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Research Article

Identification of Hand Movements using EMG and Determination of Fatigue

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Abstract

Electromyography (EMG) is a signal that conveys the health of the muscles and the nerves that control the muscles. There are two methods used to record the muscle reading of an individual using EMG 1.Using thin needle electrode pierced through the skin to take the reading and 2.Using surface electrodes which are attached to the surface of the skin. The surface electrodes are placed directly over the nerve endings inside the skin and the readings in terms of voltage fluctuations are observed on the connected system. In this work, a method to identify the wrist movement and elbow movement of the body using the data acquired through the surface electrodes connected to the body and then use the patterns obtained to formulate a method to identify the fatigue level in the respective muscles is presented.

Keywords: *surface electrodes, fatigue level, MUAP, Mean, RMS, DAMV.*

1. Introduction

Electromyography has been used in medical applications for many years and has been regarded as one of the best methods to read the muscle behavior during different body movements. The muscles in our hands are connected to the neurons which provide the muscle with the stimulating signal to perform action in the form of electrical signals. These signals are recorded by the electrodes connected to the surface of the muscles and sent for processing.

The following changes in the EMG signal can implicate muscle fatigue: an increase in the mean of the signal, increase in the amplitude and duration of the MAP (muscle action potential) and an overall shift to lower frequencies. Monitoring the changes of different frequency changes is the most common way of using Electromyography to determine levels of fatigue. The lower conduction speed enables the slower motor neurons to remain active.

A motor unit is defined as one motor neuron and all of the muscle fibers it connects. When a motor unit gets excited, the impulse (called an action potential) is carried down the motor neuron to the muscle. The place where the nerve contacts the muscle is called the neuromuscular junction, or the motor end plate. After the action potential is transmitted across the neuromuscular junction, an action potential is produced in all of the connected muscle fibers of that particular motor unit. The absolute sum of all this electrical activity is known as a motor unit action potential (MUAP). This electrophysiologic activity from multiple motor units is the signal typically computed during an EMG. The conformation of the motor unit, number of muscular fibres per motor unit, the metabolic type of muscle fibres affect the shape of the motor unit potentials in the myogram.

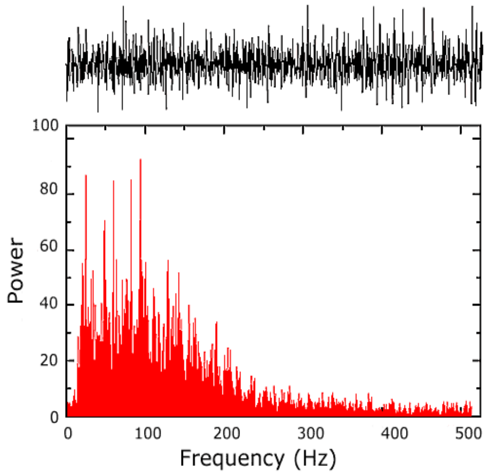

Fig 1: Frequency spectrum of the EMG signal detected from the Tibialis Anterior

It is well established that the amplitude of the Electromyography signal is random in nature and can be represented by a Gaussian distribution function. The voltage amplitude of the signal can range from 0 to

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10mV or 0 to 1.5 mV (RMS). The usable energy of the signal is limited to the 0 to 500 Hz range, with the dominant energy being in the 50-150 Hz range. Usable signals are those with energy levels above the electrical noise level. An example of the frequency spectrum is shown in Fig1 (Carlo J. De Luca *et al*, 2002).

In this experiment, the wrist and the elbow muscle readings of four subjects within the age group of 19 to 22, is taken for these two following movements

- The subjects are told to move their hand up and down with 2.5 Kg weights around their wrist; the hand must be perfectly stretched and then moved upwards keeping the arm parallel to the ground.
- The subjects are told to move the wrist up and down with the same amount of weight around their wrist.

