ANALYSIS OF ELECTROMIOGRAPHIC SIGNALS FROM THE FLEX-EXTENSION MOVEMENT OF THE KNEE

Edwin Guerrero, Iván Iglesias

Carrera de Ingeniería en Mecatrónica, FICA, Universidad Técnica del Norte, Av. 17 de Julio, Ibarra, Ecuador

egguerrero@utn.edu.ec, iiglesias@utn.edu.ec

Abstract. *This paper shows the development of analysis of electromyographic signals (EMG) from thigh muscles. It aims to characterize, through software, EMG signals in the time domain, focused on devices for the help of people with physical disabilities, helping the process of training orthoses or myoelectric prostheses.*

Currently commercial orthoses or prostheses that have greater control compared to conventional devices, which can execute more precise movements, but, disabled people have more access to common prostheses because they are not as costly as high technology ones. For this reason, this investigation tries to generate technology in our own environment and not depend on the foreigner, and so, to be able to adapt the devices of assistance to the needs of the population with prices that can be accessible, mainly focused to Zone 1, Where in Imbabura we can find 4826 people with physical disabilities.

As result of the investigation, a graphical user interface was obtained able to obtain characteristics of the EMG signal in the time domain given a region of interest that will help the process of training and control of a prosthesis driven by EMG signals generated by the muscles of the thigh.

Keywords

Characteristics, time domain electromyography, graphic interface, muscles, prosthesis, software,

1. INTRODUCTION

Inside of the field of medicine, can found biological signals produced by the muscles of the body, such as the electromyographic (EMG) signal, which is oriented to the diagnosis of neuromuscular diseases as well as muscular treatments. The EMG signal can obtained from voluntary movements or contractions making possible its implementation in intelligent prostheses, contributing to improve the quality of life of people who have suffered partial or total loss of limb. With proper control and training, myoelectric prostheses can replace the lost limbs totally or partially, creating an artificial limb as if it were a real one.

This paper presents a way to characterize, in the time domain, the electromyographic signals of the thigh muscles involved in the flex-extension movement of the knee. Using a graphical user interface capable of monitoring and analyzing these signals, where, preliminary tests performed on healthy people, both men and women of different ages.

ELECTROMIOGRAPHY

Electromyography is a record of muscular electrical activity, and therefore constitutes an extension of the physical examination and a test in the integrity of the motor system, a representation of this electrical activity can observed in Figure 1.1. It can said that surface electromyography (EMGS), sometimes-called kinesiological electromyography, is the electromyographic analysis that allows collecting the electrical signal of a muscle in a moving body. The main purpose of this type of measurement is to know the activity of one or several muscles in a concrete action [1].

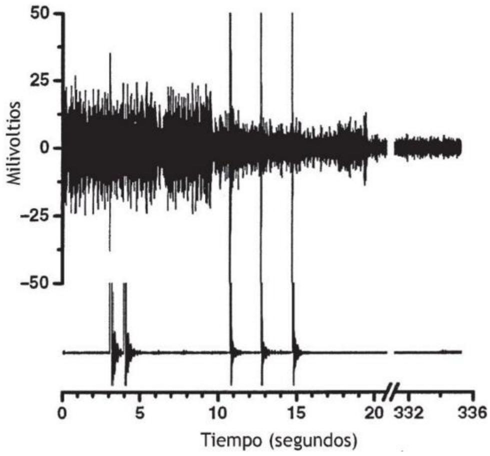

Figure 1.1 Muscular activity for spontaneous spinal cord in the lower lumbar vertebrae [2].

Characteristics of the EMG signal

Between the important aspects of the EMG signal, it can mentioned that it has a random amplitude in nature and can reasonably represented by a Gaussian distribution function.

This amplitude may range from 0 to 10 [mV] (peak to peak) or from 0 to 1.5 [mV] (rms), the usable power of the signal being limited to the frequency range 0 to 500 [Hz] [3].

From the most relevant information of the EMG signals is in an oscillating frequency between 50 and 150 Hz, it follows that the appropriate sampling frequency must not be less than 300 Hz [4].

2. METHODOLOGY

2.1 EMG SIGNALS CONDITIONING CARD

The following steps used from the EMG signal conditioning card:

- Pre-amplification stage.
- Butterworth band pass filter of fourth order from 20 to 500 [Hz].
- Notch filter of 60 [Hz] with bandwidth of 2 [Hz].
- Final amplification stage.

3. DEVELOPMENT OF THE USER'S GRAPHIC INTERFACE

3.1 FLOWCHART

Figure 3.1 shows the graphical user interface flowchart developed on the LabVIEW platform in its 2014 version.

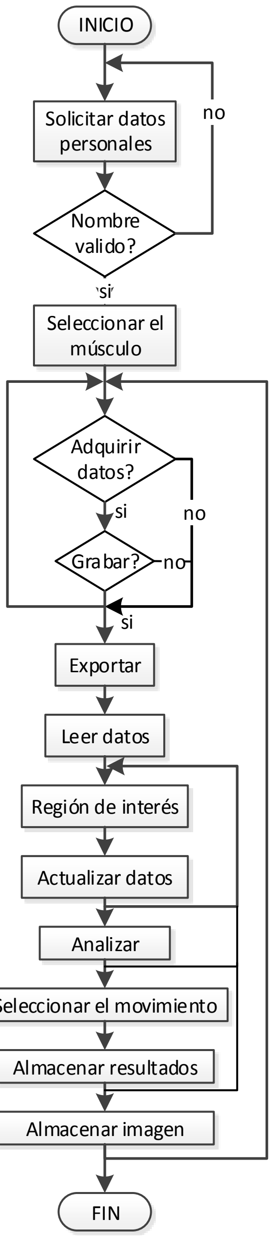

Figure 3.1 Graphical interface flowchart.

3.2 INITIAL STAGE

In the stage the VI Express used is File Dialog (see figure 3.2), which specifies the default name of the file, as well as its extension, in this case it will have an .xls extension (Excel workbook).

