ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XV ISSN – 1454 – 9832 – 2013; ISSN-L 1454 - 9832

EXPERIMENTAL RESEACH REGARDING THE ACTIVITY OF MUSCLES

Claudiu MEREUTA, Carmina Liana MUSAT, Daniel GANEA, Elena MEREUTA
"Dunarea de Jos" University of Galati, Romania

Abstract:
The paper presents some experimental research regarding the activity of muscles during the flexion extension motion of the human upper limb. The experiment involves electromyography as a non invasive method. The paper describes the technical instrumentation, the protocol and the process of collecting data. The results reveal the muscle contraction phases. So, the EMG analysis can provide a tool for estimating muscle activity and together with a muscle model, the force developed by the muscle can be much better estimated and the stages of muscular activity are highlighted.
Key words: *muscle, contraction, electromyography*

1. INTRODUCTION

The electrical activity of biological systems is essential to the integration in environment of all living beings. It is located in the membranes of excitable cells, acting as a receiver of signals from the external and internal environments, followed by transmission and processing of information.

The registration of potential differences in biological structures can be achieved either by using macro or micro electrodes. Electrodes with the best performance and the widest use today are those of Ag/AgCl.

Electromyography (EMG) is a non-invasive method of para clinical investigation which enables studying the striated muscle bioelectric activity at rest and during contraction, respectively in normal and pathological conditions.

The collected electrical signals are processed by amplification, filtering, followed by the graphical representation (on an oscilloscope screen or paper tape) or a specific storage e.g. magnetic tape. At present, the signals are subjected to analogue-digital conversion (A/D), followed by computer processing of the signals.

2. TECHNICAL INSTRUMENTATION

The technical instrumentation used in the experiment is the BIOPAC system (Fig.1), consisting of:

A. Computer with AcqKnowledge program. AcqKnowledge is the software component of BIOPAC acquisition system and is an interactive and intuitive way to view, measure, analyze and transform data. The main functions AcqKnowledge can perform are:

– monitoring data acquisition, i.e. establishing the recording channels, calibration, setting the analogue/digital acquisition and conversion parameters, defining the mathematical functions for on-line processing of waveforms;

– storing and handling data in the computer;

– discrete signal processing after registration, i.e. mathematical, analytical functions, frequency analysis, filtering, statistical functions;

– accessing a proper editor (journal), this allows marking some comments specific to a set of records.

B. BIOPAC MP150 data acquisition (A) station. The component MP150 (fig.1) is the central unit of the experimental data acquisition. This component retrieves the signal from the external drive which is the EMG100C module, processes it and then forwards it to the computer.

C. STM100C stimulating module (B), which is used to filter the signal.

D. UIM100C signal amplifier (C) links the external modules, meaning the EMG100C and MP150 acquisition unit. The module is the input interface for pre-amplified signal and / or digital signal for the MP acquisition unit. It also offers a direct path between analogue or digital channels 0/1, and MP device when acquiring or transmitting data to external equipment.

E. EMG100C external mode (D) for data acquisition which amplifies bio-electric potential characterizing the activity of skeletal and striated muscles.

