Myolectric Response of the Upper Limbs to Temperature Variation

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***Abstract*—This article presents preliminary results of the effect of temperature variation in the environment on the human body at the myoelectric level, in order to be able to characterize it. The application of the results of this research aims to contribute in the future to the improvement of the prosthesis and therefore to the lifestyle of its users. The procedure used in the investigation required a temperature-controlled chamber, in which the right arm of the patient, who is exposed to these changes, is introduced. The information of the electromyographic signals (EMG) of the forearm was collected, as well as the temperatures of the body, T_b, chamber, T_c and environment T_a, for further analysis. The experiment was performed with ten patients who do not use any type of prosthesis. For the data adquisition, specialized electronic interfaces from several manufacturers and MATLAB & Simulink support software were used. The response of the EMG signal is shown in four different scenarios of the temperature variable: low steady state, increasing, high steady state and decreasing, effectively demonstrating changes of the EMG signal due to temperature variations.**

***Index Terms*—myoelectric, EMG signal, temperature characterization.**

I. Introduction

NOWADAYS, the science is incurring in the prosthesis field for lower and upper extremities for different purposes that can be the handicapped or elder people.

This research pursues the ability to recognize the temperature changing in a healthy person, felt in hands, and how they affect the myoelectric signals. The relation between this two variables will be corroborated in the ongoing project.

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In order to develop this kind of technology, its necessary to take data from a group of random people; by measuring the neuromuscular activities in their bodies, more specifically in their hands when they are being submitted to different temperature changes, above $30°C$. This information will be analyzed to characterize and model the effect of the temperature.

Even though computer methods are not too advantageous in case of a daily, portable device; it will be used to identify a pattern in order to develop an automated system that will be capable of working by itself without needing a computer system.

This innovated system will later be embedded in an upper extremity prosthesis to improve the ones that are currently available and therefore the lifestyle of the users, offering assurance and confidence.

A. General Objective

To model the incidence of the temperature in myoelectric levels of the human body by using surface electrodes, electronic devices and software that allows to characterize this effect.

B. Specific Objectives

To acquire and process the data of the effects of temperature in the human body.

To relate the variables, temperature and amplitude of myoelectric signals for applications in upper limb prosthesis.

To develop a system that will be capable of the transmission of impulses that simulate the real response of temperature changes in the hands and arms.