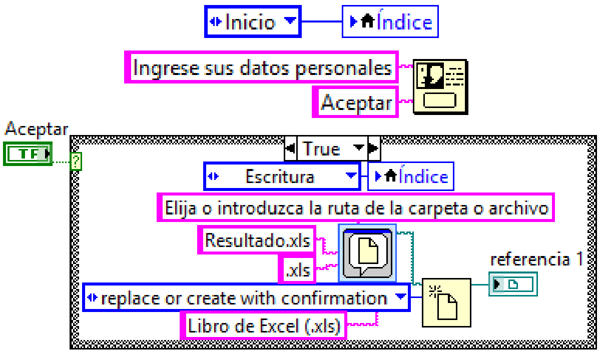

Figure 3.2 Start.

3.3 STAGE OF DATA ACQUISITION

At this stage, a DAQ Assistant (see figure 3.3) used to acquire the EMG signal from the output of the final amplification stage of the EMG signal conditioning card developed at the Universidad Técnica del Norte “UTN”.

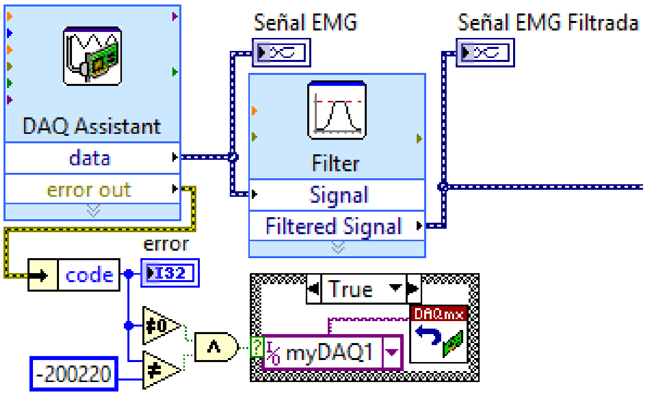

Figure 3.3 Data Acquisition.

3.4 SIGNAL SAMPLING

The most important thing to be able to make a good signal treatment is to ensure at each step that the original information has not altered. The Nyquist theorem, considered the most important in signal acquisition, establishes a necessary and sufficient condition for the reconstruction in the temporal domain of an acquired signal. The sampling frequency must be at least 2 times higher than the highest frequency of the signal you want to reconstruct [5].

Nyquist-Shannon Theorem.

The Nyquist-Shannon theorem states that, for a band-limited signal, the sampling frequency (F_{MS}) must be greater than twice the maximum signal frequency (F_{MAXS}) so that it can be rebuilt without errors. In this way [6]:

$$F_{MS} > 2.F_{MAXS}$$

Equation 3.1 Nyquist Theorem.

According to the Nyquist-Shannon theorem, the sampling frequency for each of the biological signals can see in the following table 3.1 [6].

Tipo de señal	Frecuencia Máxima (Hz)	Frecuencia de muestreo mínima (Hz)
ECG (electrocardiograma)	250	500
EMG (electromiograma)	500	1000
EEG (electroencefalograma)	150	300
EGG (electrogastrograma)	1	2
EOG (electrooculograma)	50	100
ERG (electroretinograma)	50	100

Table 3.1 Summary with sampling frequencies signals.

According to Table 3.1, the minimum sampling frequency must be 1000 [Hz]. Therefore, an over-sampling of 2000 [Hz] (see figure 3.4) was used in the configuration of the DAQ Assistant (see figure 3.3) so that there is no loss of information.

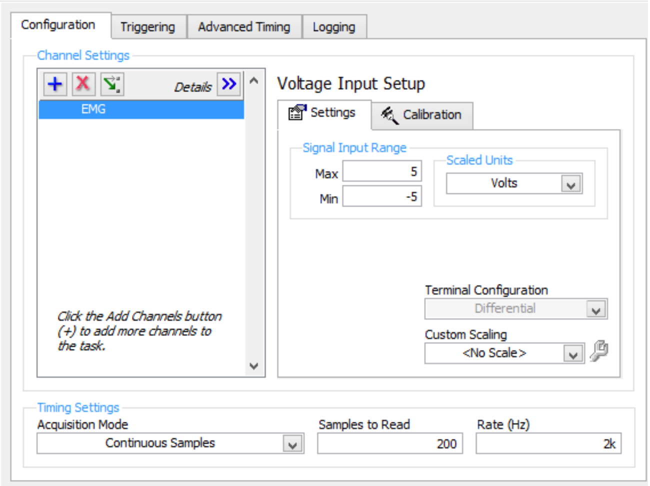

Figure 3.4 DAQ Assistant Configuration.

3.5 EMG SIGNAL STORAGE STAGE

For the storage stage of the EMG signal, two case structures used: recording and exporting. In the recording case structure, (see Figure 3.5) a waveform chart created to display the signal from the output of the digital filter. In addition, a double waveform chart created, which will store the data as if it were a buffer. Store a maximum value of 30000 data. (This value can modified).

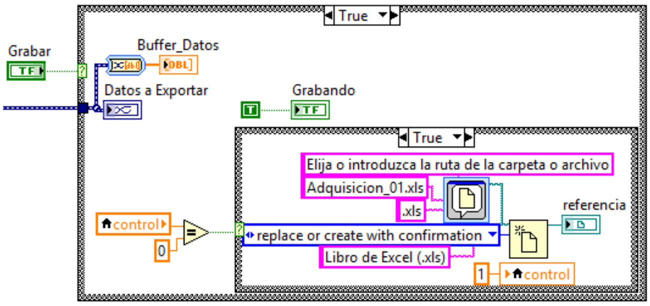

Figure 3.5 Record case structure.

In the export case structure (see figure 3.6), the property invoke method of the waveform chart named *Buffer_Datos* of the record case was created, in order to export the data to the clipboard so that it can stored in the file previously created in the record case structure.

