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THE USE OF ELECTROMYOGRAPHY IN SPORTS

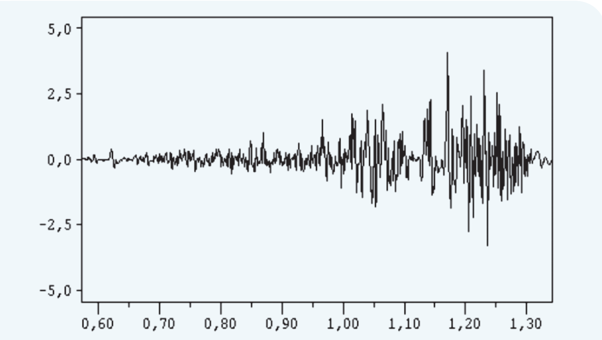
HANS-JOACHIM MENZEL
Federal University of Minas Gerais

Electromyography (EMG) is a method which allows the analysis of the muscular activity. This is possible because the muscular excitement is subject to electrical activity, whose effects may be usually measured by electrodes stuck to the athlete's skin, known as surface electrodes. The impulses from the central nervous system hit the skeletal muscle via the lower motor neurons. Each neuron innervates a group of muscular fibers, such functional structure is named motor unit, which is the smallest functional unit of the neuromuscular system. While resting, there is a difference of electrical charge between the two sides of the muscular cell membrane, keeping the lower part with a negative charge in relation to the outside of the cell (resting action). The membrane's excitement by a nervous impulse causes its depolarization, which then results in positive charge on the interior part (action potential). This depolarization is transmitted until the muscular fibers, provoking the muscular contraction. When the action potential reaches its peak, the depolarization of the membrane will be reverted (repolarization) and the potential returns to its resting amount. The duration of the action potential on the skeletal muscle comprehends between 0.1 to 0.5 s and the velocity of conduction between 3 to 5 m/s. The electrical activity captured by the surface electrodes consists on the sum of the action potentials transmitted to the muscular fibers on a given moment.

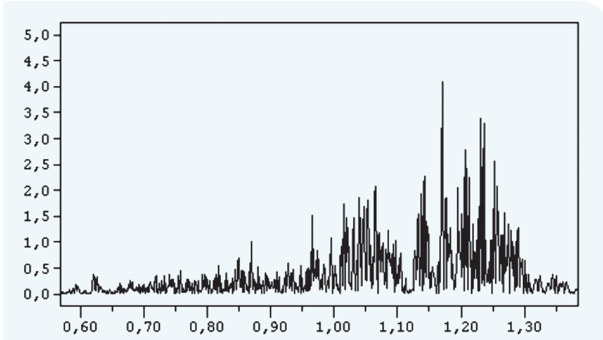

Picture 1. Surface electrodes on the straight femoral muscle.
Picture 2. Bipolar electrode with ground and amplifier.

The alterations of the electrical potentials may be measured by electrodes. On clinical applications, and when it is necessary to analyze the innervation of the specific motor units (intramuscular coordination), needles electrodes are being used. Due to the fact that it is an invasive method, it may provoke side effects (risk of infection, pain). This type of electrode may not be used on the practice of analysis of sport movements. For the analysis of the coordination pattern of different superficial muscular groups, which represents the intermuscular coordination, surface electrodes are stuck to the skin (Pictures 1 and 2).

Bipolar electrodes are usually used within a distance of 2 to 4 cm between them. Thus, the surface electrodes evaluate the activity of various motor units which participate on the muscular contraction. However, it is necessary to place a pair of electrodes on each muscle to be studied and one reference electrode (ground) somewhere without any electrical activity (patella, malleolus or over another appropriate bone). For the correct register of the electromyographic activity, the frequency of acquisition should be, at least, the double of the higher frequency of the signal. As the higher frequency is around 400 to 500 Hz, the acquisition frequency should be, at least, 1000 Hz. The maximum frequency of electromyographic activity depends on the motor unit, on the muscular work type, on the electrode area (detection surface) and on the distance between them. The electrodes are usually composed by silver-silver choride (Ag-AgCl), as they are considered as the most electrochemically stable. According to Hermens[1], the electrodes should be placed



Picture 3. Rough signal



Picture 4. Rectified signal

between the motor point and the distal tendon. The motor point is the region of the muscle where a small electrical stimulus causes the greater response of contraction of the muscular fibers. As the propagation of the action potential follows the longitudinal axis of the muscular fibers, the electrodes should be aligned on the same direction (Picture 1).