Both of the above actions are performed until the subject becomes tired and then the readings are processed to observe the results. A Data Acquisition Card from National Instruments is used to take the readings from the surface of the skin and send it to the computer connected where the readings are then saved in the form of an excel sheet. In order to eliminate the greater noise signal from power sources, a differential detecting setting is employed. The differential amplification configuration is shown schematically in *Figure 2*. The process is simple. The signal is recorded at two sites, electronic circuitry subtracts the two signals and then amplifies the difference. As a result, any signal that is **common** to both sites will be eliminated and signals that are different at the two sites will have a **differential** value that will be amplified. Any signal that is produced far away from the detection sites will appear as a common signal, while signals in the immediate vicinity of the surfaces will be different and consequently will be amplified (Carlo J. De Luca *et al* 2002). This data is then processed using MATLAB.

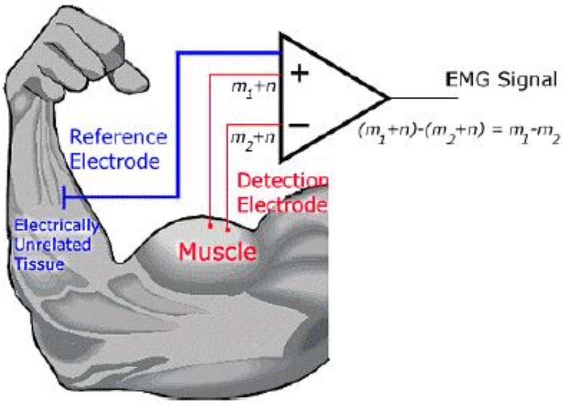

Figure 2: The differential amplifier configuration. The EMG signal is represented by 'm' and the noise signals by 'n'

The entire process is divided into two steps .First is the identification of the muscle movement and second is the determination of fatigue and the creation of a standalone application/device capable of providing information on the health of the subject's muscles spontaneously.

Identification of Wrist and Elbow Movement (Step 1)

There are 2 pair of electrodes placed on the subject's left hand; one pair to record the elbow muscle readings and the other pair to record the wrist muscle readings. The first pair of electrodes are placed on the biceps and the other on the triceps (i.e. on the area most sensitive to the movements being made and the second pair is placed above the midline near the Extensor Carpi (radialis longus) separated with a small distance).

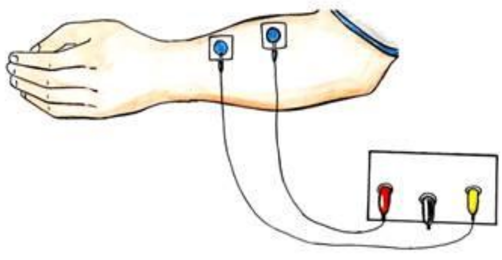

Figure 3: A schematic of the placement of the two surface electrodes for recording wrist muscles readings

The readings from these electrodes are recorded for both the movements and then processed using MATLAB.

Processing: Rectification is the translation of the raw EMG signal to a single polarity frequency. The purpose of rectifying a signal is to ensure that the average of the signal does not become zero due to the raw EMG signal having positive and negative components. It expedites the signals and process and calculates the mean, integration and the fast Fourier transform. The two types of refinement of signals denote what happens to the EMG wave when it is processed. They are full length frequency and half length. Full length frequency adds the negative Electromyography signal (the signal below the baseline usually with negative polarity) to the signal above the baseline making a refined signal that is only positive.

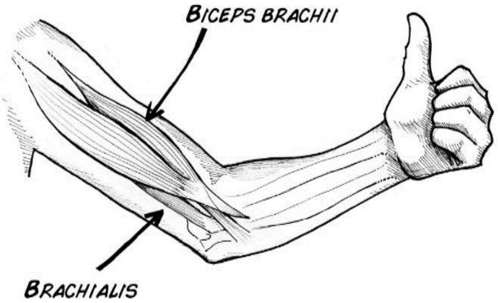

Figure 4: A schematic of the placement of the two surface electrodes for recording elbow muscles readings

This is the chosen method of rectification because it preserves all signal energy for analysis, usually in the positive polarity. Half-length rectification removes the signal below zero. As a result, the average of the data is no longer zero therefore it can be used in statistical data analysis. The only difference between the two types of rectification is that full-wave rectification takes the absolute value of all the values in the data array.