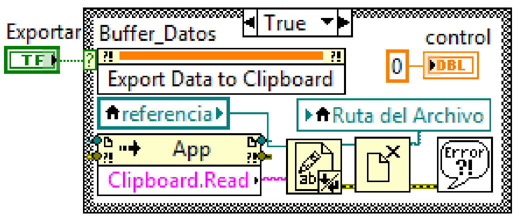

Figure 3.6 Export case structure.

3.6 SIGNAL READING STAGE EMG

At this stage, the data previously stored in an Excel file is read. It specifies that the file to read be in Excel format, besides indicating the path of the file (see figure 3.7). It mentions the Excel sheet where the data to be exported is found (in the case it is sheet 0).

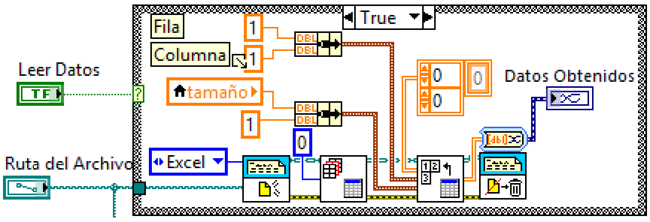

Figure 3.7 Export case structure.

3.7 DATA UPDATE STAGE

In order to extract only a part of the signal to analyze, a new reading of the file containing the data made, indicating the new beginning and end of the reading. The property node tool used to create start & end cursors and thus restrict the range to be read (see figure 3.8).

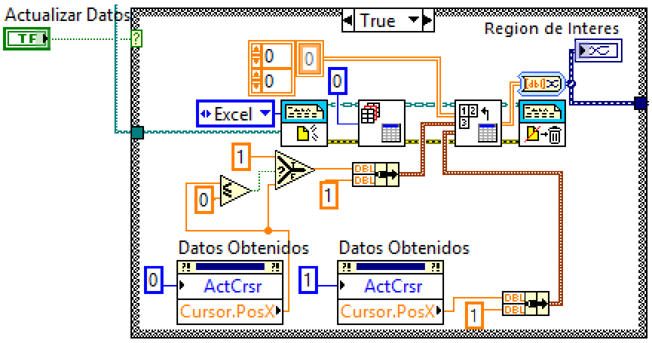

Figure 3.8 Updated reading of the EMG signal.

3.8 SIGNAL ANALYSIS STAGE EMG

Once the updated data extracted, a wave generated with the data, and then the following blocks used to obtain the characteristics required for the analysis. In obtaining characteristics of the EMG signal, the case structure shown in Figure 3.9 used.

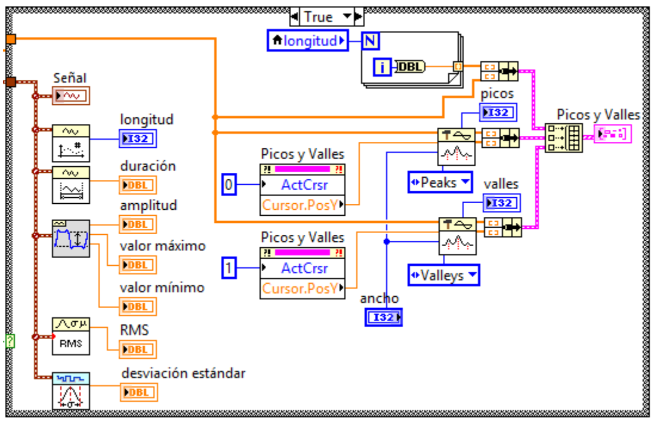

Figure 3.9 Analysis of the EMG signal.

3.9 RESULTS STORAGE STAGE

The file created in the initial stage used to store the personal data and the results obtained from the analysis. The patient's personal data are stored, in addition to the results obtained from the analysis performed on the EMG signal in text format (see figure 3.10) in the previously created file.

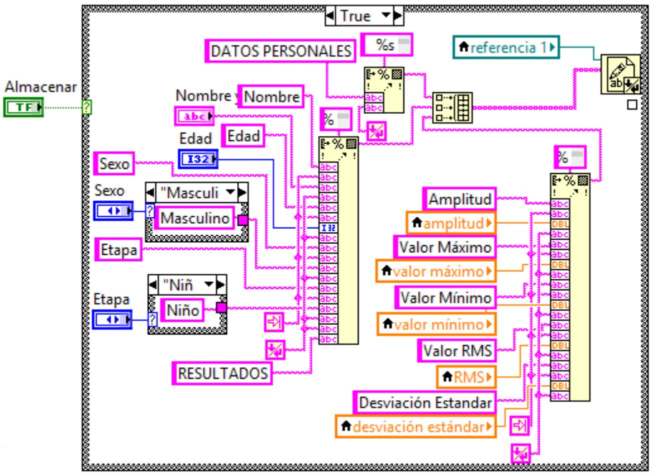

Figure 3.10 Analysis of the EMG signal.

4. RESULTS OBTAINED.

The results obtained according to the ages of the male patients are below.

4.1 AMPLITUD

Figure 4.1 shows the amplitude values of the patients, obtained from the EMG signal of the study muscles, effecting the gait movement, where it can see that the muscle that generates the maximum amplitude value is the vast mean of A 10 year old boy.

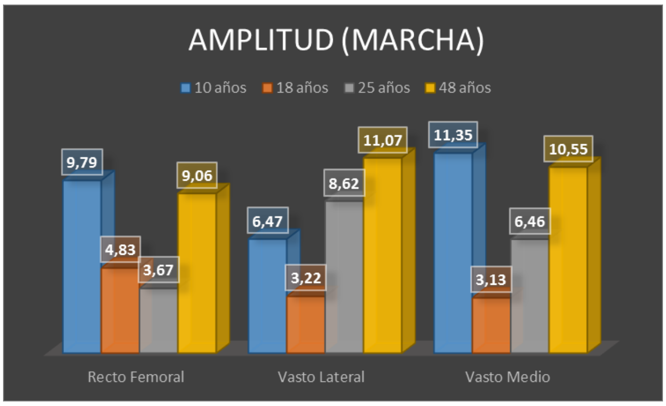

Figure 4.1 Amplitude of the EMG signal making the walk motion.