The registered signal depends on the orientation of the motor units in relation to the electrodes. They also influence the signal according to their recruiting and frequency of activation. From this signal, the characteristics of temporal intensity and their frequencies may be analyzed.

The rough signal (Picture 3) is the base for possible later analysis steps. It may be analyzed with the objective of detecting the start and the end of the muscular innervation. To identify the start and the end of the activation, it is necessary to define a limit value of activation which should be surpassed (start) or not reached anymore (end).

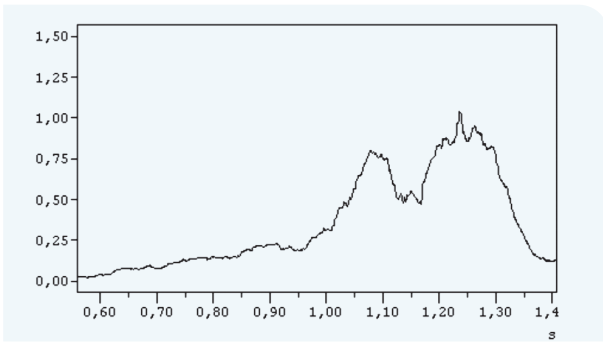
Due to the fact that the amplitude of the signal depends on the type of muscular fiber, on the location of the electrodes, on the muscle's diameter, on the tissue between the muscle and the electrodes, on the distance between the electrodes and their area, the signal cannot be directly analyzed. Thus, the electromyographic rough signal (Picture 3) has to be treated. For this purpose, there are various processing methods among which the most common are the RMS (root mean square), the rectification, integration and linear envelope.

$$RMS = \sqrt[2]{\frac{1}{N}\sum_{i=1}^{N} x_i^2}$$

To analyze the alterations of the EMG signal in time, it is possible to determine the mobile RMS which is the RMS in a time interval moved along the signal. The intervals may be overlaid, which allows a continuity of the signal. For dynamic contractions, the intervals for the mobile RMS are of 100 to 200 ms. For non-dynamic contractions the intervals should be of 0.25 until 0.5s, for intensities higher than 50% of the maximum voluntary contraction and of 1 to 2 s for intensities smaller than 50% of the maximum voluntary contraction[1,2].

Rectification means to take the absolute value of the signal (Picture 4). From this step on, it is possible to determine the maximum peak and the signal's mean (mean EMG or ARV – averaged rectified voltage). This value represents the average intensity of the innervation during the interval studied. Another variable of average intensity is the integration of the signal (IEMG), which means the determination of the area below the rectified curve of the EMG.

In order to make the curve of the rectified signal more legible and to suppress the high frequencies, the rectified signal (Picture 4) may be analyzed by a low-pass filter resulting in a linear envelope (Picture 5). The frequency of cut is usually between 3 to 50 Hz[3]. This curve represents the signal's trend.



Picture 5. Envelope curve of the rectified signal

PTo analyze the signals of different individuals, muscles or measurements, the signal has to be normalized, that is, transformed from absolute values of the amplitudes into relative values referring to a standard value of amplitude considered as 100%. The forms of normalization are the maximum voluntary isometric contraction (MVIC), the signal mean, the maximum peak of the signal and a fixed value of the signal, like for example, a submaximal contraction. According to Robertson4, the maximum peak is the best criterion for the normalization of dynamic contractions. According to the movement to be analyzed, many authors discuss the adequate type of normalization[3,5].

The determination of the spectrum of frequencies by FFT – Fast Fourier Transformation is another method of analysis of the EMG signal to identify the combination of various independent functions which represent the EMG signal. The different distances between the innerved fibers and the electrodes are the main reason why the action potentials alter their form. Along with the potentials form, the frequencies also change. This is one of the characteristics of fatigue. Thus, fatigue can be identified by the alteration of the average and the mean of the frequencies[1,6].

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