We use the full length frequency method for the rectification of the signal. The rectified signal is then used to measure the Absolute Mean, Root Mean Square and Differential Absolute Mean Values.

Absolute Mean

The Absolute Mean of the all the trials is taken and then plotted in order to observe a pattern. The formulae used to calculate mean is (Rubana H. Chowdhury 1, Mamun B. I. Reaz 1, Mohd Alauddin Bin Mohd Ali 1, Ashrif A. A. Bakar 1, Kalaivani Chellappan 1 and Tae G. Chang *et al* 2013):

$$\overline{x_i} = \frac{1}{N}\sum_{k=1}^{N}|x_k| \qquad (1)$$

x_k : the *k*-sample in the segment *i*.

Differential Absolute Mean Value

The Differential Absolute Mean Value gives us the small changes in the readings and provides us with a set of readings stating the increasing or decreasing or fluctuating pattern of the data recorded. The formula to calculate DAMV is is (Rubana H. Chowdhury 1, Mamun B. I. Reaz 1, Mohd Alauddin Bin Mohd Ali 1, Ashrif A. A. Bakar 1, Kalaivani Chellappan 1 and Tae G. Chang *et al* 2013):

$$\overline{\Delta x_i} = \frac{1}{N-1}\sum_{k=1}^{N-1}|x_{k+1} - x_k| \qquad (2)$$

where N is the total no. of samples.

Root Mean Square (RMS)

The Root Mean Square represents the square root of the average power of the EMG signal for a given period of time. It is known as a time domain variable as the amplitude of the signal is measured as a function of time. The formula to calculate RMS of the readings is (Rubana H. Chowdhury 1, Mamun B. I. Reaz 1, Mohd Alauddin Bin Mohd Ali 1, Ashrif A. A. Bakar 1, Kalaivani Chellappan 1 and Tae G. Chang *et al* 2013):

$$RMS = \sqrt{\frac{1}{N}\sum_{k=1}^{N}[x_k]^2}\ \mathrm{k} = 1, 2,\ ...., \mathrm{N} \qquad (3)$$

N: number of samples, x_k: the *k*-sample

Observation: The following data was obtained after the signals were processed and the data was plotted using MATLAB.

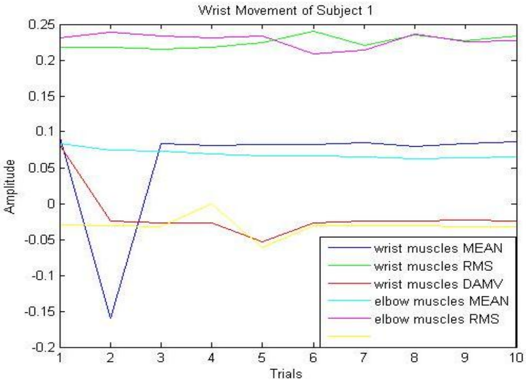

Fig 1.1-Wrist Movement of Subject 1

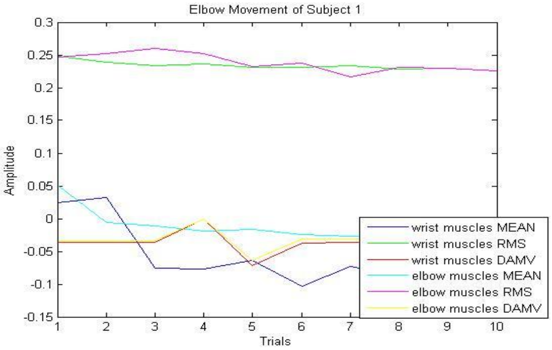

Fig 1.2-Elbow Movement of Subject 1

Comparison of Mean, DAMV and RMS values of the wrist movement and elbow movement of subject 1

The mean and DAMV in **Fig 1.1** and **Fig 1.2** show opposite pattern. As can be seen in **Fig 1.1** the mean for the wrist muscles has a higher magnitude than the mean for the elbow muscles while in **Fig. 1.2** the mean for the wrist muscles has lesser magnitude than the mean for the elbow muscles. The same pattern can be observed for the DAMV readings of the two movements.

