# FIRING RATE ESTIMATION FROM INTRAMUSCULAR RECORDINGS

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## ABSTRACT

*A deconvolution algorithm for estimating motor unit (MU) firing rate (FR) from surface electromyographic (EMG) signal is being developed. To validate the results obtained with this algorithm, indwelling and surface EMG signals were recorded simultaneously so that firing rates could be estimated from both sets independently. A decomposition program was used for extracting intramuscular signals into their constituent motor unit action potential (MUAP) trains and estimating their corresponding FR. Some preliminary results of the MUAP decomposition is presented here.*

## INTRODUCTION

EMG signal constitutes an important source of information on the neuromuscular system. As technical and signal processing progresses are made, more information is sought from less invasive approaches. For instance, MUs firing rates estimation from surface recordings could help for neuromuscular diagnoses, rehabilitation therapies, control of functional prosthesis and sports medicine supervision. For such a goal, a deconvolution algorithm is under development for the estimation of FRs of active MUs from surface EMG power spectrum. While synthetic signals can be used to test the method, a more conclusive validation requires experimental data. For this purpose, intramuscular and surface EMG signals were collected simultaneously. The decomposition of the intramuscular signals into their constituent MUAP trains will permit a direct estimation of their FRs. Preliminary results concerning the MUAP trains extracted from the intramuscular signals are presented.

## MATERIALS AND METHODS

The first two authors participated in the experiments. As illustrated in Fig.1, two double fine wire electrodes (Chalgren, USA) were inserted below the right biceps brachi belly at a depth of 10 mm approximately and distanced by 10 mm from each other. An armcuff with 7 Ag/AgCl surface electrodes (6 mm diameter, center-to-center: 20 mm vertically and 25 mm horizontally) was put around the wire electrodes. Analog signals were amplified (gain: 1000-5000, filtered: 3-3000 Hz) before A/D conversion at 8 kHz. Isometric and isotonic contraction of the elbow was produced at level ranging from 5% to 30% of the maximum voluntary contraction (100% MVC). During the 10 s of each contraction, the reading of a dynamometer was used by the subject as a feedback signal to produce a constant force. Five contractions were done at each level. To prevent fatigue, the order in which the contractions were done was 30%, 20%, 10% and at 25%, 15% and 5% MVC.

The decomposition program and its application on synthetic data was presented previously [5]. Essentially, it is a pattern-matching method inspired from the works of Chistodoulou and Pattichis [3] and Stashuk [6]. The signal is filtered by a low-pass differentiator, for baseline drift attenuation and spike enhancement, a threshold is then set proportional to signal energy. Peaks above this threshold are detected and segments containing a few ms of data on each side of the maximum are stored. A self-similarity approach is applied to these segments to associate a waveform to a given train of MUAPs. Similar waveforms are merged and mean MUAP templates obtained. Each detected peak is then compared to these templates and associated to the most similar one. For this, a matching criterion takes into account the number of segment samples falling within the proximity of the MUAP templates. To identify superimposed potentials, the "peel-off" approach [4] is used. Too large intervals associated to a miss (multiple of a train mean value) are divided by 2, or more to get intervals similar to the mean value. Bins with low counts (associated to wrong detections) are emptied. The FR of each train is then displayed in a 100-bin histogram and mean firing rates calculated.

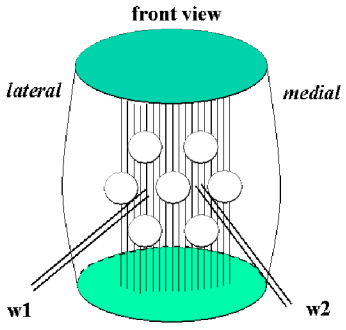


**Fig.1:** Right arm illustration with two double wire electrodes (w1, w2) and 7 surface electrodes.

## RESULTS

A sample of intramuscular EMG obtained at different MVC is shown in Fig.2. At 25% MVC, many MUAPs of large amplitude can be observed. When the force was reduced to 15%, the number of large active MUAPs was somewhat reduced, but disappeared completely at 5%; similar trends were found for 30%, 20% and 10% MVC. In other recordings, presence of large MUAPs was more evenly distributed among these MVC.