Figure 4.2 shows the amplitude values of the patients, obtained from the EMG signal of the study muscles, making the movement of getting up from a chair, where it can see that the muscle that generates the maximum amplitude value is the vast lateral of an adult of 48 years.

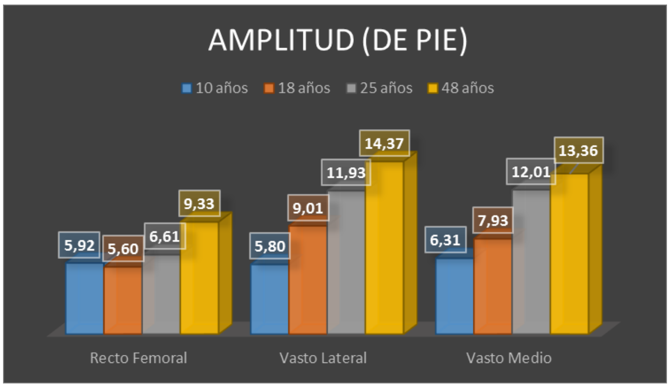

Figure 4.2 Amplitude of the EMG signal performing the movement of getting up from a chair.

Figure 4.3 shows the amplitude values of the patients, obtained from the EMG signal of the study muscles, making the movement of sitting in a chair, where it can see that the muscle that generates the maximum amplitude value is the vast lateral of an adult of 48 years.

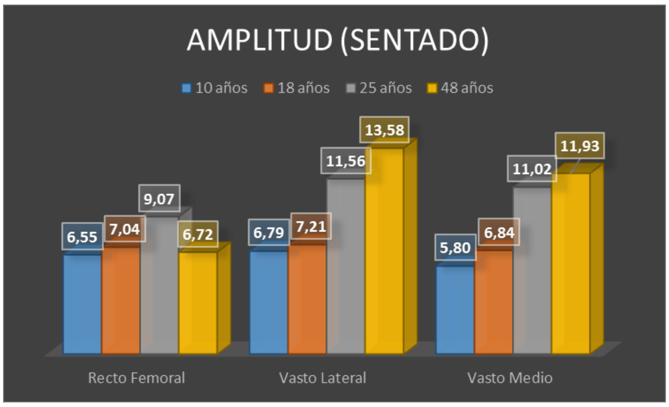

Figure 4.3 Amplitude of the EMG signal making the movement of sitting in a chair.

4.2 MAXIMUM VALUE

Figure 4.4 shows the maximum values of the patients, obtained from the EMG signal of the study muscles, effecting the walking movement, where it can see that the muscle that generates the maximum value of the signal is the vast mean of A 10 year old boy.

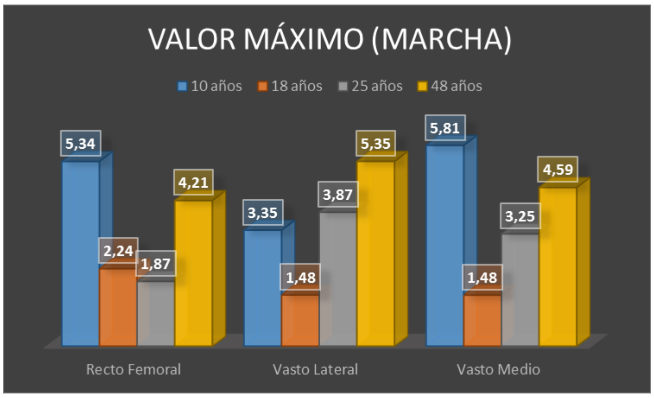

Figure 4.4 Maximum value of the EMG signal making the movement.

Figure 4.5 shows the maximum values of the patients, obtained from the EMG signal of the study muscles, making the movement of getting up from a chair, where it can see that the muscle that generates the maximum value of the signal is the vast lateral of an adult of 48 years.

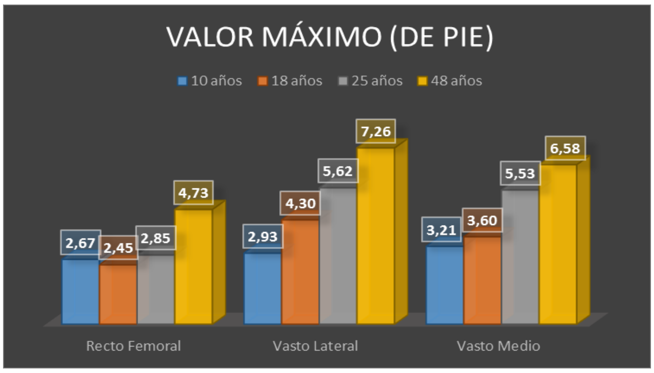

Figure 4.5 Maximum value of the EMG signal performing the movement of getting up from a chair.

Figure 4.6 shows the maximum values of the patients, obtained from the EMG signal of the study muscles, making the movement of sitting in a chair, where it can see that the muscle that generates the maximum value of the signal is the vast lateral of an adult of 48 years.

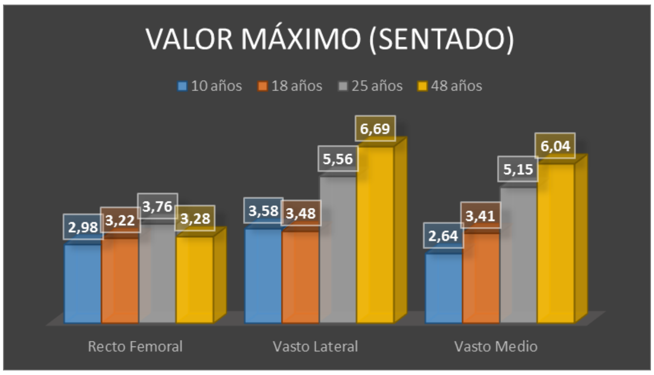

Figure 4.6 Maximum value of the EMG signal making the movement of sitting in a chair.