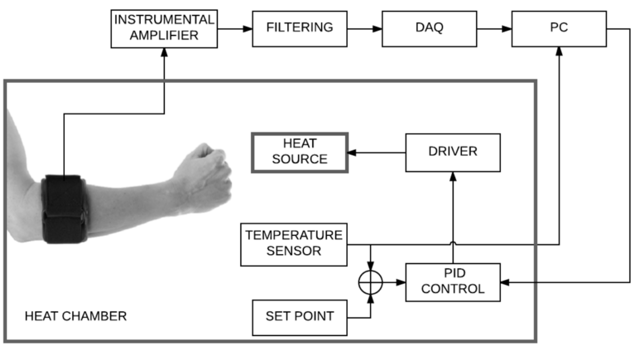

Fig. 1: Block Diagram of the Experiment

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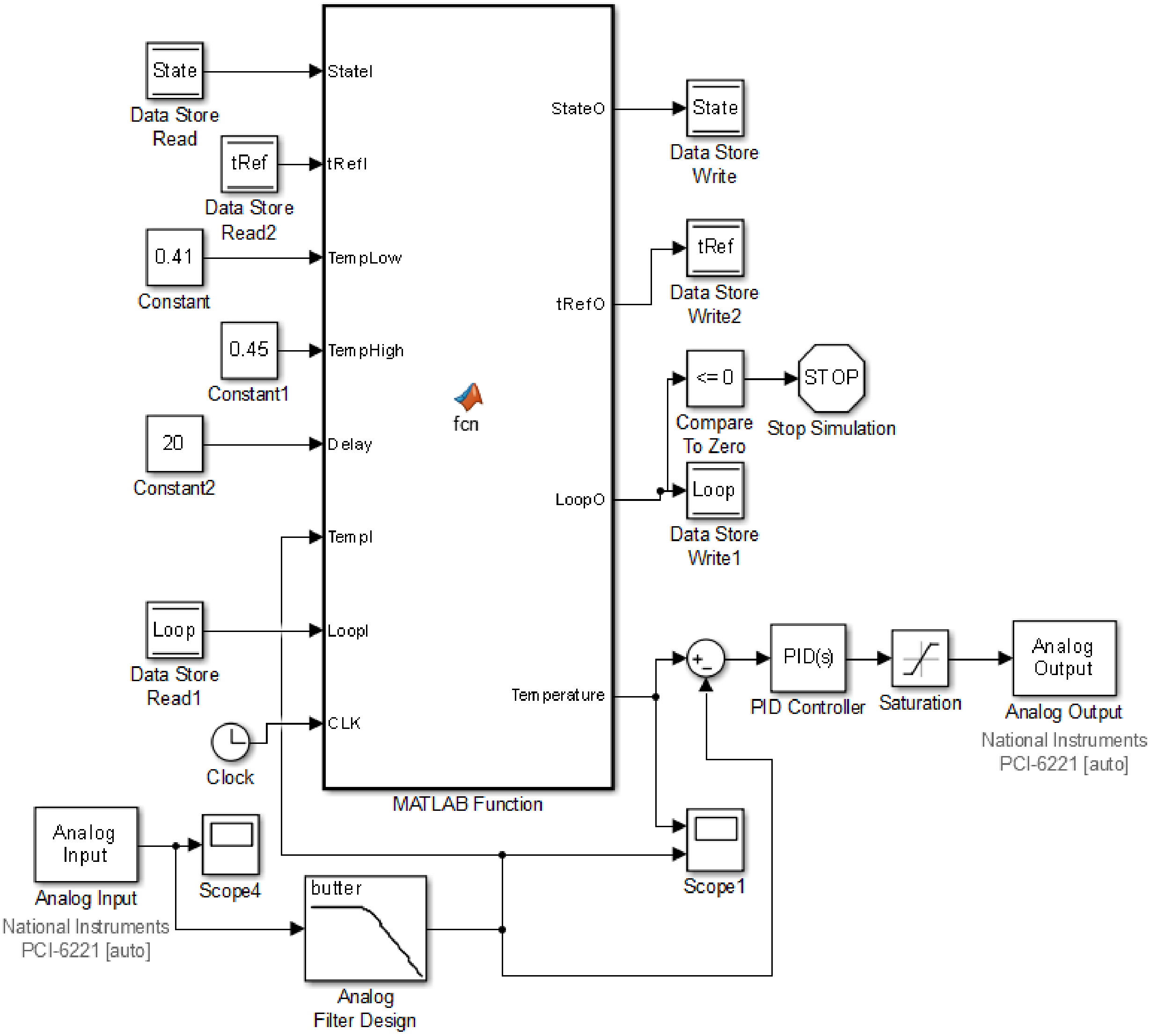

Fig. 2: Simulink Control Software

II. Method

The right hand of a healthy person is subjected to controlled temperature changes. PID controlled heat chamber was built in order to perform the experimentation[1]. This chamber has four 100 Watt lamps as heat source. Hardware is interfaced with MATLAB and Simulink to collect, with a sampling rate of 1024 Hz, Electromyography EMG data; chamber, room and body temperature. A general description of the experiment is shown on Fig. 1.

A. Hardware

Olimex SHIELD-EKG-EMG was used in order to sample EMG information[2]. This board includes an Instrumentation Amplifier (INA321EA), Operational Amplifier with regulated gain and Third Order "Besselworth" filter. Finally the total gain of the board is $G_{total} = 2848$.

Room temperature T_a, temperature-controlled chamber T_c and body temperature T_b is also collected by three different LM35 sensors. Body temperature sensor is placed on the upper arm, by the biceps muscle.

NI PCI-6221 Data Adquisition is used to interface all sensors to the computer, all by analog channels.

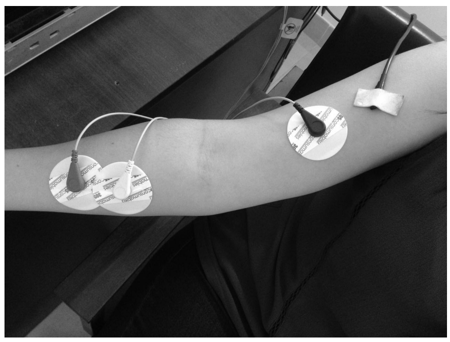

Fig. 3: Electrodes Possitioning. From left to right: CHin+, CHin-, Reference and LM35 for body temperature

B. EMG Specifications

EMG signal was collected through non-invasive surface pre-gelled disposable electrodes, sEMG. These were placed on the right hand; differential voltage electrodes at the flexor pronator muscle group[3] and reference electrode on the biceps, as shown in Fig. 3. Previous work by authors show that these muscles, related to middle and ring finger, show more signal variation when temperature change is sensed.

