Application of Surface Electromyography in the Dynamics of Human Movement

César Ferreira Amorim and Runer Augusto Marson

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/52463

1. Introduction

Surface electromyography (sEMG) is a generic term for a method of recording electrical muscle activity. Numerous applications for this method have been developed in clinical practice, such as diagnosing neuromuscular diseases, analyzing and determining abnormalities or disorders and muscular rehabilitation (biofeedback) [3, 12, 27, 28].

sEMG is mainly used in the fields of physiotherapy, dentistry, physical education and biomechanics [12].

The duration of sEMG activity corresponds to the duration of muscle activation. The amplitude is the level of signal activity and varies with the amount of electrical activity detected in the muscle; it provides information about intensity of muscle activation. The observed sEMG frequency is due to a wide range of factors: muscle composition, characteristics of the action potential of the active muscles fibers, the intramuscular coordination process and electrode properties [22, 23, 28].

sEMG signals are also affected by the anatomical and physiological properties of the muscles, neuromuscular control of the peripheral nervous system and the instrumentation used to collect the signal.

The electronic EMG device amplifies, isolates and filters the electrical signal of muscles that occurs during muscle contraction. This signal must undergo conditioning to be captured [12].

A differential amplifier is, ideally, insensitive to noise and amplifies only the EMG signal, although in practice this is not the case. This situation occurs, first of all, because the noise that reaches the electrodes (inputs) doesn't necessarily have the same magnitude. Moreover, due to technological limitations, differential amplifiers cannot perfectly separate two-signal input.

The measurement that indicates the success of this separation is the common mode rejection ratio (CMRR), which is usually expressed in decibels (dB). The CMRR value of the differential amplifiers used in sEMG is on the order of 80 to 100 dB [3, 22, 24].

The sEMG equipment should be calibrated before recording signals. Calibration is important for fidelity, accuracy and reliability when reading the signal. The amplification factor is critical during the calibration process, since it is the ratio between the input voltage and that which comes out of the amplifier. The gain is selected according to the requirements of the type of experiment, the studied muscles, the type of electrodes involved and the planned use of the amplified signal. Whereas an sEMG signal has a maximum voluntary contraction amplitude not exceeding 5 millivolts (mV) peak-to-peak, the gain should be adjusted to 500-1000x [2,3,5].

During the mathematical processing of the sEMG signal, filters can be used to remove components that don't belong to the signal or components that are irrelevant for a given analysis.

The useful information in the sEMG signal is located in a particular frequency band (20-500 Hz), and is reduced by a filtering effect from the tissue located between the muscle fibers and the active sensing surface. The filter band corresponds to the frequency between the low- and high-cut filter frequencies [28].

Time-based signal processing can be carried out using a set of processing procedures intended to characterize the signal's curve and measure signal strength during the contraction. Signal processing applications in the time domain are widely used in areas such as neuromuscular coordination, motor control, the relationship between EMG and strength and muscular coordination in the dynamics of human movement.

This chapter will report, therefore, on the importance of sEMG with respect the dynamics of human movement [27].

2. Electromyography

The hypothesis that muscles generate electricity was by Francesco Redi in 1666 due to the suspicion that the discharges of electric fish were of muscular origin.

Along with other scientific developments during the Renaissance, interest in the muscles also began to increase. Leonardo da Vinci (1452 - 1519), for example, devoted careful attention to muscles and their anatomical function by conducting dissections of cadavers [12]

The main objectives of the first scientific experiments on muscles were to understand their structure and function [12]. A number of scientists since studied muscle dynamics. Luigi Galvani presented the first study on the electrical properties of muscles and nerves in 1791. He termed this neuromuscular potential "Animal Electricity". This discovery was recognized as the starting point for neurophysiology. Thereafter, a growing number of studies have been developed in this field [11]. sEMG is a technique for recording and monitoring the electrical signals from muscle contractions. A major methodological problem for EMG is the frequent presence of artifacts or noise. Artifacts or noise are defined as information whose origin is distinct from the neuroelectrical muscle activity signal. Some examples of this include interference, heart rate, poor contact between the electrode and the skin, etc.[12].

The presence of artifacts is difficult to avoid with this type of signal acquisition, since in order to amplify the signal, which is received in microvolts (μV), unwanted signals are also amplified and can compromise interpretation of the EMG signal. Thus, the signal-to-noise ratio has been a problem, and numerous studies have been undertaken to resolve EMG signal interpretation problems. After several attempts, a solution was found in the development of the differential amplifier [3] (ACIERNO, BARATTA & SOLOMONOW, 1995).

The signal amplifier is an electronic device that filters, amplifies and records bands of signals.

The initial problem with the amplifiers was that signal acquisition was dependent on the electrical resistance of the skin. Thus, in many studies skin resistance and temperature were initially monitored when the test was performed, conditions that made it difficult or impossible to reproduce and some EMG experiments [1].

Over time, corrections have been made to this system so that the amplifiers currently have high input impedance and attenuate noise levels, which allows the reproduction of experiments without interference with the results.

A main feature of this new generation of amplifiers is that they can amplify a particular type of biological signal independent of skin resistance [28]. The evolution of cables and connectors must also be considered in the development process of EMG acquisition equipment, since the type of conductive material and insulation system help minimize noise.

The main purpose of these developments is to help investigate and analyze human movement. The field of biomechanics is a practical example of the use of technological resources to interpret human movement [28].

Biomechanics can be defined generally as the study of the mechanics of living beings, or more specifically, the science that examines forces acting upon and within a structure and the biological effects produced by these forces [17]. Given the complex approach involved in biomechanics and human movement analysis [17], it is important to discuss the concepts, criteria and methods involved, focusing on the use of EMG for reliable interpretations.