F. Cables LEAD108 and LEAD110S-R;

G. Modular Extension Cord MEC111C;

H. EL503 sensors.

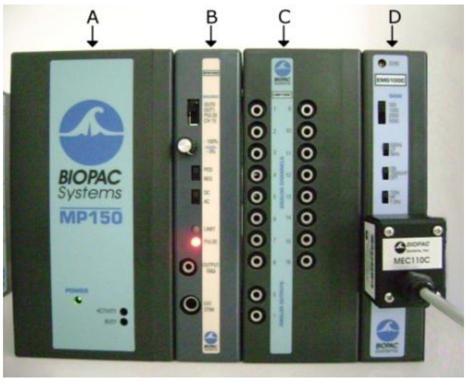


Figure 1. BIOPAC system

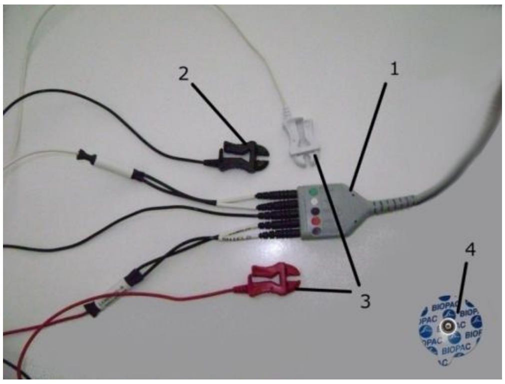


Figure 2. Connecting elements

The connecting elements (Fig.2) which ensure the connection between the BIOPAC system and the subject of the experiment are: MEC111C modular extension, LEAD110 cable, LEAD108 cable, EL503 sensor. The LEAD108 cable (Fig. 2) is made of carbon fibber, having a clamp at one end to attach to the sensor and the other end a pin that can be connected to any external module or modular extension. The cable has a length of 1.8 m and a diameter of 1.5 mm with a resistance of 156 ohm/m. This cable is recommended to be used for the grounding electrode (GND). The LEAD110 cable (Fig.2) has a length of 1m and two pins, one connecting to the electrode contact (+ / -) and the other to the shield.

The MEC111C modular extension MEC111C (Fig. 3) is recommended for measurements using bio potential amplifiers (e.g. EMG110C) and is designed to increase the length of acquisition cable, thus increasing the subject's range of motion and comfort.

Figure 3. Modular extension

The extension comes with a clip to attach to the subject's belt or clothes, thus eliminating the errors due to extension movements during the experiment.

The EL503 sensors (Fig.2) are surface sensors providing excellent signals for all bio-potential recordings. These sensors are self-adhesive, so the use of special glue is not needed. They are made of vinyl and have a diameter of 35mm and a contact area of about 10 mm^2.

To measure the electrical activity of a muscle using electromyography is necessary to use three surface EL503 sensors: two sensors are applied on the skin covering the muscle that we want to analyze, first sensor at the proximal end, the second sensor at the distal end of muscle, and the third sensor on a neutral zone.

3. DESCRIPTION OF THE EXPERIMENT

For conducting the experiment under optimum conditions the protocol to be met includes the following conditions:

a. The ambient temperature should be 20-25° C (lower temperatures disturb the EMG recording because the muscle involuntary contractions are caused by chills), [Szilágyi 2008];

b. The subject should be aware of the EMG examination procedure (to help to relax);

c. The hair in areas of application of sensors should be removed in order to eliminate disturbances caused by the contact between the sensor and the skin;

d. The subject's state must be a relaxed and comfortable one [Nemes, Gogulescu 2006]

e. The subject should not talk or laugh during measurements [Szilagyi 2008];

f. During the experiment, no movements beyond those provided for by the protocol are allowed;

g. During the experiment, no visual access to monitor is allowed;

h. No metallic objects are allowed (watch, bracelet) that might alter the measurement results;

i. The modular extension should be stationary during recording process;

j. The sensors must not come into contact with the body parts or foreign objects like cables of experimental equipment, furniture, sporting equipment, and clothing.

During the experiment it was intended to determine in a non-invasive way, the biceps muscle activity during the flexion-extension motion of the forearm, as voluntary movement [Nemes, Gogulescu 2006]. This motion is caused by isotonic contraction of the above mentioned muscle [Nenciu 2005, Todea 2006, Postolache 2007]. We have chosen to perform this motion because it is one of the most common motions that an individual carries out both in daily and in sports activities.

Figure 4. Sensors positioning

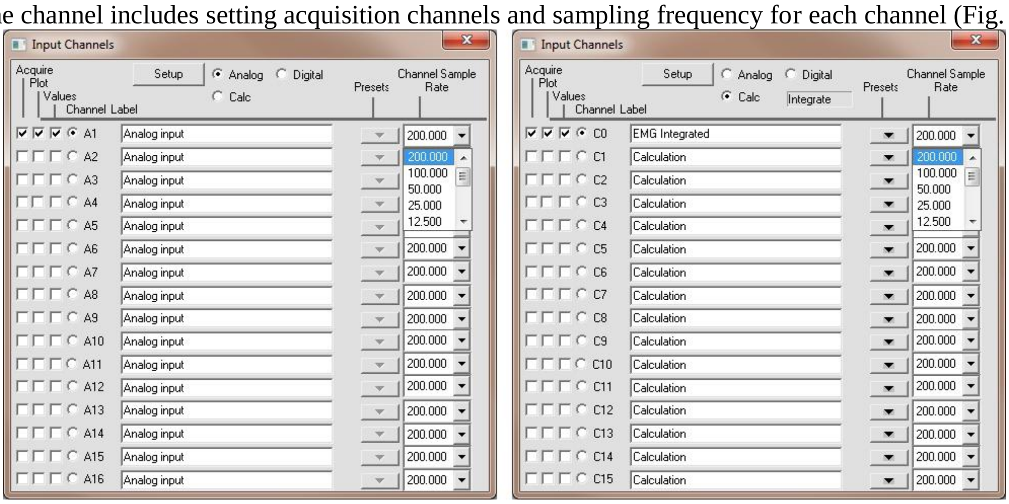
The experiment was conducted under three loading conditions:

1. No loading, just the weight of the forearm and hand (Fig. 4)
2. Loading the subject with 2kg weight (only dumbbell bar);
3. Loading the subject with 5kg weight (Fig. 5).

Figure 5. Experiment snapshot

4. COLLECTING DATA

Setting the channel includes setting acquisition channels and sampling frequency for each channel (Fig. 6).



a) analogue channel b) processed channel

Figure 6. Channel settings

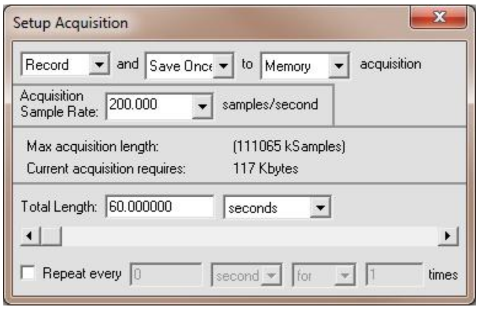


Figure 7. Setting up the data acquisition process

Setting the acquisition mode requires establishing the storage and saving mode, the storage location, and the frequency of acquisition as well as the duration (Fig.7).

For each loading condition, the experiment duration is 60 seconds, during which 18 flexion-extension repetitions were performed. Corresponding to these three loading conditions three recordings of muscle activity were get (Figs.8, 9, 10).

The red signal signifies the raw EMG signal and blue one is the processed signal. Signal processing is carried out by integration, eliminating the noise.

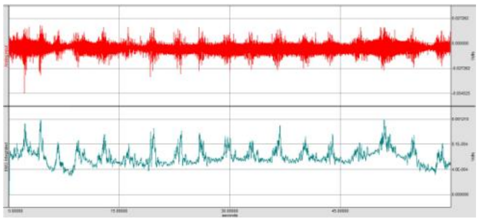


Fig. 8 EMG signal for the first loading case

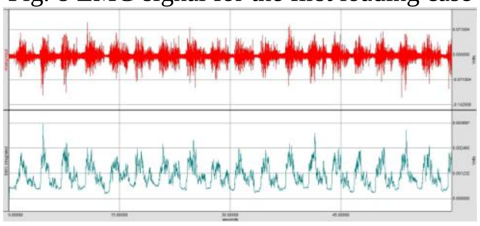


Fig. 9 EMG signal for the second loading case

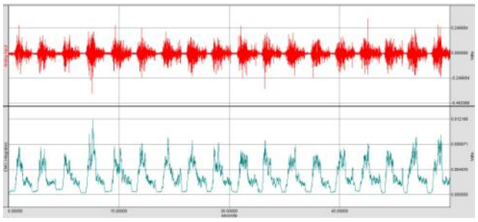


Figure 10. EMG signal for the third loading case

5. DATA PROCESSING

The analysis of the electrical signal and its spectrum involves the identification of the limits beyond which the presence of the signal can be neglected. Spectral range of the signal is called signal band (between f_{min} and f_{max}). Experimental study of different types of electrical bio-signals (EEG, ECG, EMG, etc.) indicates that some type of bio-signal has a certain spectral bandwidth and the maximum allowed values are about the same for a certain type of bio-signal.

