. The sEMG signal is the sum of all the motor unit action potentials (MUAPs) coming from the muscle. When the sEMG signal is resulting from a big number of MUAPs that have a high chance of superposition, visualizing the originating MUAPs is not possible. On the other hand, when only two or three MUs are active near the electrode, leading to a lower probability of superposition between the resulting MUAPs, the visualization of different MUAPs becomes possible as explained in De Luca et al. 2006. Following this hypothesis, the decomposition of sEMG signals into MUAPs, during a submaximal isometric contraction, should be easier when the signal is composed of a small number of active MUAPs. This can be related to a weaker muscle, indicating low muscle resilience, compared to a stronger muscle, indicating higher muscle resilience, where more MUs will be active and therefore the decomposition to identify the MUAPs is harder. In order to test this hypothesis, canonical correlation analysis (CCA) (Al Harrach et al. 2016) will be used to decompose HD-sEMG signals of two

patients in two different states each, where the physical state of the patient at each time is measured by the clinical test ‘short physical performance battery’ (SPPB) (Loubna Imrani Sallak 2021). In this preliminary study, we will test a new method to assess muscle resilience of elderly subjects after FESF, by evaluating the possibility of decomposing its HD-sEMG signals into single MUAPs.

2. Methods

2.1 HD-sEMG dataset

Four HD-sEMG signal sets will be used in this study, each having 32 channel isometric signals recorded from the rectus femoris (RF) muscle and sampled at 1Khz. The signals were recorded from two different patients from the HIPRESM dataset (AP-HP, clinical trials.gov NCT04167020) which is a dataset of patients that had a fracture of the higher extremity of the femur. The HD-sEMG was recorded 7 and 30 days after the surgery in order to assess their muscle resilience. The signals were recorded as follows: an isometric contraction with an ankle bracelet having a weight calculated as 20% of the patient’s maximum voluntary contraction; the patient should then hold his/her thigh with both hands and make an angle of 90° at the level of his knee for around 6 seconds. Along with the HD-sEMG recordings, each patient underwent the SPPB test to have a score that evaluates its physical performance at both day 7 and 30. Patient 1 is a female of 94 years old, her SPPB d7 was 7 and SPPB d30 decreased to 2. Patient 2 is a female aged 75 years old, her SPPB d7 is 5 and increased to 9 on d30.

2.2 HD-sEMG decomposition using canonical correlation analysis and detecting MUAPs

For each patient, the HD-sEMG signal grids at d7 and d30 were first filtered by a bandpass filter (20-500 Hz) to remove motion artifacts. The powerline interference was then removed from the signals using CCA, a semi-blind source separation technique (Al Harrach et al. 2016). In addition, the obtained sources were then inspected visually to identify whether one includes repetitive MUAP Train (MUAPT) or not. Today, there are automatic recognition methods for MUAPs as in Avrillon et al. (2023), however, a visual inspection is always recommended. Having information about the motor abilities from each patient at both days by the SPPB test score, we can relate the ability to detect the MUAPs by CCA to muscle resilience level after surgery.

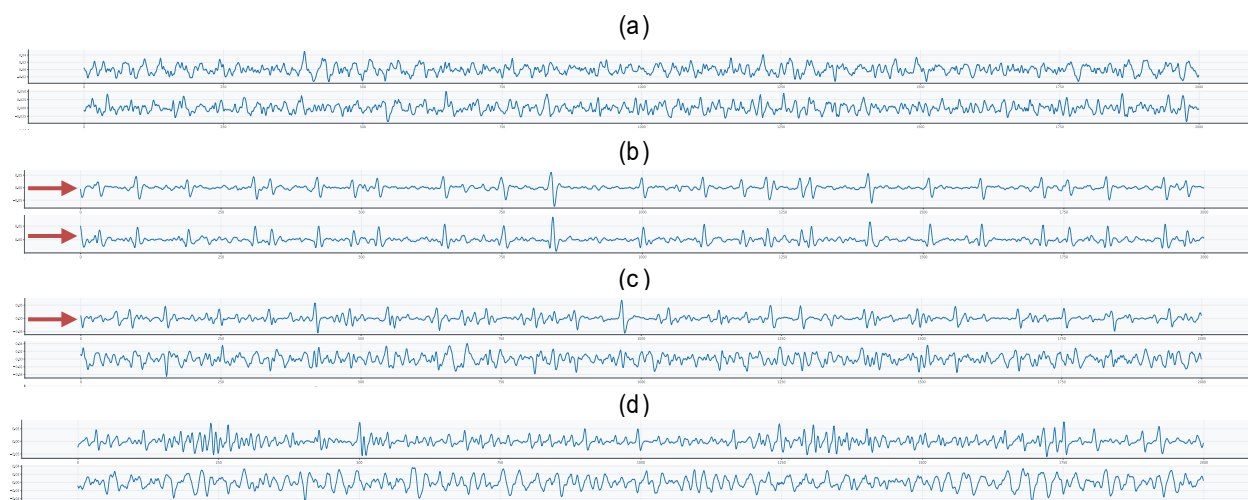


Figure 1. Two sources of each signal set after CCA decomposition of the HD-sEMG signals for (a) Patient 1 d7 (b) Patient 1 d30 (c) Patient 2 d7 and (d) Patient 2 d30. The arrows are showing visible MUAPTs.

3. Results and discussion

Figure 1 shows some sources of the decomposed HD-sEMG signals for patients 1 and 2, all the sources were observed in the study but not shown in the figure. For patient 1, we cannot observe any MUAPTs at d7 shown in Figure 1 (a) but two MUAPTs are clearly observed after decomposition at d30 in Figure 1 (b). Patient 1 had a d7 SPPB of 7 that decreased to 2 at d30, which means that her muscle quality was better at day 7, and thus more motor units (MUs) were active in the isometric contraction and therefore the inability to decompose the HD-sEMG signal into identifiable MUAPTs. On day 30 on the contrary, when the physical performance decreased (SPPB = 2), the decomposition was possible and two MUAPTs were identified. For patient 2, the decomposition of the HD-sEMG at d7 resulted in one MUAPT train shown in Figure 1 (c) even though it's not perfectly isolated. At d30 on the other hand, the MUAPT is less identifiable in Figure 1 (d), and it looks like more MUs were recruited and therefore there is a higher superposition of MUAPs. This is also explainable for patient 2; on d7 her SPPB was 5 and increased to 9 on d30, meaning that muscle quality was improved at d30 and hence the decomposition into MUAPs becoming harder related to a higher muscle resilience level compared to subject 1.

4. Conclusions

In this work, a preliminary study about evaluating possible relationship between muscle resilience, after hip fracture surgery, and the ability to decompose the HD-sEMG signals into MUAPTs using canonical correlation analysis was conducted on two patients from the HIPRESM dataset. It was shown that the decomposition into MUAPTs was related to physical performance at d7 and d30 after the hip fracture surgery. Another remark is that the decomposition

into MUAPTs gave the best visual results with the lower SPPB value (SPPB = 2) of the study. Further studies are planned to validate the proposed hypothesis with the goal to test different decomposition techniques and compare them with the CCA method.

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Conflict of Interest Statement:

The authors declare no conflict of interest.

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