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Tested subjects were in a relaxed position to avoid artifacts and muscle temperature increasing due to its contraction [4][5].

C. Focus Group

A group of ten healthy people, five men and five women, were randomly selected to be the test subjects of this experiment. All of them are students from Escuela Superior Politécnica del Litoral. Relevant characteristics of them are shown on Table I.

TABLE I: Characteristics of Test Subjects

	Gender	Height[cm]	Weight[lbs]	Age[$years$]
Subject 1	male	158	186	25
Subject 2	female	160	186	25
Subject 3	male	167	139	24
Subject 4	male	153	112	24
Subject 5	male	179	206	23
Subject 6	female	165	175	25
Subject 7	female	169	146	24
Subject 8	male	170	187	26
Subject 9	female	161	150	22
Subject 10	female	165	196	24

Three different experiments were made, each has at least ten iterations. Not all experiments were done to all test subjects. The tests consisted in subjecting the patient's hand to three cycles of temperature changing. Each step occurs after previous temperature is in steady state T_{ss} for $20s$. Each experiment is specified on Table II.

TABLE II: Experiment Specifications

Test #	Initial Temperature [°C]	Final Temperature [°C]	Time in Steady State [s]
1	30	35	20
2	35	40	20
3	40	45	20

D. Software

The main program was developed in Simulink (see Fig. 2). A Matlab function controls that the T_{ss} is constant for each step, so the temperature set point for the PID is changed automatically, as explained on Table II.

Inputs and Outputs signals are interfaced to the DAQ through Simulink Desktop Real-Time Library.

Digital signal processing is done after all data is captured.

III. Results

With hardware described on section II, chamber temperature and raw EMG response to variation of temperature is shown on Fig. 4, Fig. 5 and Fig. 6 for Test # 1, # 2 and # 3 respectively.