EMG can be defined as the study of muscle function by analyzing the electrical signal generated during muscle contraction. Studying muscle function by means of EMG can be carried out under both normal and pathological conditions [12]. EMG has been used in important studies on muscle activity that have both qualitatively and quantitatively addressed the function of human movement. New information about muscle activity has been discovered as developments in processing and instrumentation have been applied to EMG [3,12, 15, 28] .

However, the purpose of this study is to present and discuss the use of sEMG as a quantification tool for studying motor and functional rehabilitation and neurophysiological abnormalities in the nervous system in comparison with peripheral stimuli.

Many authors have used different procedures to analyze EMG signals, which impedes both the comparison and reproducibility of results obtained in laboratory experiments, although their experiments have been described in internationally recognized scientific journals.

Thus, although there is diversity in the procedures for both applying EMG and analyzing the signals, this technique for investigating myoelectrical activity can be used in many different areas of study for different research purposes.

It is important, therefore, to demonstrate some of the applications of EMG as a research tool as well as different methods of analyzing EMG signals to facilitate the design of future and to foster appropriate analysis methods for signal data.

3. Kinesiological electromyography

The numerous applications of EMG include the diagnosis of neuromuscular disease or trauma in clinical practice, rehabilitation and the study of kinesiological muscle function in specific activities [2].

In one study [13] the EMG behavior of some of the major muscles of mastication was compared while subjects chewed different materials (two brands of chewing gum, cotton and parafilm) in order to identify the best material based on performance during bilateral chewing.

The EMG signal serves as an indicator of the initiation of muscle activity and can provide the firing sequence of one or more muscles involved in a specific task [12]. Information from the EMG signal is used to indicate the strength contributed by individual muscles and muscle groups.

In EMG, potentials are produced as a direct result of voluntary effort [18].

The electrodes used in EMG convert the electrical signal resulting from muscle depolarization into an electrical potential that can be amplified, and the difference in electrical potential can be processed. The potential amplitude depends on the difference in potential between the electrodes, such that the greater the potential difference, the greater the amplitude of the electrical potential or voltage [24].

The instrumentation used during the collection of EMG signals includes electrodes, amplifiers, filters, registers, decoders and sound equipment [27]. The choice of the electrode will depend on the muscle being studied.

The factors that influence the EMG signal can be divided into three categories: causes, determinants and intermediate factors [14].

Causative factors have an effect on the basic or elementary signal and are divided into extrinsic and intrinsic factors. Among the extrinsic factors are electrode configuration, the distance between the electrodes, the location of the electrodes over the motor point and the myotendonous junction, the location of the electrodes in relationship to the lateral border of the muscle and the orientation of the electrode in relation to muscle fibers. Intrinsic factors are the physiological, anatomical and biochemical characteristics of the muscle, such as the number of active motor units at the time a particular contraction occurs, the muscle fiber type, blood flow in the muscle, the fiber diameter, depth and location of the active fibers of the muscles in relation to the detection electrodes, the amount of tissue between the electrode and the muscle surface, as well as other factors such as the length of the depolarization zone and the ion flux across the membrane.

The intermediate factors are the physical and physiological phenomena that are influenced by one or more causative factors and, in turn, influence the determinants. Among this type are the detection electrode volume, the overlap of the action potential in the EMG signal, "cross-talk" with neighboring muscles, the conduction velocity of the action potential and the effect of spatial filtering. Since the determinant factors have a direct effect on the EMG signal and include the number of active motor units, the mechanical interaction between muscle fibers, the firing rate and the number of motor units detected, the amplitude, duration and shape of action potentials of motor units, as well as the recruitment and the stability of these units.

Soderberg and Cook described the limitations, collection methods and interpretation of electrical activity. Regarding the type of electrode, they believe that the sEMG can be used to analyze superficial muscles without causing discomfort to the volunteer [25].

The normalization procedure is usually considered necessary for recording, quantifying and comparing the EMG data obtained from different individuals or the same individual on different days [27].

Concern about the establishment of common standards for the collection, recording, analysis and interpretation of EMG signals has been expressed by a number of authors [12,27,28,], and more recently a practical guide for standardizing procedures to be used in EMG studies has been presented [1]. Thus, there is a tendency toward consensus among researchers on the use of appropriate instrumentation for collecting, recording and processing EMG signals.

Several studies [3, 5, 16, 27] have described the need to normalize the EMG signal amplitude when trying to make comparisons between different muscles, subjects, materials and days. This is due to the great variability observed in EMG tracings obtained from both different individuals and different muscles.

The EMG signal can be rectified by mathematical processing or by the root mean square (RMS) of squared instantaneous values . This signal can be passed through a low-pass filter for a presentation wrap the curve. Signal processing can then be carried out in accordance with the specific aim of the work [2]. In general, it is necessary to normalize the EMG signal in order to minimize the differences between individuals [16], when not comparing pre-and post-treatment.

4. Type and placement of electrodes

The electrodes available for kinesiological EMG are the passive and active surface type and the intramuscular type, each with its distinct characteristics, recommendations for use, advantages and disadvantages. The choice of electrode for capturing the EMG signal depends on the characteristics of the evaluated muscles. Thus, when analyzing certain muscles, size and location should be considered in the selection and application of electrodes [27].

The placement of surface electrodes is also another factor that influences the reliability of EMG recordings. The size, orientation and topography of electrodes influence EMG recordings [25].

