1 Introduction

The scope of this paper is to describe -with the aim of allowing re-productivity- the steps carried out to process signals obtained in three different experiments and topics, specifically, EMG (Section 2), psycho-physiology (Section 3) and Anthropometry (Section 4). In each section is included a detailed description of the experiment, the post-acquisition processing steps that were carried out in order to achieve the purpose of each experiment, and a final conclusion derived from the analyzed and processed data, considering the theoretical points explained in each introductory sub-section. These three experiments namely were ElectrMyoGraphy (Section 2), robot-aided rehabilitation (Section 3) and a bio-mechanics study (Section 4).

Some informative, theoretical sections may also be included in order to bestow the reader with a perspective and basic knowledge into the matter of study.

2 ElectroMyoGraphy

This section delves into the theory of Muscle Activity. Within this section; in the first section, we provide some insight into what is really occurring at a molecular level. Section 2 deals with the science that underlays reading an action potential. Section 3 describes the experiment, including the preparation, tasks, signal processing and a final conclusion inferred from all the former subsections.

2.1 Anatomical and Physiological Background on Muscle Physiology

Most skeletal muscle fibers are innervated by a single motor neuron. Since there more muscle fibers than motor neurons, individual motor axons branch in order to synapse different fibers within the muscle over a wide area. Thus, we ensure the exertion of a contractile force is spread evenly. (6) Motor units are the basic functional unit of the neuromuscular system. (2) It is also worth mentioning muscle fibers, which cover muscle tissue and the sarcolemma.

An action potential arrives at the terminal bottom of a neuromuscular junction, stimulating the release of acetylcholine, which diffuses across the cleft and triggers an action potential in the muscle fiber. It arrives via the T tubules onto the sarcoplasmic reticulum, triggering the release of Ca^{2+} into the cytosol.

The molecules of Ca^{2+} binds on troponin thin filaments, which induces in it a change of shape. Thus, the binding sites of actin are uncovered for the myosin cross bridges to attach. ATP molecules give the energy for this bridges to bend, pulling the filament towards the center of the sarcomere. After such stroke, if there is Ca^{2+} still present, the myosin cross bridges are created anew, repeating the same process. (4)

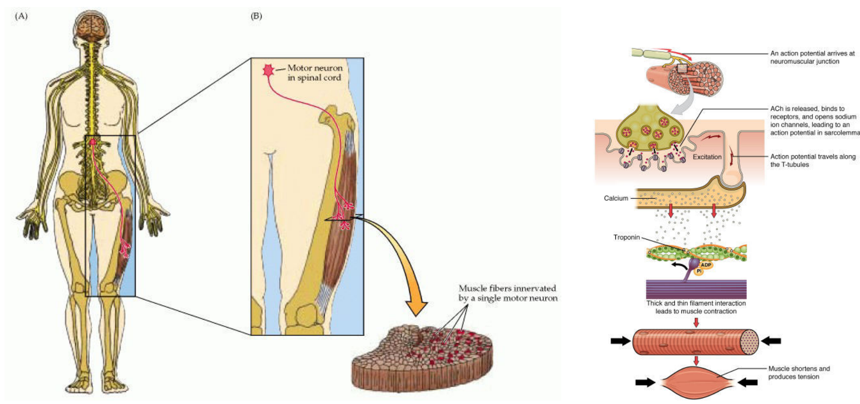

Figure 1: Left: Motor Unit (6). Right: Muscular Contraction at the Molecular Level

2.2 Reading an action potential

The action potential that initiates all these afore-described, physiological processes can be recorded by the proper positioning of the electrodes and enhances by sub-sequential adequate manipulation (2). More specifically, we must consider that the cellular membrane is negatively charged in the inside and positively in the outside (due to proteins and other intrinsic components, like he Na/K pump), having a potential difference ranging from -70mV up to -90mV. In that case, the membrane is initially at rest, that is, polarized. As the impulse arrives, the membrane depolarizes (if a threshold is achieved) and the potential difference increases (grows positive) -as Na^+ rushes in the inside of the membrane- and repolarizes as K^+. It may also happen that the cell membrane is hyperpolarized, that is, it goes below the resting potential (2). Generally, however, this process is repeated and transmitted along the nerve, showing a behaviour that resembles that of a dipole, at a speed of 2-3m/s. In Figure 2, we can observe such transmission (left) and the sum of different signals (left) which, depending on the distance to the surface, will arrive weaker or stronger. Therefore, since the electrodes are indeed in the surface of our skin, we should not expect any pattern in the signal that reaches our electrodes.

2.3 Experiment

The experiment referred in the following sub-sections was performed independently of our work. We shall retake the work performed in other years by students in UCBM as our data source, and use it in our project, which will deal mainly with processing of such signals by means of MatLab software.