4.3 MINIMUM VALUE

Figure 4.7 shows the minimum values of the patients, obtained from the EMG signal of the study muscles, effecting the walking movement, where it can see that the muscle that generates the minimum value of the signal is the vast mean of an adult of 48 years.

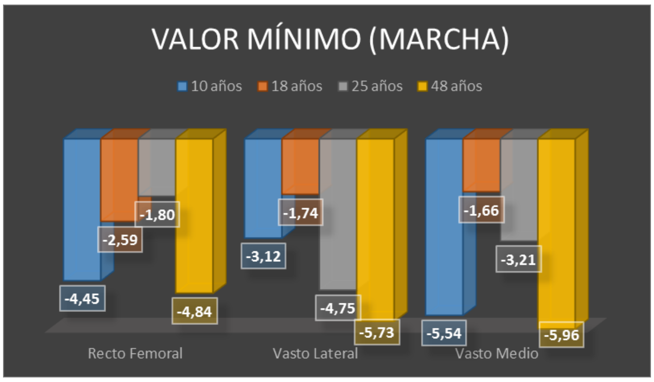

Figure 4.7 Minimum value of the EMG signal making the walking movement.

Figure 4.8 shows the minimum values of the patients, obtained from the EMG signal of the study muscles, making the movement of getting up from a chair, where, it can see that the muscle that generates the minimum value of the signal is the vast lateral of an adult of 48 years.

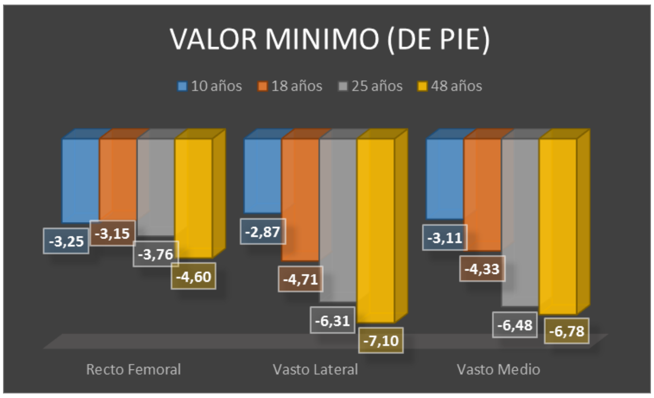

Figure 4.8 Minimum value of the EMG signal performing the movement of getting up from a chair.

Figure 4.9 shows the minimum values of the patients, obtained from the EMG signal of the study muscles, making the movement of getting up from a chair, where, it can see that the muscle that generates the minimum value of the signal is the vast lateral of an adult of 48 years.

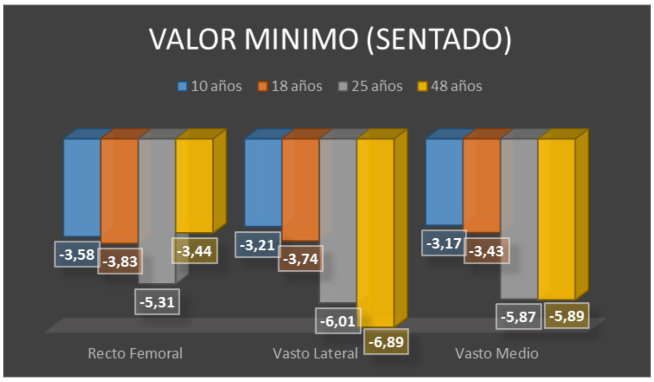

Figure 4.9 Minimum value of the EMG signal making the movement of sitting in a chair.

4.4 WAVE LENGTH

Figure 4.10 shows the wavelength values of the patients, obtained from the EMG signal of the study muscles, making the walking movement, where it can see that the muscle that generates the maximum wavelength value is the rectus femoris of A 10 year old child.

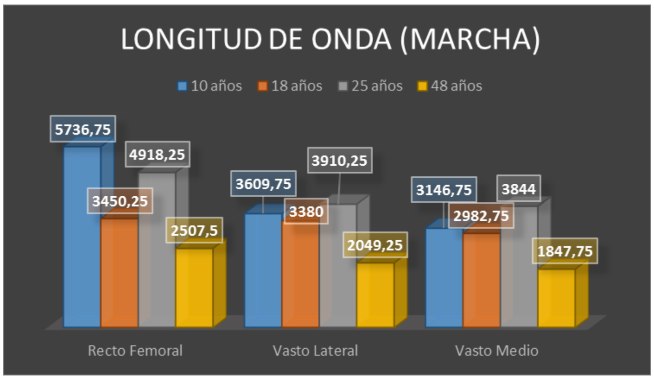

Figure 4.10 Wavelength of the EMG signal making the walking movement.

Figure 4.11 shows the wavelength values of the patients, obtained from the EMG signal of the study muscles, effecting the movement of getting up from a chair, where it can see that the muscle that generates the maximum value of length is the rectus femoris of A 10 year old boy.

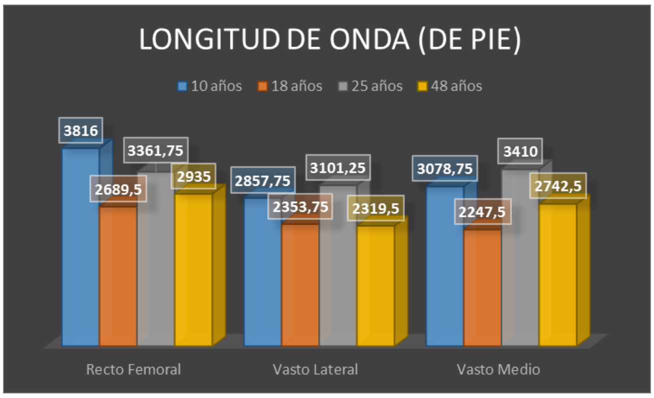

Figure 4.11 Wavelength of the EMG signal performing the movement of getting up from a chair.