Since the amplitude of the electrical potential is derived from the difference in potential observed between the electrodes, the inter-electrode distance should be controlled. Due to changes in distance, the same levels of contraction can result in different EMG signal amplitudes [24]. A major concern in sEMG is signal interference (cross-talk) from muscles surrounding the electrode. In one study [12], the surface electrodes were positioned on the midline of the muscle venter between the motor and the myotendonous junction with the detection surface towards the oriented fibers. However, this study was limited in that the electrodes were positioned between the motor and the myotendonous junction without electrically stimulating the motor points.

The surface area and shape of the electrode's contact surface as well as its location affect the signal amplitude, and the distance between the contact surfaces of the electrode affects the signal frequency. Figure 1 shows the characteristics of the EMG signal relative to the electrode position over the fibers. The most suitable location for electrode placement is in the direction of muscle fibers (Figure 2) and near the point of greatest electrical activity.

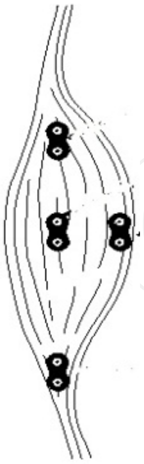

Figure 1. Representative signal results from different points in the muscle [3].

The electrodes must be carefully placed with regard to the adjacent muscles, since if the electrodes are too close to the other muscles then cross-talk may occur. Another important factor is the placement of the ground or reference electrode, which must have a good contact area.

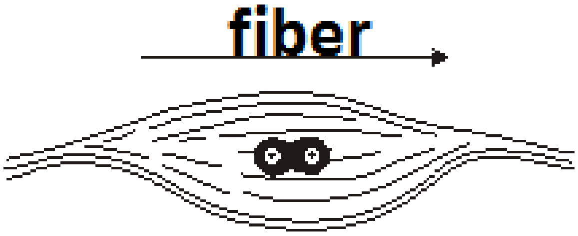

Figure 2. Diagram representing the placement of surface electrodes the direction of muscle fibers [3].

4.1. Considerations on the acquisition of EMG signals

EMG is a generic term for a method of recording the electrical activity of a muscle contraction. The numerous applications of electromyography (EMG) include diagnosing neuromuscular disease and determining the presence of dysfunctions or abnormalities in clinical practice, the rehabilitation of muscle action via EMG biofeedback, demonstrating kinesiology in anatomical studies, use in ergonomics as a tool for studying kinesiological muscle function related to posture and other biomechanical stress indicators, as well as a movement pattern identifier and a nervous system control parameter of the nervous system [28].

When interpreting the EMG signal for quantitative analysis, three fundamental characteristics can be distinguished: duration, amplitude and frequency, each of which is briefly described below [12].

The duration of EMG activity corresponds to the activation time of the selected muscle. The amplitude expresses the level of signal activity and varies with the amount of electrical activity detected in the muscle. It provides information on the intensity of muscle activation. RMS, average value, peak value and peak-to-peak value are ways of evaluating the amplitude of the signal. The frequency can be understood as the rate of excitation of the muscle cell. The frequency distribution of the EMG signal is due to a wide range of factors: muscle composition, the characteristics of the action potential of the active muscle fibers, the intramuscular coordination processes, the properties of the electrodes and their placement.

It can be said that signal processing begins, indirectly, as soon as the electrodes are placed. Electrode placement involves several factors that are decisive for the level and purity of the EMG signal to be collected, including: cleaning the skin, the amount and temperature of the conductive gel, the position of the electrodes and the signal-to-noise ratio, which expresses the balance between the energy of the signal generated during muscle contraction and the energy of noise from various undesirable sources [27].

The EMG signals are affected by anatomical and physiological muscle properties, peripheral nervous system control and the instrumentation used to collect the signal. Thus it is important to understand the basic muscle functions to correctly record EMG signals [12].

5. Biological amplifiers

In signal acquisition, analyzable information is obtained by studying the physical quantities involved in the activation process. These physical quantities can be measured by sensors that convert them into electrical signals and then record them using a data acquisition system (Figure 3). Computers make data acquisition more efficient and reliable and have the advantage of combining data storage with analysis and processing capability [21].

Figure 3. Diagram of a biological signal acquisition system [3].

Sensors and transducers are devices that convert physical quantities into electrical signals or current. Signal conditioners are electronic devices that modify the input signal in some way, whether by amplification, attenuation, filtering or isolation. The EMG signal, for example, enters at an amplitude of μV and must be amplified and filtered [3].

There are basically two techniques capturing an EMG signal: either monopolar or bipolar electrodes. In the monopolar configuration, only one electrode is placed on the skin over the muscle in question (Figure 4). This electrode detects the electrical potential relative to a reference electrode, which is placed in a location unaffected by the electrical activity generated by the analyzed muscle. In the bipolar configuration, two electrodes are used on the muscle as well as a reference (or ground) electrode placed in a neutral location (Figure 5). The human body is actually a good antenna for electromagnetic energy [3].