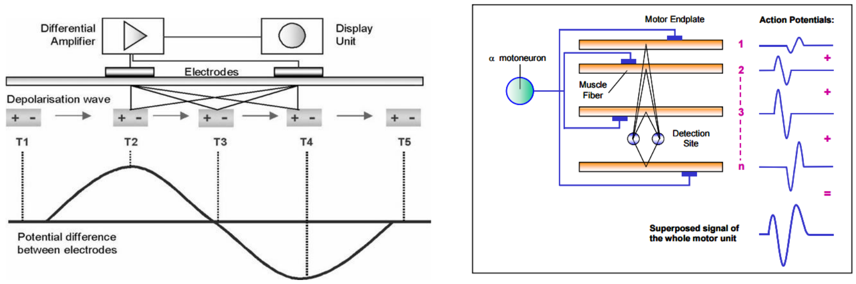

Figure 2: Left: Electrical Dipole (7). Right: Distance and Signal received. (8)

2.3.1 Preparing the skin

We do, nonetheless, highlight some key aspects to bear in mind while reproducing the experiment. Small electrodes will have higher selectivity and lower cross-talk, but also higher impedance. A proper balance was attained with electrodes having a diameter between 1 and 2cm, which can be adhesive (handleable) or gel (lower impedance). For slow movements, alcohol is enough to prepare the skin before the experiment, which should be properly cleansed to enhance signal reception. Besides, electrodes must always be parallel to the muscle fiber and cannot be detached during muscle contraction.

2.3.2 Activities and Signal Acquisition

Several records were taken. Firstly, in order to later be able to normalize all our data, we took two MVC (Maximum Voluntary Contraction), both from the biceps and the triceps, in which the patient was asked to exert all the force they could in three sequential occasions, during an overall 5s interval, both for triceps and biceps. After that, sixteen signal samples were obtained in different conditions, namely, half of them having the patient seated and half standing. Each subset in turn halved in loaded or unloaded (depending whether the patient held or not a weight). Each one of them was performed at a different angle - precisely, 45, 90 135, 180º- for a 15s interval. Figure 3 shows the positions that the patient adopted during the experiment just described.

2.3.3 Signal Processing

The EMG signal that our receptor receives from our muscles ranges in frequency from 6 to 500 HZ. However, from theory, we know that the frequency spectrum in which our signal is strongest in the interval between 20 and 550 Hz (2) (4). Therefore, if we take this interval only, we ensure a much higher SNR, which is easily achieved by a simple butterworth pass-band filter between 20 and 350Hz, as well as an order of 4 (steeper cut-off slope). Furthermore, we notice that the network might have introduced a 50Hz noise signal, which is to be eliminated by

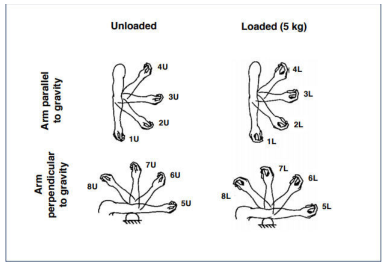

Figure 3: Positions adopted by patient during EMG experiment for signal acquisition.

a notch filter of such frequency and some units -say, 2- as margin. Furthermore, although our signal is not perfectly symmetrical, we just need one side of the x axis to correctly interpret it. Such procedure is called rectification. Finally, we take the envelope of the resulting signal, that is, the ”shape” or ”outline” of it. Similarly to the reasoning in the previous step, this might yield a different signal but actually enhances human interpretability. We can see the results of such procedure in Figure 4.

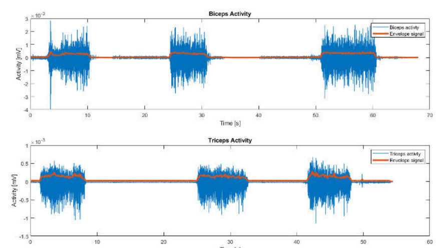

Figure 4: EMG signal from biceps (above) and triceps (below) and the processed envelope signal.

We also use the MCV that we mentioned before to normalize our data. To do so, we use a software interface like MATLAB to extract the three intervals in which the patient is exerting force. We plot all of them together in Figure 5. The dashed black line shows the mean of, in turn, the mean of the values (biceps or triceps) that overcome a threshold of 0.7 times the maximum value.

2.3.4 Conclusions

We can see from Figure 5 that all contraction are more or less equal. We also note that it is precisely on the third biceps contraction that the patient performs better and longer, which might be a sign of health, since he does not seem to grow fatigue. Finally, since the patient is exerting maximal force, he must be using both biceps and triceps muscles, so there is actually a correlation between

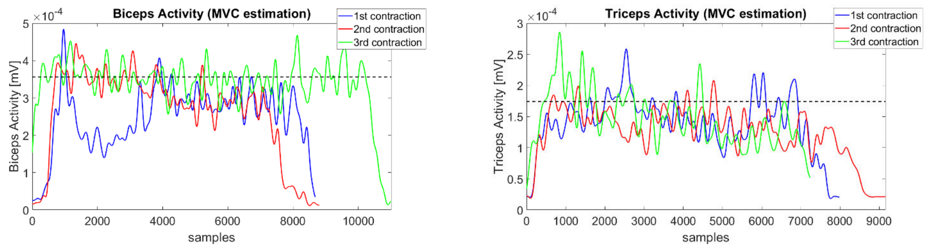

Figure 5: Left: MVC Biceps Estimation. Right: MVC Triceps Estimation.

them. In fact, albeit stronger in the biceps, muscle activity is high in both, unlike in the following exercises, where the patient was told to lift a weight and, depending on the degree that the arm holds it, would use one muscle more than the other. For the sake visualization, we plot Figure 6.