Figure 4.12 shows the wavelength values of the patients, obtained from the EMG signal of the study muscles, making the movement of sitting in a chair where, it can see that the muscle that generates the maximum value of length of Wave is the rectus femoris of A 25 year old.

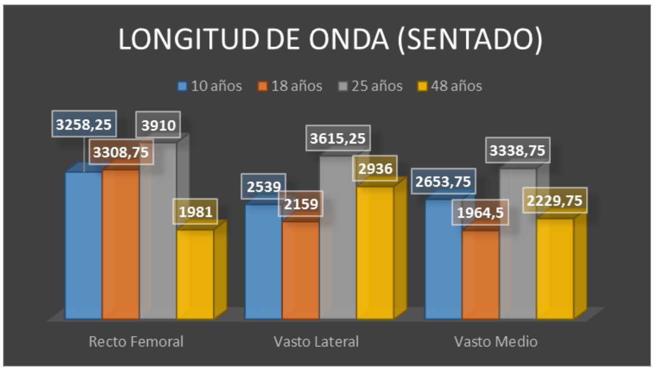

Figure 4.12 Wavelength of the EMG signal performing the movement of sitting in a chair.

4.5 RMS VALUE

Figure 4.13 shows the RMS values of the patients, obtained from the EMG signal of the study muscles, making the walking movement, where it can see that the muscle that generates the maximum RMS value is the vast medialis of A 10 year old boy.

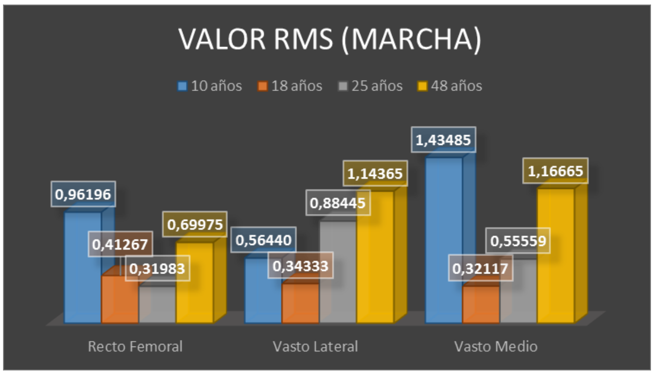

Figure 4.13 RMS value of the EMG signal making the walking movement.

Figure 4.14 shows the RMS values of the patients, obtained from the EMG signal of the study muscles, making the movement of getting up from a chair, where it can see that the muscle that generates the maximum RMS value is the vast lateral in a young person of 25 years and in an adult of 48 years old.

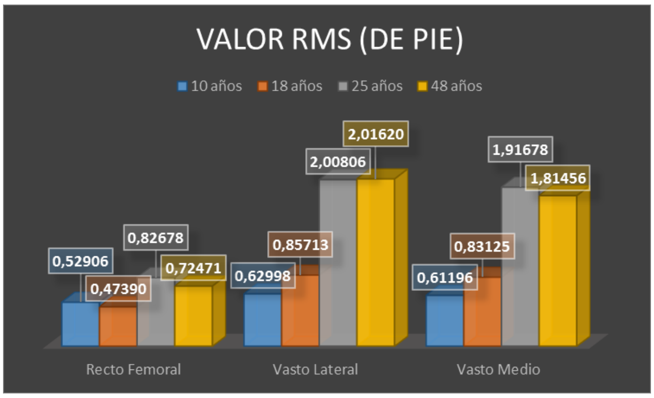

Figure 4.14 RMS value of the EMG signal performing the movement of getting up from a chair.

Figure 4.15 shows the RMS values of the patients, obtained from the EMG signal of the study muscles, making the movement of sitting in a chair, where, it can see that the muscle that generates the maximum RMS value is the vast lateral of an adult of 48 years old.

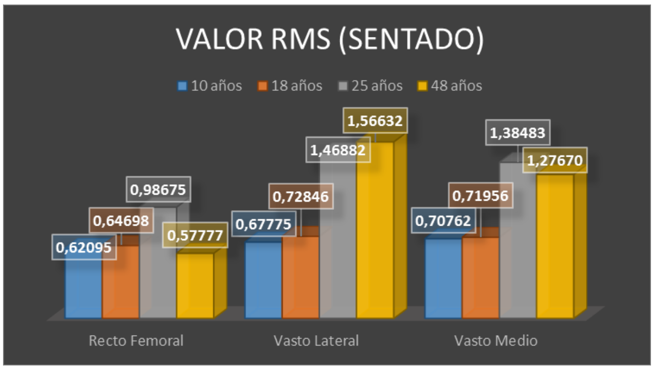

Figure 4.15 RMS value of the EMG signal making the movement of sitting in a chair.

4.6 STANDARD DEVIATION

Figure 4.16 shows the standard deviation values of the patients obtained from the EMG signal of the study muscles, performing the walking movement, where it can see that the muscle that generates the maximum value of standard deviation is the vast medialis of A 10 year old boy.

Figure 4.16 Standard deviation of the EMG signal making the walking movement.

Figure 4.17 shows the standard deviation values of the patients, obtained from the EMG signal of the study muscles, making the movement of getting up from a chair, where it can see that the muscle that generates the maximum value of standard deviation is the vast lateral of a 25 year old and a 48 year old.