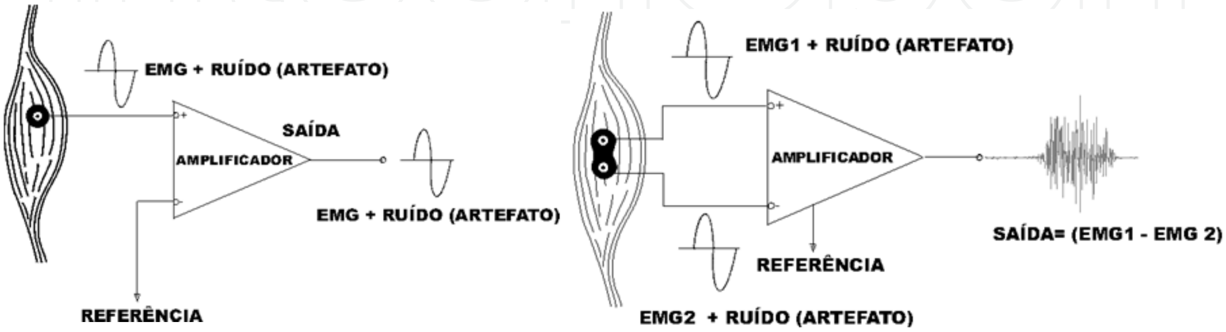

Figure 4. A) Schematic representation of a unipolar amplifier. B) Schematic representation of a bipolar amplifier [3].

6. Signal amplification

Gain is defined as the ratio between the voltage that enters and exits the amplifier. Gain should be selected to suit the characteristics of the experiment, the studied muscle, the electrode type and the use planned for the amplified signal. Considering that a sEMG signal has a maximum voluntary contraction amplitude not exceeding 5 mV peak-to-peak (Figure 6), the gain can be adjusted between 10 and 1000x. It is important to choose a gain that does not exceed at any stage the voltage expected from the system, or there will be a risk of either losing part of information or damaging the system itself [1].

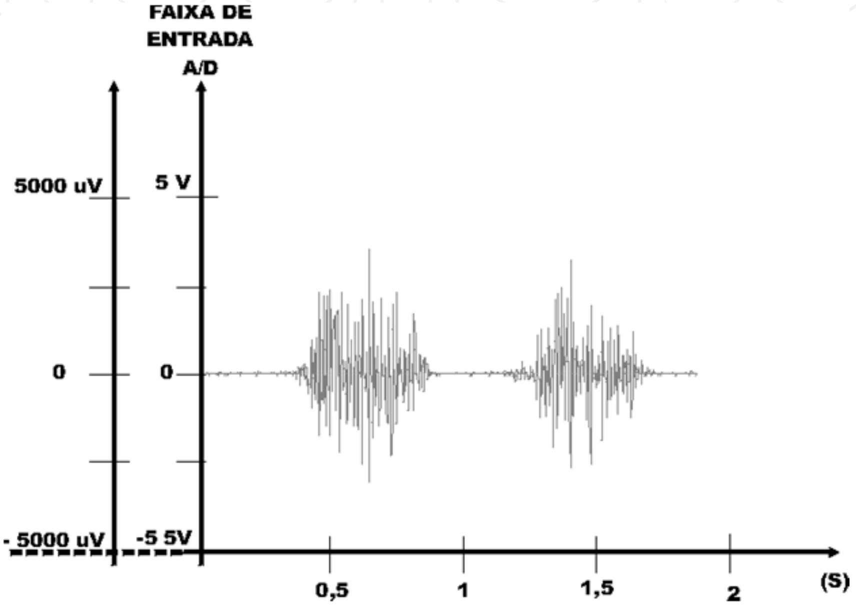

Figure 5. Appropriate gain range [3].

7. Signal filtering

Filters can be used to remove frequency components that do not belong to the signal or components that are irrelevant for a given analysis.

The captured signal can be filtered by hardware or software. Signal-filtering hardware can be used in the amplification step, while signal filtering by means of software can be performed during processing.

When using surface electrodes to measure EMG signals, interference from various sources can be mixed with the EMG signal. Each type of interference has its own characteristics that must be understood in order to remove it during the measurement phase or during processing. The useful information in the sEMG signal, which is a sum of the waves of varying frequency, is located between 20 and 500 Hz [12]. The signal is reduced due to the filtering effect of tissue located between the muscle fibers and the active sensing surface. The band pass filter corresponds to the frequency between the low frequency (high pass) and high frequency (low pass) cut-offs. Specific frequencies can also be filtered out with what are called “notch filters” [5, 11, 3, 23].

8. Analog-digital converter

An analog-digital (A/D) converter converts analog signals (EMG goniometry, force transducer) into digital data. The digitized signal can then be processed by the computer.

8.1. Input range and resolution of the A/D converter

The input range is a parameter associated with resolution and indicates the range of voltage that the A/D converter board can represent numerically. This band can be ± 5 V, ± 2.5 V, 0 to 5V, ± 10V etc.

When the input signals do not fall within the A/D card's range, it is necessary to condition them (amplify or attenuate) before inputting them into the A/D converter. Figure 6 shows an example in which the A/D converter or the conditioning gain is misaligned with the signal. Figure 7 depicts a gain adequate for visualizing the EMG signal.