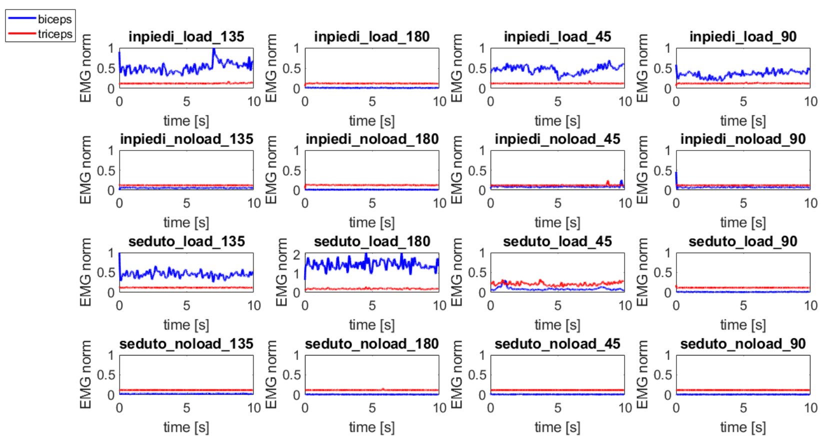

Figure 6: Biceps and triceps activity for all configurations that the patient did.

In Fig. 6 we can observe how subplots representing *no load* configurations show no sign of force, since no load is heaved and therefore, muscles are relaxed. However, sub-figures representing forces are different depending not only on the angle, but also on whether the patient is seated or standing. More precisely, when the patient lifts a 5 Kg load and maintains an arm position with a degree of 135°, the biceps must be highly active in order to sustain that weight. However, when seated and when the degree is lower, that is, the patient brings the weight closer to the body, muscle activity diminished significantly, even if loaded. This is the case of 45° and 90°. In this case it is also interesting to notice that the triceps is exerting, exceptionally, a larger force than the biceps is. This is due to the fact that such position demands a larger effort by the triceps, since the weight is already close to the body and contracting the biceps would not have much sense. It is interesting to note that the triceps, which usually serves as an antagonist -that is, a muscle that produce an opposing joint torque to the agonist muscle, the biceps- has actually a function other than retrieving the arm to its original position. In some circumstances, like this one, the gravity or the circumstances are not enough and the fore of the triceps is required. On the contrary, if the patient must hold the weight at such angles when standing, the force he must exert is much greater, as observable in the two right-most columns of Figure 6. Similarly, in the case of a 180^o degree posture, the force will be much larger if the patient is seated (5L) than that when he is on his feet (1L), since, in the former case, the with must be maintained perpendicular to gravity whereas, in the latter case, it is parallel to the gravity vector and the weight is sustained by the bone joint, rather than the muscle.

Overall, we conclude that the force of the biceps is usually much greater than that of the triceps, but the function of the triceps as an antagonist is not to be disregarded and sometimes it can have more importance than the biceps, like the case in which the patient was seated in a 45^o position.

3 Physiological Signals

This section tackles the science of Physiology, and how it can be closely related with Psychology. The first section describes the variables and mention physiological status related to them. Section 2 describes the experiment, including signal acquisition, processing and, finally, an elaborated conclusion.

3.1 Physiological variables

Throughout the experiment, we will be using all types of physiological signals, namely, Galvanic Skin Response (GSR), Heart Rate (HR), Heart Rate Variability (HRV) and Respiration Rate (RR).

With these variables, we hope to accurately distinguish between moments of stress, fatigue and attention in our patient.

The GSR is obtained from the changes in conductance on the skin, due to, for instance, the sweat. It can be distinguished (by the methods described in section 3.2.2) into SCL (baseline, tonic level) or SCR (skin response). The former is a clear sign of stress while the latter might also mean attention. HR is just the beats of the heart per minute and HRV its variability, inversely proportional betwixt them. HR is a sign of stress and attention, whereas HRV is unequivocally present in fatigue. RR refers to respirations per minute. It is highly present in stressful situation while it is less wont to appear in moments of attention or fatigue.

3.2 Experiment

The experiment was carried out upon a patient that presented back discomfort. A robot (connected to the patient by a hand support) made him follow a series