For signal processing AcqKnowledge software incorporates a module tailor–made to calculate Fast Fouriei Transform (FFT), which decomposes a signal into a series of sinusoidal components of different frequencies, making the transition from frequency domain to time domain, making the calculation of the transformed signal amplitude and phase.

$$X(j\omega) = \int_{-\infty}^{+\infty} x(t) \cdot e^{-j\omega t} dt \tag{1}$$

A frequency domain signal analysis can be performed in different ways, depending on the signal to be analyzed. This analysis highlights the harmonic composition, i.e. EMG signal power distribution in the frequency domain. We can conclude that when the spectrum of muscle activity is known, it can provide its deployment and time and vice versa.

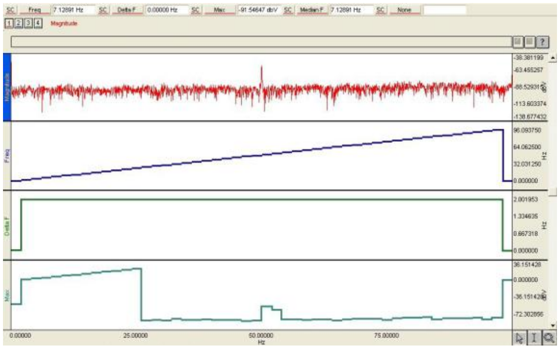


Figure 11. Muscular activity in terms of time and frequency

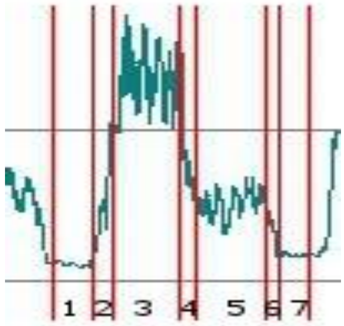


Figure 12. Muscles contraction phases

The following phases of muscle activity are shown in Fig. 12:

1. Inactivity phase - the muscle has no activity and is able to relax;
2. Loading phase - muscle develop the work to defeat the weight. In this phase the muscle performs isotonic-concentric contraction;
3. Maintenance phase – the muscle develop the necessary work to maintain the weight position. In this phase the muscle performs isometric contraction;
4. Primary discharge phase – the muscle performs isotonic eccentric contraction;
5. Motion stabilization phase - in this phase the muscle develops supplementary effort to provide precision to motion. Although this phase has a constant stage, however, due to the elastic properties of muscle and tendons, no mechanical shocks arise. The muscle activity presents is isometric but, slightly visible, due to muscle elasticity;
6. Secondary discharge phase - muscle contraction is isotonic, eccentric;
7. Phase of inactivity - muscles relax after exercise.

6. CONCLUSIONS

The EMG analysis can provide a tool for estimating muscle activity and by combination with a muscle model, such as Hill's model [Lloyd G.D. et al. 2003], the force developed by the muscle can be much better estimated and the stages of muscular activity are highlighted. A problem that still remains unsolved is related to the choice of those voluntary motions which allow the isolation of a certain muscle of the upper limb. A qualitative comparison of muscle activity between the solutions offered by the Hill and the EMG models can be a starting point for further analysis related to the forces developed by muscles and muscle action phases.

REFERENCES

1. Szilágyi Tibor, Habor Adriana, Orbán-Kis Károly, (2008), *Fiziologie umană: îndreptar de lucrări practice*, University Press Târgu Mureş.
2. Nemeş D., Gogulescu A., (2006), *Kinesiologie funcţională*, Universitatea de Medicină şi Farmacie „Victor Babeş", Timişoara.
3. Nenciu G., (2005), *Biomecanica în educaţie fizică şi sport. Aspecte generale*, Bucureşti: Editura Fundaţiei România de Mâine, ISBN 973-725-369-8.
4. Todea S.F., Sabău E.,(2006), *Note de curs, Seria Educaţie Fizică, Sport şi Kinetoterapie, anul III*, Analele Universităţii Spiru Haret, Editura Fundaţiei România de Mâine, Bucureşti.
Postolache N., Cojocaru A., Ioniţă M., (2007), *Note de curs*, Seria Educaţie Fizică, Sport şi Kinetoterapie, anul IV, Analele Universităţii Spiru Haret, Editura Fundaţiei România de Mâine, Bucureşti.
6. Lloyd G.D., Besier F.T., (2003*), An EMG-driven mussculoskeletal model to estimate muscle forces and knee joint moments in vivo*, J. Biomechanics 36: 765-776.