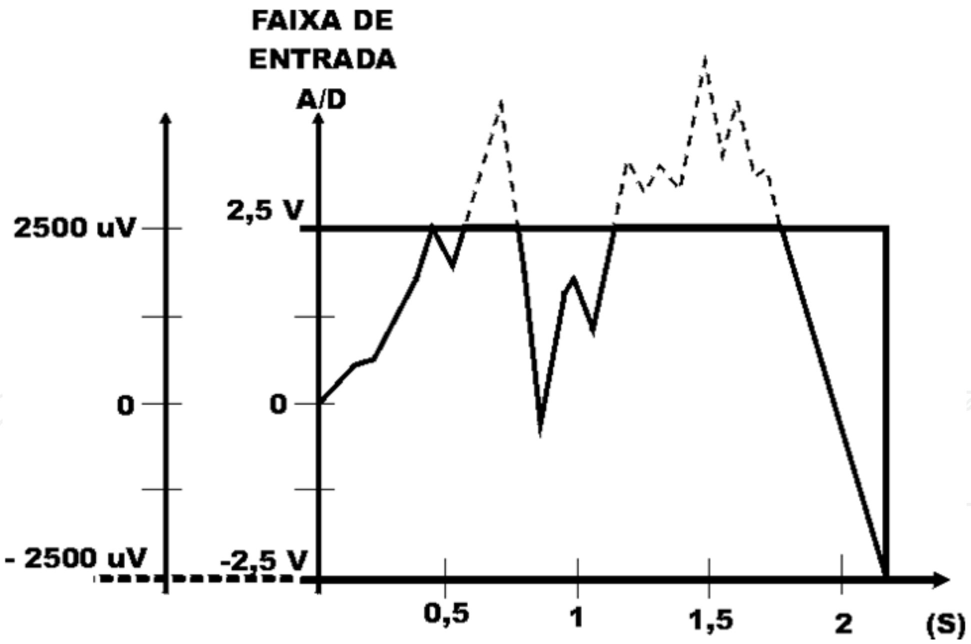

Figure 6. A/D converter range at odds with the amplification gain [3].

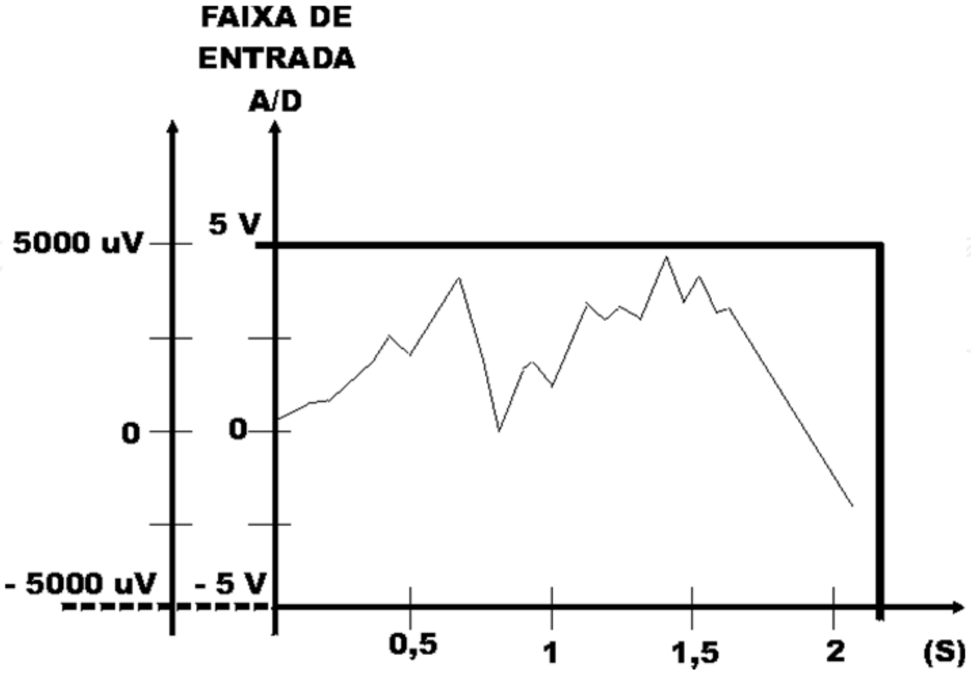

Figure 7. Properly aligned A/D converter range and amplification gain [3].

The resolution of an A/D converter indicates the lowest variation in analog signal that the converter can detect, which is generally presented in bits. Thus, converter resolutions can be 10, 12, 14 or 16 bits, etc., with the most common being 12- and 16-bit.

A converter with a 5V input range and a resolution of ± 12 bits can represent the input signal in 4096 (212) divisions and levels or detect changes of 2.4 mV (10 V divided by 4096 levels). A 16-bit converter may represent the same signal in 65536 (216) divisions and detect changes at levels of 153 μV. (10 V divided by 65,536 levels), [4].

8.2. Sampling rate

In practice, the input signal to the A/D converter varies over time; the goal is to record this variation. Since a computer's storage capacity is finite, the recording can only continue for a limited time.

The discretization of time is carried out by sampling the signal at regular intervals. The reverse of this interval is the sampling rate. For example, at a sampling rate of 100 samples per second (i.e., 100 Hz), the interval between samples is 10 ms. The sampling rate is equivalent to the resolution of the A/D conversion but applied to time.

However, due to the limited space available for data storage, there is a compromise between the sampling rate and the duration of acquisition. For example, for sampling rate of 100 samples per second, the maximum acquisition will be 166 minutes and 40 seconds. By increasing the rate to 1000 samples per second, the maximum is 16 minutes and 40 seconds.

The sampling rate must also be very low compared to the frequency of signal variation due to the effects of sub-sampling (aliasing).

An aliasing effect occurs whenever the sampling frequency is less than twice the highest frequency component of signal frequency, according to the Nyquist theorem [12].

EMG recording is usually done at a maximum frequency of 500 Hz, and the sample should be at least 1000 Hz. To analyze muscle activity in the most comprehensive way possible, it is advisable to work with a sampling rate on the order of 2000 Hz, with the highest frequency component of the signal always limited by the low-pass filter [4, 12, 28].

8.3. Calibration

The measured physical magnitude is converted to voltage using a sensor or transducer, which is then applied to the A/D converter. Knowing the input range and resolution of the A/D converter, one can calculate the voltage of the converter input value from the digitized value, as shown in Figure 8.

Figure 8. Relationship of physical quantity to a digital signal [3].