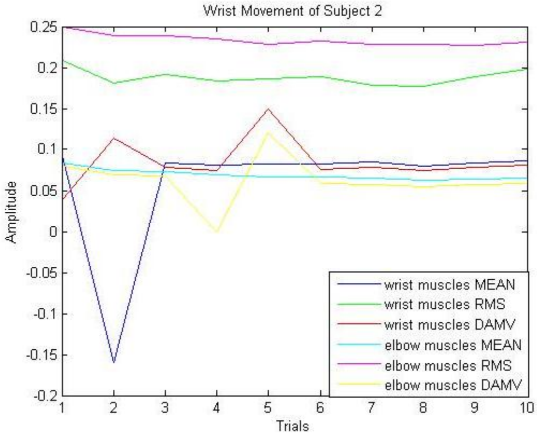

Fig 2.1 Wrist Movement of Subject 2

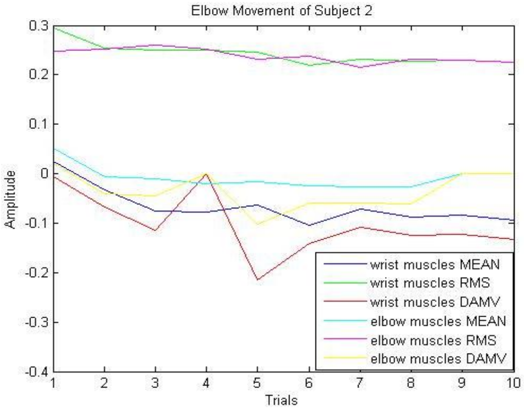

Fig 2.2 Elbow Movement of Subject 2

Comparison of Mean, DAMV and RMS values of the wrist movement and elbow movement of subject 1

The mean and DAMV in **Fig 2.1** and **Fig 2.2** show opposite pattern. As can be seen in **Fig 2.1** the mean for the wrist muscles has a higher magnitude than the mean for the elbow muscles while in **Fig. 2.2** the mean for the wrist muscles has lesser magnitude than the mean for the elbow muscles. The same pattern can be observed for the DAMV readings of the two movements. As can be seen from the above readings the Absolute Mean of the readings clearly help us differentiate between the wrist and the elbow movements. The Differential Absolute Mean Value also shows some distinction in a similar fashion. In both the wrist movements the mean values for the wrist muscles are well above 0.1V whereas for the elbow muscles are below 0.1 indicating more work done by the wrist muscles. Similarly for the elbow movements the Absolute Mean Values are more for elbow muscles than the wrist muscles indicating more work done by the elbow muscles. The Mean and DAMV gave more consistent readings than other statistical parameters like RMS as can be seen in the above figures and hence were not included in the determination of the body movements.

Determination of Fatigue (Step2)

The next step of this experiment is to determine the fatigue in the muscles as the trials go on. As can be seen from the charts mentioned above, the muscle readings slowly decrease with increase in the number of trials and becomes saturated towards the end.

Since the mean of the values have proven to be the most consistent out of all the statistical models it was chosen to determine and monitor the fatigue of the muscles.

Three subjects with different physique were chosen and made to carry out the elbow movement for as much as times as they could handle with a load of 2.5 Kg.

The first subject chosen was one weighing around 75 kgs the second was one around 65 kgs and the third was around 60 kgs.

Conclusion and Future Prospect

In this paper we present the method to determine the hand movements using the readings obtained from the surface electrodes using the DAQ card from national instruments and then processing the results in MATLAB in time domain and observing the results. We also present the detailed analysis of this process to predict fatigue in the muscles of various subjects with different physical properties.

Using this as a standalone application to identify/predict the fatigue of the muscles can be devised which can be very useful for personnel use as well as in medical applications. Fuzzy logic and neural network can be used to first identify the muscles involved in the movement and then determine the fatigue level in the muscles and predict any danger to the muscles that might arise as a result of the movements and prevent them from happening by informing the subject of this danger.

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