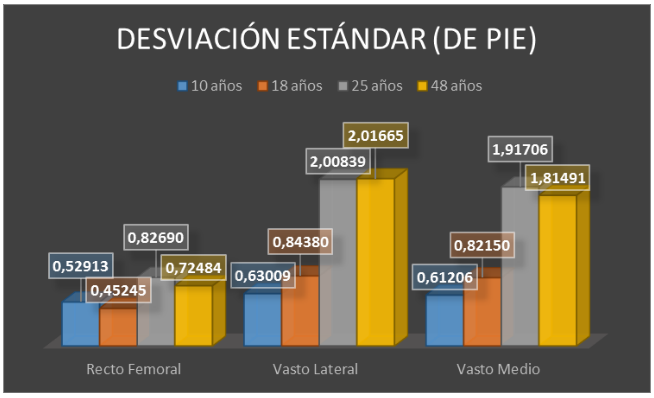

Figure 4.17 Standard deviation of the EMG signal making the movement of getting up from a chair.

Figure 4.18 shows the standard deviation values of the patients, obtained from the EMG signal of the study muscles, making the movement of sitting in a chair, where it can see that the muscle that generates the maximum value of standard deviation is the vast lateral of an adult of 48 years.

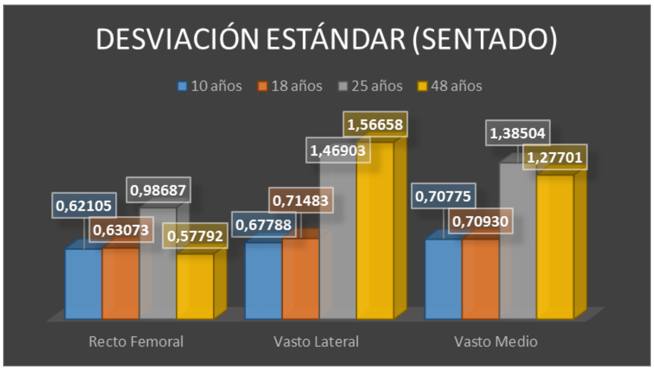

Figure 4.18 Standard deviation of the EMG signal making the movement of sitting in a chair.

5. RESULTS AND DISCUSSIONS

Initially, performance tests of the duplicate EMG signal conditioning card performed to debug errors. Once verified the correct operation of the card integrated with the data acquisition card NI MyDAQ, and through the software of LabVIEW could observe the EMG signal with its characteristics.

A graphical user interface created in the LabVIEW software that will carry out the respective analysis of the statistical parameters mentioned above.

Once corrected the errors generated by the graphical interface, preliminary tests performed with a thigh muscle performing a contraction (see figure 5.1), in this case, the rectus femoris selected.

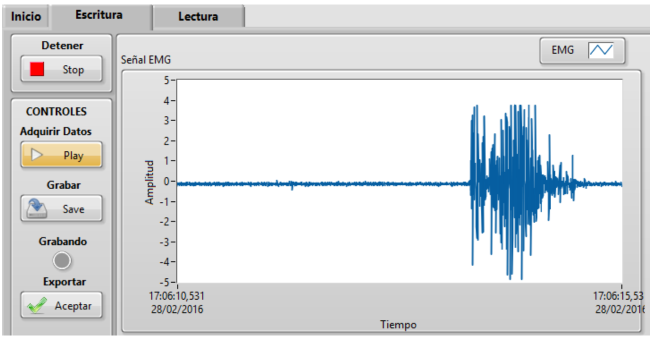

Figure 5.1 Test of contraction with the rectus femoris muscle.

Signal storage tests performed on a waveform chart that will simulate data buffering (see Figure 5.2).

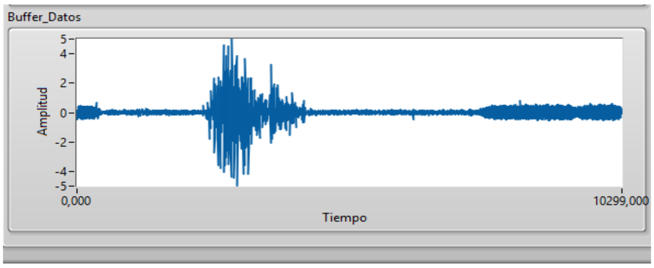

Figure 5.2 Recorded data.

Later tests performed on the restriction of the start and end of the movement in interest and processing of data (see Figure 5.3).

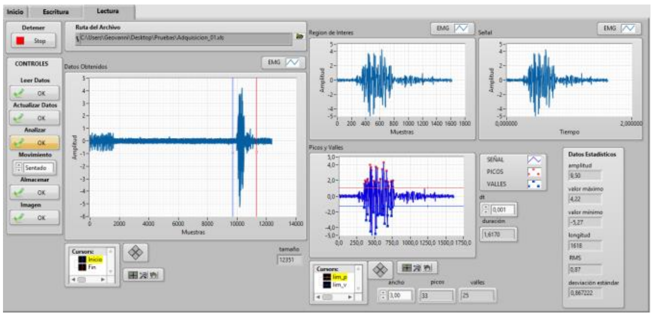

Figure 5.3 Restriction of the region of interest and statistical results.

6. CONCLUSIONS

The application allows obtaining from the quadriceps muscles, executing three types of movements, statistical data of amplitude, maximum values, minimum values, wavelength, RMS value and standard deviation of the EMG signal.

The designed graphical interface allows obtaining the characteristics of an electromyographic signal, given a previously selected region of interest.

Using the Excel functions, from the application it is possible to generate reports, as well as store the data of the acquired signal and the obtained results.

To avoid a saturation in data acquisition, we used the National Instruments recommendation to use a ratio of 1/10 between the number of samples and the sampling frequency, respectively.

During the walking movement, it was possible to see that the data of the patients of 10 and 48 years were the highest in relation to the patients of 18 and 25 years. This is because the first patients did not have previous training doing this type of movement.