9. Mathematical processing

Two types of processing are usually used in research: time domain processing, used when one is interested in the temporal analysis of EMG amplitude, and frequency domain processing [1, 26, 28].

9.1. Processing in the time domain

In order to process EMG signals in the time domain, there is a set of processing procedures for characterizing the curve and measuring the signal strength during muscle contraction. Having several kinesiological applications, EMG time domain analysis is often used in areas such as neuromuscular coordination, motor control, the relationship between EMG and muscle force or human movement [25].

9.1.1. Removing the slow-drift (or DC) component present in the signal

Sometimes the signal involves a DC component that causes displacement of the baseline signal. This component is a common signal that has no relation with myoelectric activity. It can be the result of electrochemical phenomena between the electrodes and skin or the limitations of the amplifiers. An easy way to remove it is to calculate the average of all sampling points and shift the curve of the EMG result (high-pass filter) [12, 28].

9.1.2. Signal rectification

Correcting the curve is an operation normally used to enable the subsequent integration of the signal, since it transforms a curve containing both positive and negative values (Figure 10) and a zero mean to a curve of only positive absolute values (Figure 11).

There are two ways to rectify the curve: eliminating the negative values (half-wave rectification), or reversing the negative values and adding them to the positive values (full wave rectification). Full-wave rectification has the advantage of maintaining all of the information contained in the signal, unlike half-wave rectification [5, 28].

9.1.3. Root-mean-square value of the signal

The RMS is the amount of continuous signal able to contain the same amount of energy. It is mathematically defined as the square root of the mean of the squares of the instantaneous values of the signal [4, 12, 22, 23].

9.1.4. Normalization of the signal in the time domain

One problem when comparing different EMG signals has to do with differences in the duration of the various signals to be compared.

Normalizing means transforming, without changing the signal’s structure, the duration differences into signals with the same number of samples. This can be done, for example, by taking the signal containing the lowest number of samples as a reference. An algorithm can be applied that determines, depending on the duration of each signal, the number of samples to be removed at certain intervals, reducing all signals to the same number of samples contained in the shorter of the two signals, and thus retaining the original forms [16].

9.1.5. Amplitude normalization

The EMG signal varies greatly upon comparison with recordings from the same individual or different individuals. The absolute value of the EMG signal thus provides little information, especially when dealing with signals from different individuals or the same individual at different times. One way to compensate for this limitation is to normaliz EMG amplitude curves. This technique consists of transforming the absolute amplitude values of the different curves to be compared into values relative to a reference EMG taken as 100% [4, 7, 15].

9.1.6. Integral of the EMG signal

The mathematical interpretation of the integral concept consists of determining the area enclosed by curve, whether an EMG or any other signal. In the case of the EMG, so that the result of integration is not zero, a rectified signal must be used. By integrating the EMG signal, a result that is proportional to the number of electrical impulses is obtained [3].

9.1.7. Filtering of the rectified signal

The signals collected in real time in the original format are stored in files. After this phase certain mathematical processes are applied. The purpose of this processing is to make correction, i.e., to transform negative signals into positive signals. This is necessary to allow averaging of the analyzed signal, since if such correction is not performed, the average of the signals will be near zero. This is because the negative and positive are symmetrical. In the post-rectification, a 5 Hz low-pass filter can be run in order to have a signal wrap. The lower the value of this filter, the smoother the curve will be [27, 28].