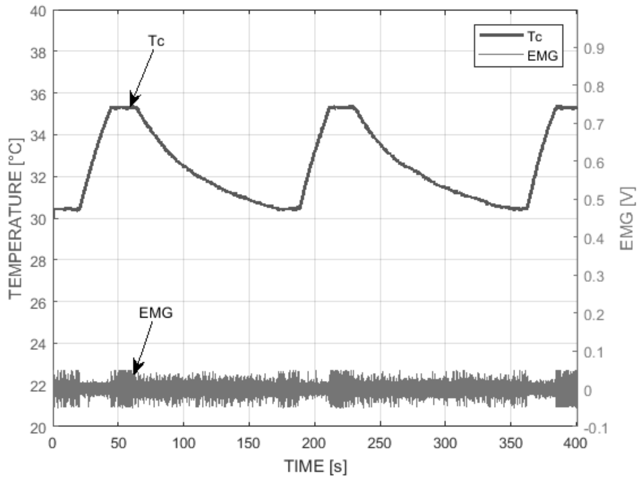

Fig. 4: EMG Response fro Subject # 1 for Test # 1

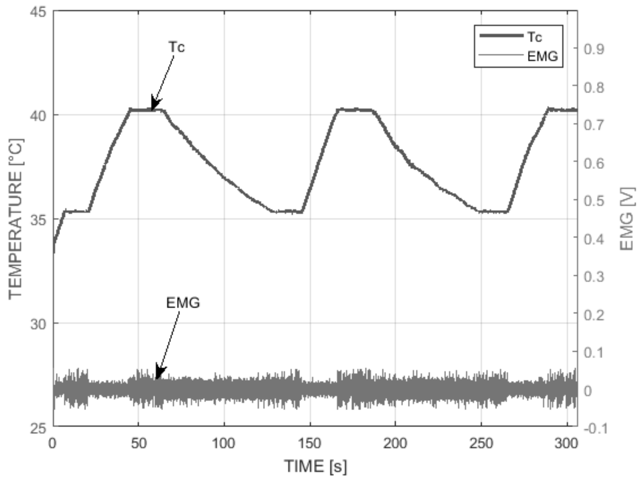

Fig. 5: EMG Response from Subject # 6 for Test # 2

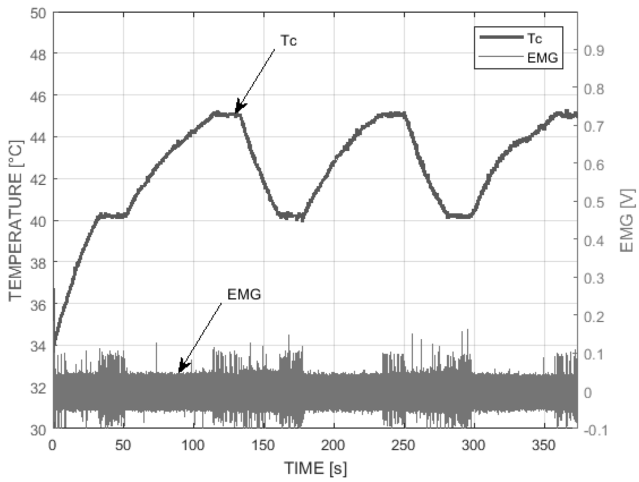

Fig. 6: EMG Response from Subject # 4 for Test # 3

Chowdhury et al [6] recommends the following filters to be implemented to get a cleanner EMG signal:

a. Direct Current, DC, filter.
b. Electromagnetic Interference at $60Hz$ and $120Hz$
c. Trends supressing.
d. Artifact movement noise supressing.

A good predictor is the analaysis of the Root Mean Square[7], RMS, of the signal. RMS is obtained using equation (1) to the filtered EMG signal.

$$RMS = \sqrt{\frac{1}{N}\sum_{n=1}^{N} x_n^2} \quad (1)$$

N: total number of samples.

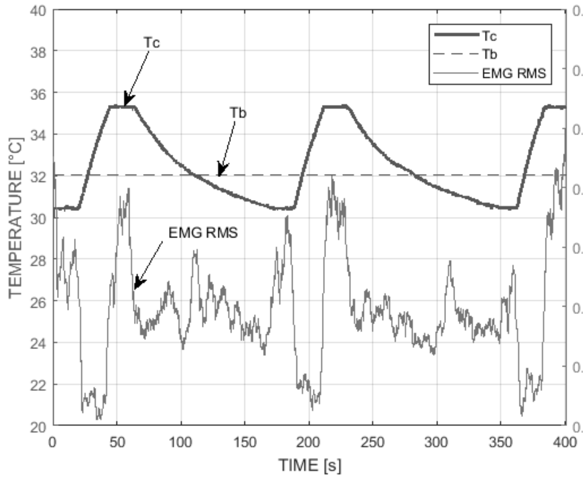

Fig. 7: EMG RMS from Subject # 1 for Test # 1

After applying (1) to filtered EMG from Test # 1, five different signals can be distinguished from Fig. 7 (Section 1 to Section 5). This behaviour is repeated in the other two temperature cycles of the experiment.

Section 1: From $0s$ to $20s$
Section 2: From $20s$ to $44s$
Section 3: From $44s$ to $64s$
Section 4: From $64s$ to $110s$
Section 5: From $110s$ to $167s$
Section 6: From $167s$ to $187s$
Section 7: From $187s$ to $210s$
Section 8: From $210s$ to $230s$
Section 9: From $230s$ to $283s$
Section 10: From $283s$ to $341s$
Section 11: From $341s$ to $361s$
Section 12: From $361s$ to $381s$
Section 13: From $381s$ to $401s$

Graphically, it can be noticed that the EMG RMS signal is also cyclic, so Sections with similar behavior are:

Section 1 $\approx$ Section 6 $\approx$ Section 11
Section 2 $\approx$ Section 7 $\approx$ Section 12
Section 3 $\approx$ Section 8 $\approx$ Section 13
Section 4 $\approx$ Section 9
Section 5 $\approx$ Section 10

For this subject, $T_b < T_f$, (T_f: final temperature, see Table II). When $T_c < T_b$ in the falling region, EMG RMS changes its behaviour, as seen in the transition from Section 4 to 5 and Section 9 to 10. This event occurs in all patients in whom $T_b < T_f$. In the same way, the signal presents changes in the other two experiments. Results for Tests # 2 and # 3 are shown of Fig. 8 and Fig. 9 respectively.