When performing the movement of getting up and sitting in a chair, analyzing the vastus lateralis and vastus medialis muscle, it could evidence that there is an upward growth in the value of the statistical data, except in the results of wavelength.

7. BIBLIOGRAPHIC REFERENCES

[1] N. Massó, F. Rey, D. Romero, G. Gual, L. Costa y A. Germán, Aplicaciones de la electromiografía de superficie en el deporte, Barcelona: apunts, 2010.

[2] J. G. Pickar, Efectos neurofisiológicos de la manipulación vertebral, Iowa : The Spine Journal, 2002.

[3] G. De Luca, Fundamental Concepts in EMG Signal Acquisition, Delsys Inc., 2003.

[4] R. R. Rubio, 03 Mayo 2016. [En línea]. Available: http://www.encuentros.uma.es/encuentros53/aplicaciones.html.

[5] J. Alvarado Reyes y C. Stern Forgach, Un complemento al teorema de Nyquist, México: Universidad Nacional Autonoma de México, 2010.

[6] J. Calle Plaza, Sistema inalámbrico y multicanal para monitorización de señales biológicas en tiempo real., Madrid: Universidad Rey Juan Carlos., 2010.

[7] CONADIS, «Una mano para la inclusión,» 14 08 2015. [En línea]. Available: http://prometeo.educacionsuperior.gob.ec/una-mano-para-la-inclusion/.

[9] SENIAM, «Surface Electromyography for the Non-Invasive Assessment of Muscles,» 2015. [En línea]. Available: http://www.seniam.org/. [Último acceso: 06 Enero 2015].

[10] J. V. Basmajian y C. J. De Luca, Muscles Alive, Fifth ed., Baltimore: Williams and Wilkins, 1985.

[11] K. L. Moore, A. F. Dalley and A. Agur, Anatomía con orientación clínica, Seventh ed., China: Wolters Kluwer Health, S.A., Lippincott Williams & Wilkins, 2013.

[12] Ministerio de Salud Pública, «Consejo Nacional para la Igualdad de Discapacidades,» 2015. [En línea]. Available: http://www.consejodiscapacidades.gob.ec/wp-content/uploads/downloads/2015/04/registro_nacional_discapacidades.pdf. [Último acceso: 29 Mayo 2015].

[13] Organización Mundial de la Salud, «Informe mundial sobre la discapacidad,» 2011. [En línea]. Available: http://www.who.int/disabilities/world_report/2011/es/. [Último acceso: 10 Diciembre 2014].

[14] D. Graupe y W. K., Functional Separation of EMG Signals via ARMA Identification Methods for Prosthesis Control Purposes, IEEE Transactions on, 1975.

[15] S. FERGUSON y R. DUNLOP, Grasp Recognition From Myoelectric Signals, New Zealand, 2002.

[16] A. Chan y K. Englehart, Continuous myoelectric control for powered prostheses using hidden Markov models, IEEE Transactions on, 2005.

[17] E. J. Bronzino J., INTRODUCTION TO BIOMEDICAL ENGINEERING, Elsevier, 2012.

[18] R. Churchill, Series de Fourier y Problemas de Contorno, New York: McGraw-Hill, 1978 .

[19] M. R. Guglielminotti P, Effect of electrode location on surface myoelectric signal variables: a simulation study, Florence: 9th Int. Congress of ISEK, 1992.

[20] Y. Singh, ANALYSIS AND CLASSIFICATION OF EMG SIGNAL USING LabVIEW WITH DIFFERENT WEIGHTS, Punjab, India: Department of Electrical and Instrumentation Engineering, 2013.

[21] E. J. C. R. I. P. E. J. P. Harold A. Romo, Análisis de Señales EMG Superficiales y su , Medellin: Revista Avances en Sistemas e Informática, 2007.

[22] G. D., Theory of communication., J Inst Elect Eng, 1946.

[23] O. Tabernig, Eliminación de la respuesta muscular evocada del electromiograma de superficie de un músculo estimulado eléctricamente, Entre Ríos, Argentina: Universidad Nacional de Entre Ríos, 2004.

[24] M. A. V. Aparicio, Técnicas instrumentales de diagnóstico y evaluación en rehabilitación, Madrid: J I Ibarra Lúzar Rehabilitación, 2005.

[25] WOLFRAM, «WOLFRAM MATHEMATICA,» 15 Noviembre 20015. [En línea]. Available: http://www.wolfram.com/mathematica/new-in-8/wavelet-analysis/visualize-wavelet-transform-using-common-y-axis-pl.es.html.

[26] Á. Orozco, G. Betancourt y E. Suárez, Determinación de movimientos a partir de señales electromiográficas utilizando máquinas de soporte vectorial., Pereira, Colombia: Universidad Tecnológica de Pereira, 2004.

[27] M. Raez., M. Hussain. y F. Mohd-Yasin, Techniques of EMG signal analysis: detection, processing, classification and applications, Malaysia, 2006.

[28] F. H. Maldonado, Modelos de gestión para médicos de familia, Madrid: Ediciones Díaz de Santos, 2005.

[29] D. M. M. Reyna, ELECTROMIOGRAFIA, Guatemala: UNIVERSIDAD DE SAN CARLOS DE GUATEMALA, 2015.

[30] R. B. Navarro, ELECTROMIOGRAFÏA, Entre Ríos, Argentina: UNIVERSIDAD DE ALCALÁ, 2015.

[31] J. G. Webster, Encyclopedia of Medical Devices and Instrumentation, vol. 1, New Jersey: John Wiley & Sons, Inc., 2006.

[32] F. Cadena, «TARJETA DE ACONDICIONAMIENTO PARA PRÓTESIS DE RODILLA ACCIONADA POR SEÑALES ELECTROMIOGRÁFICAS,» Ibarra, 2015.

[33] DALCAME, «Dalcame. Grupo de Investigación Biomédica,» 16 Julio 2016. [En línea]. Available: http://www.dalcame.com/emg.html#.V4p6XUZ97IU.