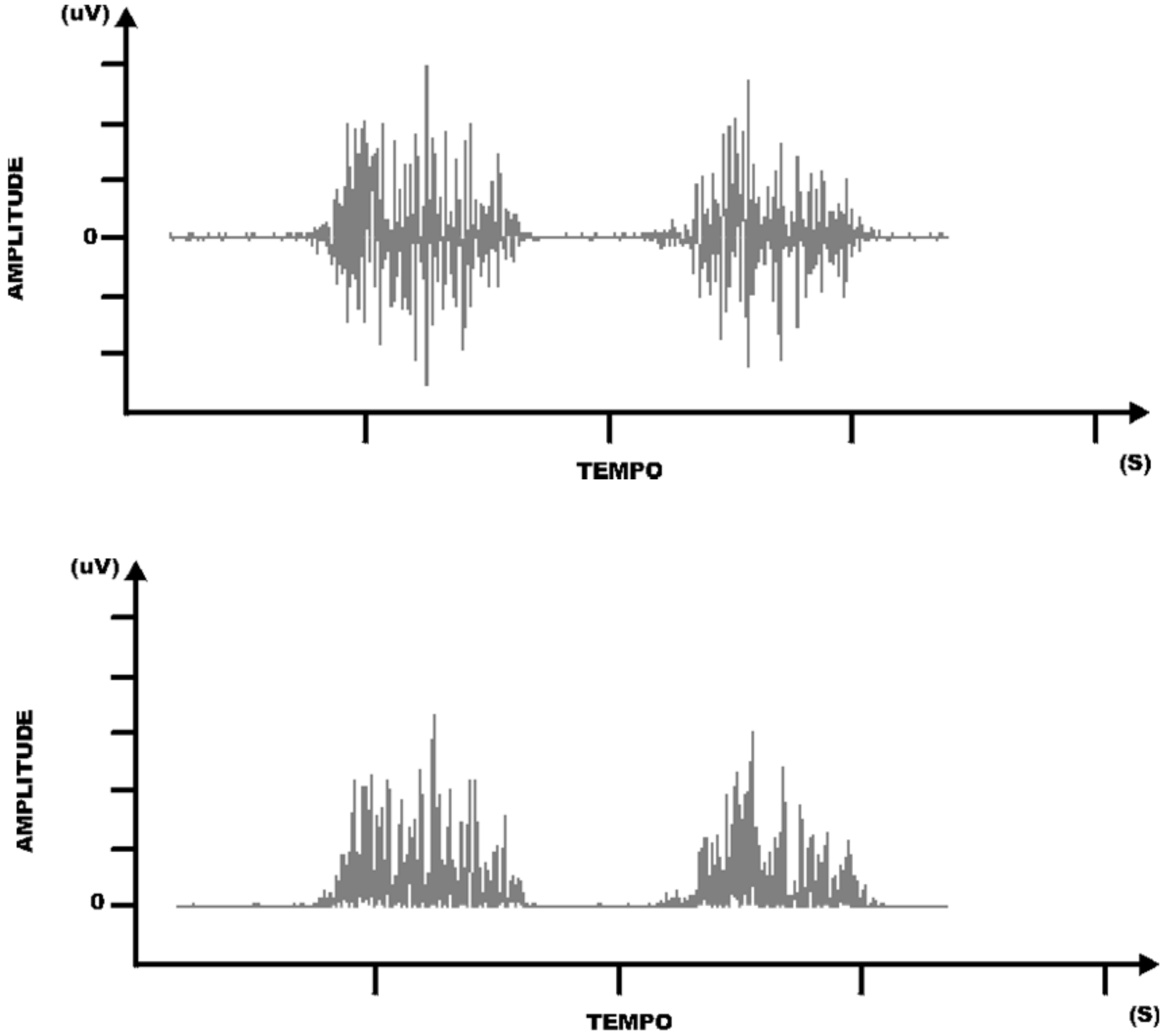

Figure 9. A) original signal interference. B) rectified original signal [3].

9.2. Processing the frequency domain – Spectral analysis

The EMG signal's frequencies are distributed between 1 and 500 Hz, with a great concentration between 20 and 250 Hz in the case of simple muscular activity. The distribution of energy at different frequencies (power spectral density) reflects the predominance of the low or high frequency components in the signal and has been used in kinesiological research. Factors that influence the spectral profile of the EMG signal have been listed by various authors.

EMG can be considered an overlapping of the action potentials of all the active motor units. The spectrum of EMG frequencies thus contains information about the characteristics of different fibers that contribute to the signal. Spectral analysis can provide information about the mean duration of the active fiber potentials, which in turn can be used to determine the mean velocity of muscle fiber conduction [3,4].

10. Conclusion

For dynamic sampling, active electrodes (with preamps) are less susceptible to artifacts or ambient noise, which can be observed when comparing them with signals collected during isometric contractions in volunteers with dysfunctions.

EMG signals are affected by the anatomical and physiological properties of muscles, the peripheral nervous system and the instrumentation used to collect the signal. Thus it is important to understand basic muscle functions to correctly record EMG signals [12].

It can be said that signal processing begins, indirectly, as soon as the electrodes are placed. Electrode placement involves several factors that are decisive for the level and purity of the EMG signal to be collected, including: cleaning the skin, the amount and temperature of the conductive gel, the position of the electrodes and the signal-to-noise ratio, which expresses the balance between the energy of the signal generated during muscle contraction and the energy of noise from various undesirable sources [27].

Therefore, sEMG can be recommended as a tool for analyzing and interpreting electrical signals emanated during muscular contractions in both normal and pathological situations and can be applied in the study of motor function and functional rehabilitation [4].

11. Future directions

Studies in the field of signal processing, especially, surface electromyography signals, have been widely used for understanding the dynamic motions by the fact that most human movements happening dynamically. Thus, processing in the field of time and frequency should be increasingly directed to this specificity.

Understanding the phenomena of depolarization of motor units, future research should be related to the physiological, mechanophysiological and functional human movement.

Applications in the area of functional biomechanics, ergonomics, rehabilitation, sports and physical activity must be analyzed dynamically so that the signal processing, fairly represent the specific characteristics of human movement-environment relationship. Thus, these factors provide parameters for understanding the non-stationary signals, the variation components of the muscle fiber in relation to the positioning of the electrodes and in the bioelectrical conductivity.

Author details

César Ferreira Amorim
University of City of São Paulo- UNICID, São Paulo - SP, Brazil

Runer Augusto Marson
Laboratory of Biomechanics, Brazilian Army Physical Capacitation Research Institute, Rio de Janeiro, Brazil
Laboratory of Biomechanics and Kinesiology, Sport Center, Federal University of Ouro Preto, Minas Gerais, Brazil

12. References

[1] Acierno, S.P. Baratta, R.V., Solomonow, M. A pratical guide to electromyography for biomechanists. Lousiana: State University, 1995.

[2] Amadio, A.C. ; Duarte, M. Fundamentos Biomecânicos para análise do movimento. São Paulo: Editora Laboratório de Biomecânica EEFUSP, 162p. 1996.

[3] Amorim, C.F; Hirata,Tamotsu. Behavior analysis of electromyographic activity of the masseter muscle in sleep bruxers, Journal of Bodywork & Movement Therapies (2009), doi:10.1016/j.jbmt.2008.12.002

[4] Amorim, C.F. Sistema de Aquisição de Sinais Eletromiográficos com Eletrodos Bipolares com Pré-Amplificação. In: 3c Biomédica,18., Setembro de 2002. Anais... São José dos Campos: Univap, 2002.