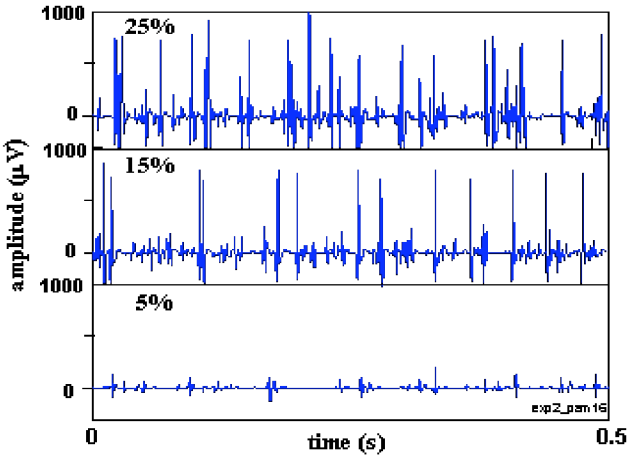


**Fig.2:** Intramuscular EMG signal recorded at 25%, 15% and 5% MVC during isometric contractions.

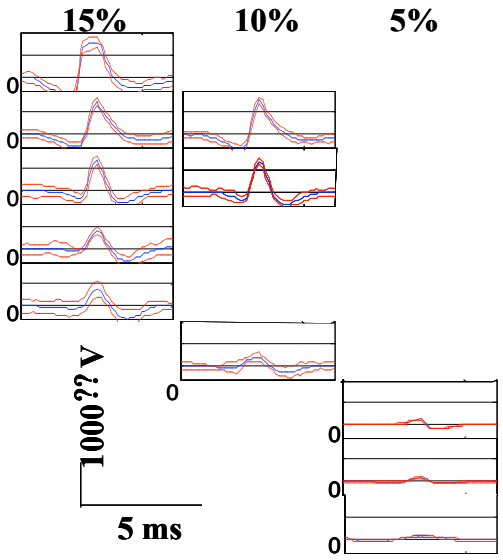


**Fig.3:** MUAPs detected at 15%, 10 and 5% MVC. Sometimes similar MUAPs can be tracked at two levels (i.e. 15% and 10%).

The decomposition program does not track previously detected MUAPs from one contraction level to another. However, the same MUAP could be observed at two force levels (Fig.2 for 15% and 10%) on some occasions. Finding different MUAPs was more prevalent. As can be observed in Table 1, mean firing rate of the detected MUs did not vary much when contraction level changed. Sometimes, increase in firing rate is observed as MUAPs amplitude get smaller (MUAP1 is the largest and MUAP3 or 4 the smaller).

**Table 1:** Mean firing frequencies (Hz) obtained for 3 and 4 MUAPs detected from 5% to 30% MVC.

| % MVC | MUAP1 | MUAP2 | MUAP3 | MUAP4 |
|---|---|---|---|---|
| 5 | 11.9 | 12.8 | 13.5 | |
| 10 | 12.4 | 12.3 | 13.7 | |
| 15 | 12.8 | 12.0 | 12.7 | 12.7 |
| 20 | 12.3 | 12.2 | 12.7 | 12.4 |
| 25 | 11.5 | 13.4 | 13.4 | 12.4 |
| 30 | 10.8 | 12.5 | 13.3 | 13.1 |

## DISCUSSION

Intramuscular recording was used to detect the firing rate of MUs close to the skin surface. As an alternative approach, an array of small surface electrodes [1] could be used but would not be technically as simple to implement when other surface electrodes are used. From the detected MUs of the biceps in one subject, it appears that force modulation in isometric and isotonic contractions could mainly be associated to MUs recruitment rather than to changes in firing rates. To get more information on this, the tracking of specific MUAP at different contraction levels, will be implemented in the decomposition program. Continuous isometric ramp contractions and non-isometric conditions [2] have also to be investigated.

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