

Naučni članak***Modern method for the muscle performance and fatigue evaluations in sport medicine******Mirela Vasilescu¹, Ligia Rusu¹, Fl. Romanescu²***¹University A.I.Cuza, Craiova, Romania,²Medicine University of Craiova, Romania**Abstract**

Authors propose a modern and complex exploration method of muscle fatigue by computerized acquisition and analysis of surface electromyography (SEMG) and mechanomyogram (MMG) during voluntary isometric maximal contraction of flexor hand fingers. The evolution of 12 classical (previously described in literature) SEMG and mechanographic parameters and new parameters and indices were analyzed with dedicated software. This modern exploration method allows precise, quantified, analysis of muscle fatigue phenomenon and, by linear regressions and statistical analysis, permits to differentiate various groups of subjects.

Keywords: surface electromyography, myomechanography, muscle fatigue.

Savremena metoda evaluacije mišićne aktivnosti i zamora u sportskoj medicini**Sažetak**

Autori su predložili savremen i kompleksan metod eksploracije mišićnog zamora upotrebom kompjuterizovanje analize površne elektromiografije i mehanomijograma tokom maksimalne voljne izometrijske kontrakcije pregibača prstiju šake. Merenje 12 klasičnih parametara površne elektromiografije i mehanomijelograma (ranije opisanih u literaturi) i novi parametri i indeksi obrađeni su posebnim kompjuterskim programom. Ovaj savremeni metod omogućava presiznu, kvantitativnu analizu fenomena mišićnog zamora i upotrebom linearne regresije i statističke analize obezbeđuje deiferenciranje različitih grupa ispitanika.

Ključne reči: površna elektromiografija, miomehanografija, mišićni zamor

INTRODUCTION

The researches related to the electrical phenomenon in the muscle fatigue are useful at the current moment especially in EMGS because, on one hand, the methods are more simple, and on the other hand, the EMGS unit cannot make a difference between motor units potentials during maximal muscle contraction. The numerous electrophysiological and muscle physiological studies made along the time by Nestianu and his team (1,4,5,6,7,8,9) have lead to better acquisition methods and processing of the EMGS

signal collected with the surface electrodes. From this experience it resulted a selection of parameters of the EMGS signal, previously quoted in literature as well as the usage of some new original parameters. In our research regarding muscular fatigue, we have chosen the usage of EMGS correlated with the simultaneous recording of the developed muscle force (MMG), with the purpose of finding a synthetical relation between the muscle force and the EMGS parameters. For this we have used modern methods of computerized processing of the EMGS recordings, methods which are used frequently only by the high rank researches.

METHODS

The method proposed by us for the study of the muscle fatigue is based on the simultaneous recording and acquisition, on the computer, followed by a very advanced processing, mostly original, of EMGS and isometric MMG during maximal voluntary contractions of hand fingers flexors, until total exhaustion.

The equipment

Muscle potentials have been collected with the bipolar AgCl surface electrodes, placed on the surface of the common flexor of the fingers (*flexor digitorum superficialis*, *flexor digitorum profundus*), using a special gel for the improvement of the electric conductivity skin – electrode. The potentials collected by the electrodes have been undertaken by an electromyograph (Medicor type MG42), the exiting signal being received by a compatible PC through out an specialized acquisition board. The collecting has been made through out two channels and there have been two active electrodes used for each channel. The mass electrode, with a larger surface (25cm²) has been established at the lower extremity of the forearm. For the two channels of the electromyograph it has been used upper band-pass filtered of 20 ms and lower band-pass filtered 20 KHz. The acquisition board (type DAP 1200), to which we have connected the two channels exits of the electromyograph, establishes a parting of each channel with a frequency of 5000Hz (200µs interval between parts) and then a conversion analog/digital (A/D) of 12 bit. The undertaking of the signal on the computer has been commanded by a specialized program (software), made at Medicine University of Craiova by V.Nestianu and his team. Through this program there has been made the acquisition of the digital signal sent by the acquisition board, simultaneously on the two channels, in segments of 410 ms at intervals of 5 seconds, on the entire period of the maximal voluntary contraction. Simultaneous with the recording of the electromyographic signal, we have made the mechanogram recording by using an isometric transducer of force (dynamometer SS25L BIOPAC, 0-100Kg, 20µV/Kg). The acquisition of the signal produced by the transducer has been made with the acquisition unit MP30 BIOPAC linked with a board, introduced in the second computer, IBM compatible. The A/D conversion of this signal has had a resolution of 10 bit, at a rate of parting of 200 Hz, the acquisition of the signal being commanded by the BIOPAC Student Lab Pro 3.6.

