

## DETECTION OF MUSCLE FATIGUE: RELATIVE STUDY WITH DIFFERENT METHODS

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**ABSTRACT.** This paper aims to investigate problem of muscle fatigue through the application of a comparative study by different processing techniques in order to see the effect of physical exercise on Electromyography characteristics. Indeed, electromyography is the best physiological examination to study muscle activity and it is translated by an electromyogram (EMG). The analysis of the biomedical signal "EMG" before and after physical exercise allowed us to quantify the physical effort and give some diagnostic elements that can help the practitioner. We applied some signal processing techniques to quantify the physical effort and therefore we were able to identify and detect muscle fatigue.

### 1. INTRODUCTION

EMG is the process by which an examiner puts a needle (or electrode) into a particular muscle and studies the electrical activity of that muscle (this electrical activity comes from the muscle itself) [1].

The EMG is a signal that must be recorded, so there are several electronic acquisition platforms (Arduino, PowerLab from ADInstruments Ltd, Data Acquisition card "DAQ" from National Instruments, etc.). We have chosen as an acquisition platform the Arduino mega card for its availability (see figure 01). This card must be connected through electrodes on the surface of the skin because the EMG is a non-invasive examination (Figure 2).



Figure 1. Model of Arduino Mega 2560 R3 Front [2].

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FIGURE 2. EMG Electrodes with electrodes.

To study the effect of physical exertion on the characteristics of the EMG, there are some typical physical exercises that take place in the research laboratory. We chose a physical exercise that causes the muscular fatigue of the hand (see figure 03); the reference being open hand.



FIGURE 3. Physical exercise provoking hand's fatigue.

## 2. MATERIALS AND METHODS

### 2.1 Data acquisition

After performing physical exercise (see Figure 03), we obtain the following results (Figure 04):

As a first observation, one sees from the shape of the acquired signals that physical exercise has caused a dilation of the signal, that is to say the peaks (representing the activity of the muscular fibers) become more and more spaced.

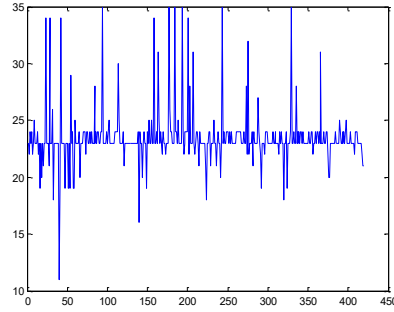
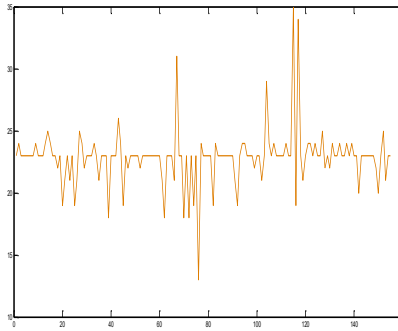
**'a': before****'b': after**

FIGURE 4. Acquired data before and after doing hard exercise.

## 2.2 Processing techniques

*2.2.1 Fast Fourier Transform.* The Fast Fourier Transform (FFT) is commonly used in analyzing the spectral content of any deterministic biosignal, it's a numerical approach for quick computation of the Discrete Fourier transform (DFT). The equation of DFT is as follows [3]:

$$X(k) = \frac{1}{N} \sum_{n=0}^{N-1} x(n) e^{-j\left(\frac{2\pi kn}{NT}\right)} \quad (2.1)$$

where:  $X(n)$  is the input biosignal whose sampling period is  $T$ . The spectrum  $X(k)$  is estimated at multiples of:  $fs/N$ , where  $fs$  is the sampling frequency.

*2.2.2 Wavelet Transform technique.* Wavelet is a wave-like oscillation with amplitude that begins at zero, increases, and then decreases back to zero. We

have two major types of wavelet: continuous wavelet transform and discrete wavelet transform [4]. The continuous wavelet transform (CWT) is defined as [5]:

$$T_x(t, a; \Psi) = \int_{-\infty}^{\infty} x(s) \Psi_{t,a}^*(s) ds \quad (2.2)$$

where  $\Psi_{t,a}^*(s)$  is obtained from the mother wavelet  $\Psi(s)$  by time translation  $t$  and dilation by scale  $a$ :

$$\Psi_{t,a}(s) = \frac{1}{\sqrt{|a|}} \Psi\left(\frac{s-t}{a}\right) \quad (2.3)$$

$a$ : is the dilation parameter.

$s$ : is the translation parameter.

There are numerous analyzing wavelet called mother wavelets such as: Haar, Mexican hat, Morlet and Daubechies. This latter seems (Duabechies) the most used in the analysis of biological signals [6]. Its shape can be seen in the following figure:

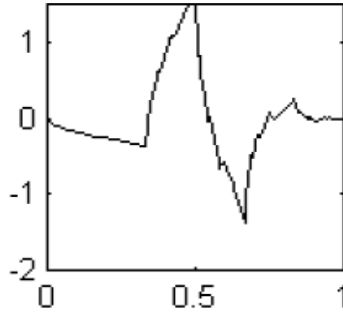


FIGURE 5: Diagram of the wavelets mother function “Daubechies”

### 3. RESULTS AND DISCUSSION

#### 3.1. Fast Fourier Transform

By applying the Fast Fourier Transform technique on the primary signals (raw data), we get the following curves:

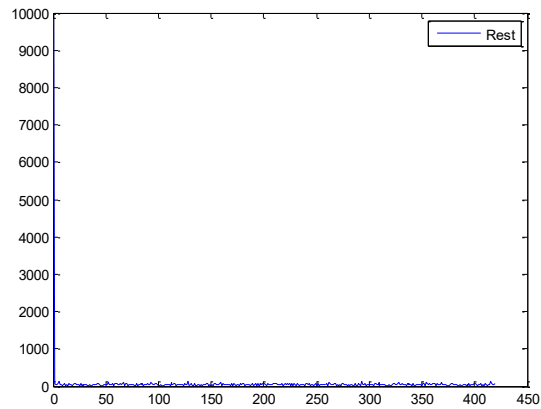


FIGURE 6. FFT of Rest's case (without effort).

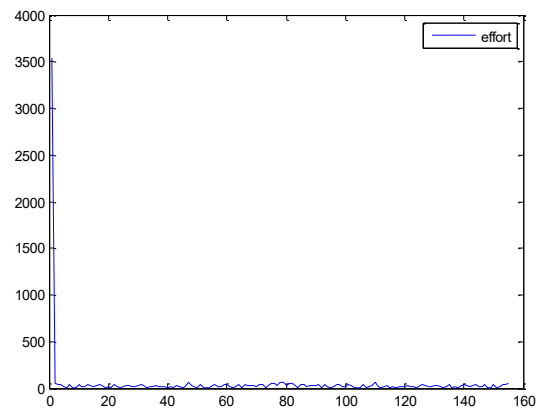


FIGURE 7. FFT of effort's case (with effort)

From the figures, we note that the effort incite an extension of the signal intensity (to 4000) compared to the signal of rest. But in general the FFT technique gives little information for the analysis of biomedical signals.

### 3.2. Technique of wavelet

We have chosen the Daubechies continuous wavelet for treating our raw data. After running the Matlab program, we obtained these signals (Figures 8 and 9):

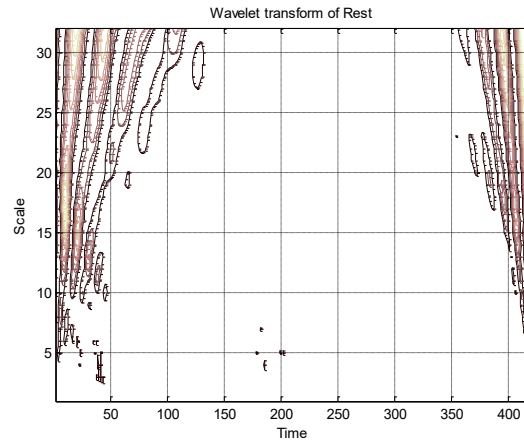


FIGURE 8. The wavelet transforms of an EMG signal (scalogram of Rest's situation).

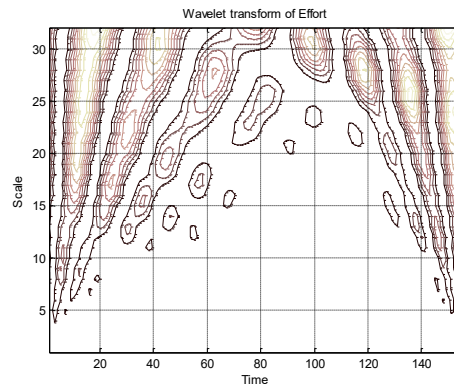


FIGURE 9. The wavelet transforms of an EMG signal (scalogram of Effort's situation).

The first result is concentration of wavelet coefficients on the peaks of the EMG signal.

Another finding, we see clearly that the signal of effort's wavelet is very rich in coefficients and in energy. So we can deduce from the shape of the signal confirms or not if there is fatigue.

### 3.3. Complementary study “Entropy”

There are complementary techniques to wavelet for processing, based in general on Shannon wavelet entropy. The modified Shannon wavelet entropy is computed by [7]:

$$H^k(f_b) = - \sum_{i=1}^M P_i^k \log P_i^k, \quad \sum_{i=1}^M P_i^k = 1, \quad (3.1)$$

$$f_c = k \in [J, K]$$

where,  $P_i^k$  is the distribution sequence obtained from wavelet coefficients.  $P_i^k$  is calculated by [7]:

$$P_i^k(f_b) = |W_x(m, n)| / \sum_{j=1}^M |W_x(m, n)| \quad (3.2)$$

By calculating the maximum of Shannon entropy coefficient for the two cases (before and after getting fatigue ‘effort’), we get this table:

TABLE 1. Maximum of Shannon entropy

Rest	Fatigue
-	-
1.4791e+00	5.1385e+00
6	5

We can deduct from the table that the fatigue’s muscle signal’s entropy is higher than the rest case. This signal of fatigue contains a lot of different information (very rich in information).

## 4. CONCLUSION

The analysis of EMG signal through the processing tools offered by Matlab is very useful to detect muscle fatigue. In this paper, we applied some signal

processing techniques to quantify the physical effort and therefore detect muscle fatigue.

The application of wavelets especially those of the Daubechies seems the best. A complementary study based on calculation of Shannon entropy was done and it has given us some explanations to wavelet results.

We hope to be able in the future to apply other digital processing techniques and to derive other results in order to identify the problem of muscular fatigue.

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