[5] Andrade, A.D.; Silva,T.N.S.;Vasconcelos, H.; Marcelino, M.; Rodrigues-Machado, M.G.; Filho, G.; Moraes, M.; Marinho, P.E.M.; Amorim, C.F. Inspiratory muscular activation during threshold therapy in elderly healthy and patients with COPD, Journal of Electromyography and Kinesiology (2005), doi:10.1016/j.jelekin.2005.06.002

[6] Araujo, R.C.;Amadio, A .C.; Furlani, J. Contribuição para a interpretação da relação força e atividade EMG. In: Congresso Nacional De Biomecânica, 4.,1992, São Paulo. Anais... São Paulo: Escola de Educação Física da Universidade de São Paulo, 1992. p. 146-153.

[7] Araujo, R.C.; Duarte, M.; Amadio, A .C. Evaluation of increase in force and EMG Activity´s Cirves. In: Congress Of The International Society Of Biomechanics, 15., Jyvaskyla, 1995. Abstract… Jyvaskyla, University Of Jyvaskyla, 1995. p.64-65.

[8] Baba, K.; Akishige, S.; Yaka, T.; Ai, M. Influence of alteration of occlusal relationship on activity of jaw closing muscles and mandibular movement during submaximal clenching. Journal of Oral Rehabilitation. v.27, p.783-801.2000.

[9] Bardsley, P.A., Bentley, S., Hall, H.S., Singh, S.J., Evans, D.H., Morgan, M.D., 1993. Measurement of inspiratory muscle performance with incremental threshold loading: a comparison of two techniques. Thorax 48, 354-359.

[10] Basmajian, J.V. Muscle Alive. 4 ed. Baltimore: Willians & Wilkins, 1978.

[11] Basmajian, J.V. Muscles alive: their function revealed by electromyography. Baltimore: Williams e Wilkins, 1962.

[12] Basmajian, J.V.; De Luca, C.J. Muscle alive: their function revealed by electromyography. 5a ed. Baltimore, Williams e Wiikins, 1985. p.501-561

[13] Biasotto, D. A. Estudo eletromiográfico de músculos do sistema estomatognático durante a mastigação de diferentes materiais. Dissertação(Mestrado) - Faculdade de Odontolocia de Piracicaba da UNICAMP, 2000. 134p.

[14] Blanksma, N.G ;Van Eijden, T.M.G.J. Electromyographic Heterogeneity in the Humam Temporalis and Masseter Muscles during Static Biting. Open Close Excursion, and Chewi. Journal of Dental Research. v.74, n.6,p. 1318- 1327. June 1995.

[15] Dainty, D.A.; Norman, R.W. Standarding biomechanical testing in sport. Champaign, Human Kinetics, 1987.

[16] Ervilha, U.F., Duarte, M Amadio, A.C. Estudo sobre procedimento de normalização do sinal eletromiográfico durante o movimento humano. Rev. Bras. Fisiot., p.15-20,1998

[17] Hatze, H. The meaning of the term"Biomechanics". Journal of Biomechanics, v.7,p.189-190,1974.

[18] Landulpho, A.B. et al. The effect of the oclusal splints on the treatment of temporomandibular disorders – a computerized electromyographic study of masseter and anterior temporalis muscles. Electomyogr. Clin. Neurophysiol. v.42, p.187-191.2002.

[19] M.A. Mananas, R. Jane, J.A. Fiz, J. Morera, P. Caminal, Study of myographic signals from sternomastoid muscle in patients with chronics obstructive pulmonary disease, IEEE Trans. Biomed. Eng. V.47, p. 674-681. 2000.

[20] Mclean L. The effect of postural correction on muscle activation amplitudes recorded from the cervicobrachial region. J Electromyogr Kinesiol., v.15,p.527–535. 2005.

[21] Nascimento, L.N.; Amorim, C.F.; Giannasi, L.C.; Oliveira, C.S.;Nacif, S.R.; Silva, A.M.; Nascimento,D.F.F.; Marchini, Daniela; Oliveira,L.V.F., Occlusal splint for sleep bruxism: na electromyographic associated to Helkimo Index evoluation, Sleep Breath,v.12, p.275–280, 2008.DOI 10.1007/s11325-007-0152-8

[22] Nobre, M.E.P.N.; Lopes, F.; Cordeiro, L.; Marinho, P.E.M.; Silva, T.N.S.S.; Amorim, C.F.; Cahalin, L.P.; Andrade, A.D., Inspiratory muscle endurance testing: pulmonary ventilation and electromyographic analysis, Respiratory Physiology & Neurobiology, (2006), doi:10.1016/j.resp.2006.04.005

[23] Politti, F., Amorim C.F., Calili L., Andrade, A.O., Palomari, E.T., The use of surface electromyography for the study of auricular acupuncture, Journal of Bodywork & Movement Therapies (2009), doi:10.1016/j.jbmt.2008.11.006

[24] Portney, L. Eletromiografia e testes de velocidade de condução nervosa. In: O'sullivan, S.B.; Schmitz, T.J. Fisioterapia: avaliação e tratamento. 2 ed. São Paulo- Manole, 1993. Cap. 10, p. 183-223.

[25] Soderberg, G.L. & Cook, T.M. Electromyography in Biomechanics. Physical Therapy, v.64, p.: 1813-20,1984.

[26] Suda, E.Y; Amorim, C.F.; Sacco, I.C.N. Influence of ankle functional instability on the ankle electromyography during landin after volleyball blocking, Journal of Electromyography and Kinesiology (2007), doi:10.1016/j.jelekin.2007.10.007

[27] Turker, K.S. Electromyographyc: Some methodological problems and issues. Physical .Therapy. v.73, n.10,p. 698-710, 1993.

[28] Winter, D.A. Biomechanics and Motor Control of Human Movement. New York: John Wiley & Sons Inc.,1990.