Signal Processing

On the basis of a vast specialty literature studied during several years (2,3,10,11), it has been concluded that only the following parameters are important for our research.

Average value of the redressed signal (rAav) in mV. This parameter is a measurement for the average value of the redressed signal, calculated after the formula:

$$rAav = \frac{\sum_{k=1}^N s(t_k)}{N}$$

where N is the number of segments. *Root mean square (Rms)* in mV, which reveals an particular average of the signal, calculated by the formula:

$$R_{ms}(s(t)) = \frac{\sqrt{\int_t^{t+T} s(t)^2 dt}}{\sqrt{T}}$$

Local Peaks Number, Turns Number of EMGS curve (*Npl*), *Zero Crossings Number* of the EMGS curve (*Ncz*). *Redressed Signal Integral (Isr)*, in mV.ms, takes values dependent on the amplitude, duration and frequency of the electromyographic potentials. *Area Amplitude Ratio (Raa)*, in ms,

$$Raa = \frac{S_{med}}{A_{med}} = \frac{\sum_{i=1}^n \frac{S_i}{A_i}}{n}$$

where *Smed* is the sum of all areas fazes of the redressed signal, divided to the total fazes number, *Amed* is the sum of all fazes amplitudes of the redressed signal divided to the total number of fazes, *Si* is the area of a singular faze of the redressed signal, *A* is the amplitude of a faze, and *n* is the total number of fazes. *Average frequency (Fav)*, in Hz, is the average frequency of the power spectrum:

$$Fav = \frac{\int_0^{\infty} f \cdot S(f) df}{\int_0^{\infty} S(f) df}$$

where *f* is the frequency, *S(f)* is the power spectrum obtained through out fast Fourier transform (FFT). *Median frequency (Fmed)* in Hz, is the frequency to which the power spectrum divides in two equal areas. *Smax* (mV²/ms) is the maximal power spectrum determined by FFT.

$$PSD(\omega) = |FFT(x_n)|^2$$

The frequency of the maximal power spectrum (FSmax), in Hz, is the frequency at which the power spectrum has its maximal amplitude. All the recordings EMGS obtained have been processed with an original software, made by V.Nestianu and his team. The first six parameters are time parameters (or related to time), calculated for each segment of 410 ms of acquired signal from 5 to 5seconds, and are printed separately by the following four parameters, parameters of the frequency spectrum determined by FFT, calculated also on segments of 410 ms. We have also studied *the*

EMGS Synchronization (Syn) simultaneously recorded on two adjacent zones, parallel, of the same finger flexor muscle. For the obtaining of the value of the two EMGS peaks synchronization, from the two channels, of the same muscle, it has been made a special program. The synchronization has been considered positive when two peaks, one for each collector channel, coincide in time, in the 200 μ s limit. The percent representation of the synchronization is made through reporting to the lowest frequency, from the channel with the smallest frequency. Finally, its obtained the percent values of the synchronization of the two channels, on EMG portions of 410 ms, from 5 to 5 seconds, as in the case of the EMG presented previously. *The muscle force curve*, mechanogram, has been divided to obtain 5 seconds intervals, corresponding in time to the values of the EMGS parameters calculated for each 410 ms segment, from 5 to 5 seconds. For each set of values of EMGS parameters it has been obtained a value of the muscle force (F) at the specified moment (Kgf). *The Index of excitation-contraction coupling efficiency (ECCEI)*. Observing that at the young athletes at low F_{med} (under 100Hz) we obtain higher values of force, and at the older untrained subjects, at higher F_{med} (about 150Hz) we obtained lower force values, we have reached a conclusion that the trained youth have higher efficiency, the electrophysiological command through the action potential produces a force much bigger then the one at young and old untrained subjects. Because of this cause we proposed the calculation of the report between the muscle force and the median frequency, the Index of excitation-contraction coupling efficiency (ECCEI). In practice, we have divided the power of the muscular force (Kgf) to the average value of the F_{med} of the two channels. *The area of the mechanogram*, in Kgf.s, is a measure of the total value of the undertaken effort during the entire muscular contraction, represented by a single value for the whole contraction period.