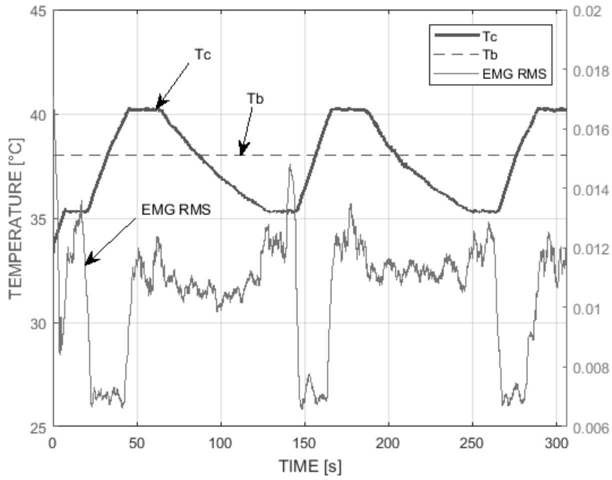

Fig. 8: EMG RMS from Subject # 6 for Test # 2

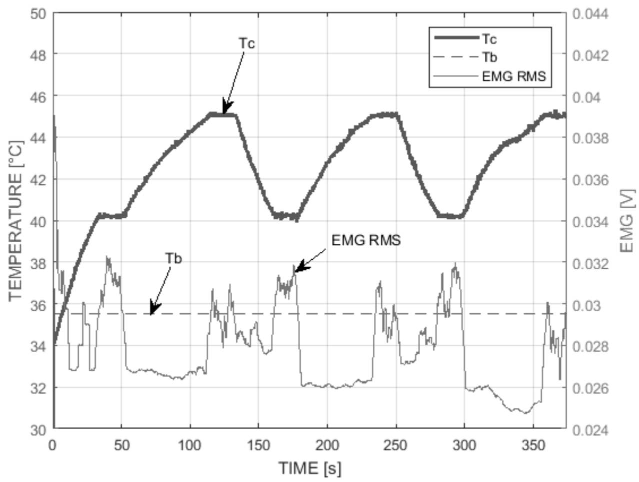

Fig. 9: EMG RMS from Subject # 4 for Test # 3

IV. Conclusion

In order to know if EMG RMS values are similar for subjects in the same Test, descriptive statistics analysis is done, this includes Mean Absolute Value (μ) and Standard Deviation (σ) of EMG RMS signal as shown on (2) and (3).

$$\mu = \frac{1}{N}\sum_{n=1}^{N} |x_n| \quad (2)$$

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N} x_n^2} \quad (3)$$

For Subject 1, mean and standard deviation is shown on Table III. It can be seen that EMG RMS and temperature are related for a single subject. Statistical information is shown for T_{ss} in the first and third column, and for the increasing and decreasing transient in the second and fourth column.

On the other hand, doing the same analysis for all subjects, standard deviation, in most of the cases, increases. This could be caused by biological variations between test subjects such as sex, corporal mass index, even skin conductance wich is related with emotional arousal [8]. Results are shown on Table IV.

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TABLE III: Statistical Results - Subject 1

EMG[mV]					
Test # 1		@ 30°C	↑ Temp.	@ 35°C	↓ Temp.
	μ	11.7119	7.2971	14.0512	10.0485
	σ	0.5308	0.1442	0.2359	0.0160
Test # 2		@ 35°C	↑ Temp.	@ 40°C	↓ Temp.
	μ	17.0819	7.9639	16.3419	16.9213
	σ	1.7149	0.3531	0.9499	1.1751
Test # 3		@ 40°C	↑ Temp.	@ 45°C	↓ Temp.
	μ	27.8484	8.5429	28.6280	29.6015
	σ	3.3224	0.3548	3.7265	2.9301

The data collected show that there is indeed a relationship between temperature and myoelectric response. It is observed that, as the temperature increases, the myoelectric activity vary for constant temperature states. More information is required to establish what kind of variation is caused on the EMG activity, increased or decreased, and how much it varies for different temperature steps.

TABLE IV: Statistical Results -All Subjects

EMG[mV]					
Test # 1		@ 30°C	↑ Temp.	@ 35°C	↓ Temp.
	μ	13.7427	6.8519	17.3687	10.4519
	σ	2.1477	0.3181	0.5508	0.2038
Test # 2		@ 35°C	↑ Temp.	@ 40°C	↓ Temp.
	μ	32.4380	9.8597	32.9230	24.5571
	σ	1.2011	0.6362	1.2915	0.1378
Test # 3		@ 40°C	↑ Temp.	@ 45°C	↓ Temp.
	μ	27.6538	12.0587	26.1984	26.3259
	σ	2.1118	0.3822	2.3127	1.4378

V. Further Work

Collect data from more people with different physical characteristics and ages.

Improve the isolation of the heat camera and its control circuit in order to eliminate any kind of noise produced by the startup of the heating lights.

Prepare the patients to have them in the same conditions such as physicals and emotional.

Submit the people into same intermediate stages, in that way the results wont be affected by the human body adaptation.

Measure skin conductance or galvanic skin response in order to infer caulitative characteristics of the subject.

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