Mathematical and statistical processing

Because the interpretation of the curves with evolution in time of the parameters previously presented (each having values from 5 to 5 seconds, on all the period of the contraction), it's pretty difficult, we have calculated the I order regression lines, noting for each regression line the values of the slope and intercept. For a better comparison, the amplitude of the intercept value modification, we have calculated the slope/intercept ratio. The percentage value of this report, indicates how many percentage of the intercept value (noted 100%) have decreased or increased after 5 seconds of maximal contraction.

CONCLUSIONS

The original part of this method consists in the calculation of the Area Amplitude Ratio (R_{aa}) for the EMGSS; the determination of the percentage of the Synchronization (*Syn*) between the two EMGS on the same muscle; the proposal of the Excitation-Contraction Coupling Efficiency Index (*ECCEI*) who differentiate very well the categories of subjects; the study in time of the parameters through out the I order regression lines; the establishment of the relation between the mechanical and electrical activity of the muscle. With the help of this modern technique, we have studied different athletes categories obtaining very interesting results for the performance and muscle fatigue evaluation.

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APPENDIX

Modern method for the muscle performance and fatigue evaluations in sport medicine

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FIGURES ACCOMPANIED TO ABOVE ARTICLE

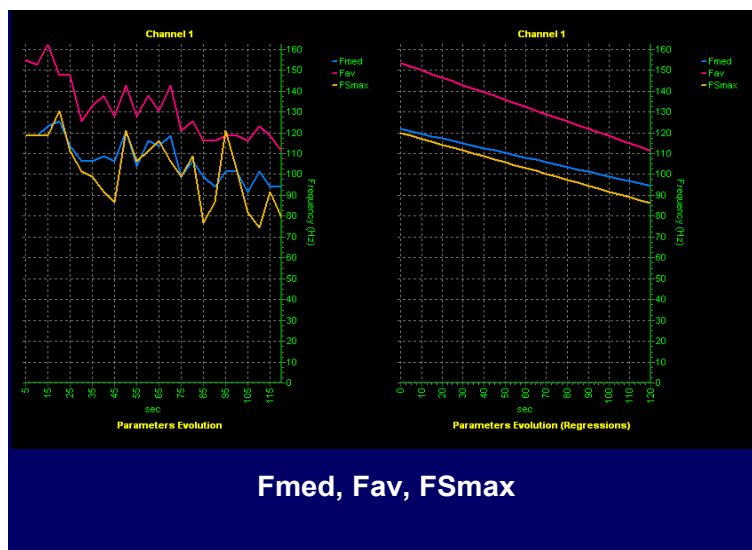


Figure 1

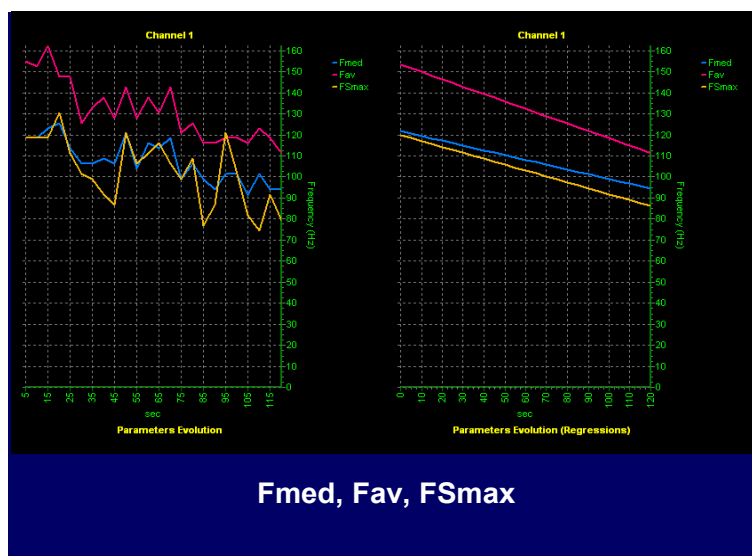


Figure 2

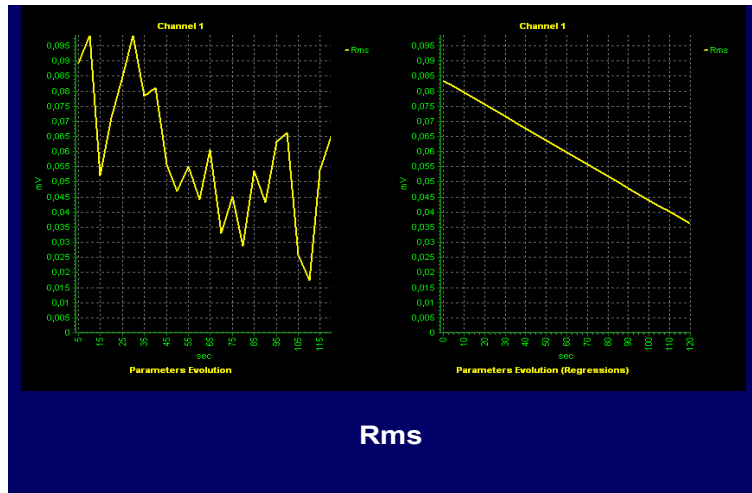


Figure 3

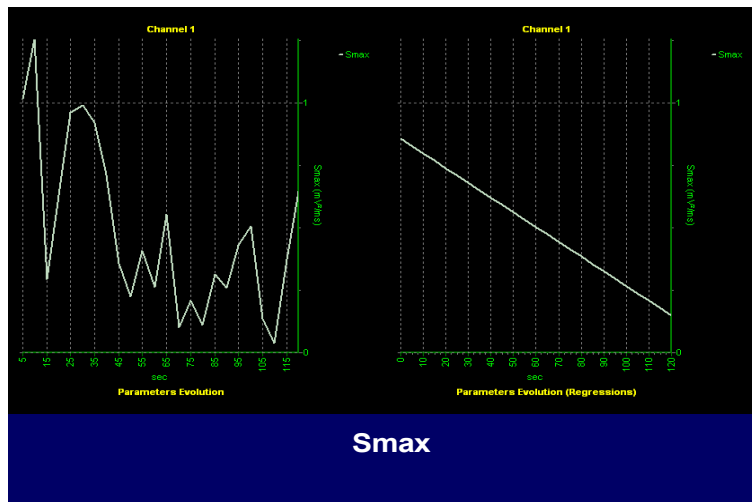


Figure 4

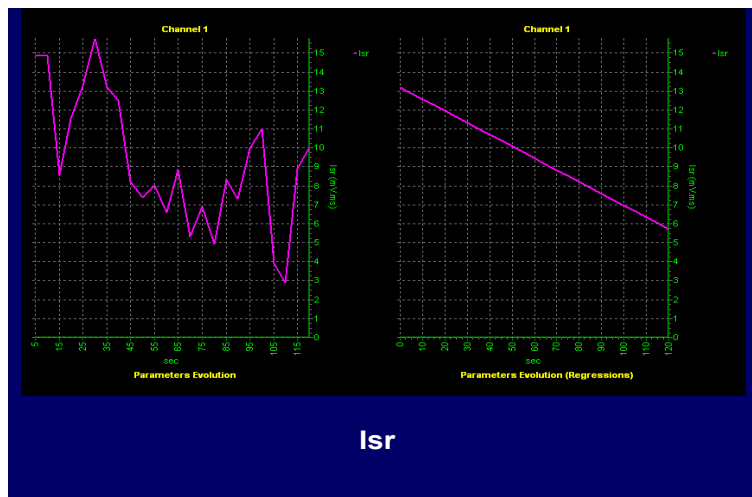


Figure 5

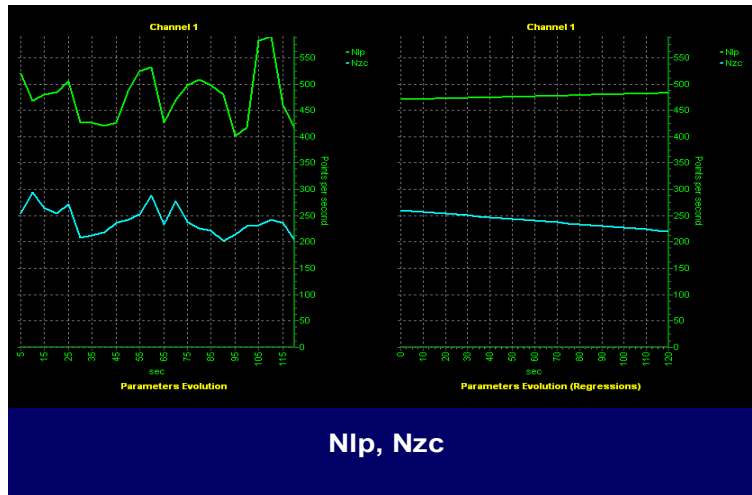


Figure 6

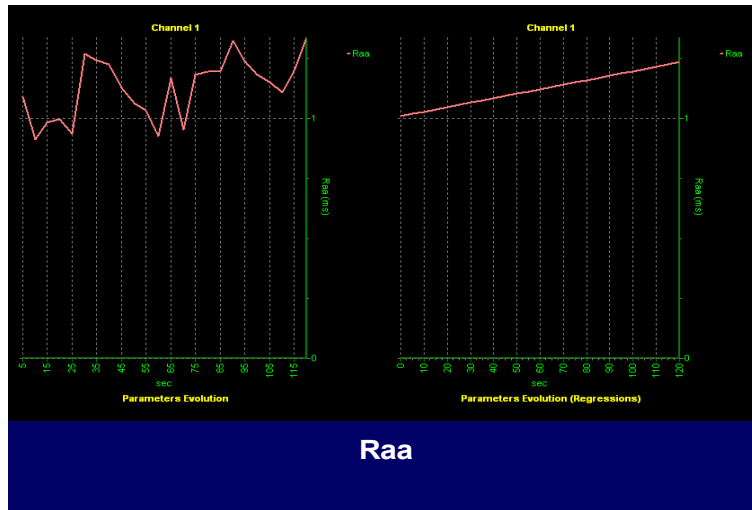


Figure 7

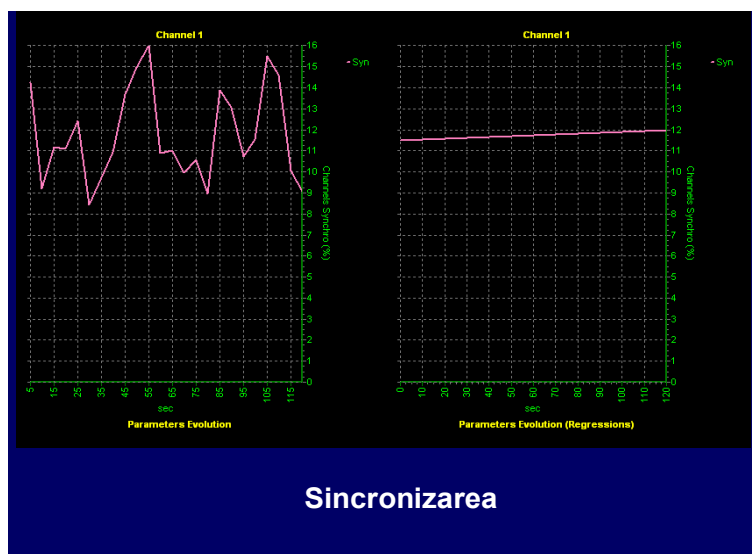


Figure 8