Nonlinear Dynamics and Applications. Vol. 14 (2007) 183 - 186

The bioelectric activity of different muscles influenced by dozed loading

A.V. Sidorenko,* Kazakevich V. B., Romanovsky N. P., and Selitsky A. P.
Belarusian State University, Nezalezhnasti Ave. 4, 220050 Minsk, Belarus

PACS numbers: 05.45.Gg, 47.52.+j, 02.50.Fz, 87.19.la, 87.80.Tg
Keywords: bioelectric activity, correlation dimension, Kolmogorov entropy

The measures aimed at preventive maintenance, elimination or decreasing of possible negative effects due to external technogenic factors necessitate diagnostication of various states exhibited by the central nervous and nervous - muscular systems of a human organism [1,2]. Such a variability is shown in dynamics of the bioelectric information displaying activity of these systems. To describe bioelectric signals and the states exhibited by the nervous - muscular system, it is important to know the frequency structure of the recorded signal and its dynamics. Therefore, the spectral methods regarding the processes under study as stationary have found wide use in analysis of electromyograms [3]. And the turn-peak analysis that is a general practice in electromyography is based on the same model [4]. Of particular importance for estimation of electromyograms are nonstationary fluctuations associated with the bioelectric activity that is overlapping the background activity and calling for other approaches. This work presents nonlinear analytical methods, and specifically the delayed-coordinate method.

Besides, the work reveals the problems related to processing and nonlinear analysis of electromyograms characteristics for different muscles displaying normal activity under physical load.

During experimental research the skin interference electromyograms of healthy volunteers were recorded in laboratory conditions, processed and analyzed using a specially developed information – measuring system [5].

Physical loading of the specified groups of muscles was provided by their burdening of various kinds, with weight varying from 1 to 16 kg. The tests were performed as the bioelectric signals were recorded in the form of skin electromyograms for 10 healthy test subjects.

Among the research methods used, the delayed-coordinate method was the principal one. Reconstruction of a dynamic system in the phase space was based on analysis of the time realization of a bioelectric signal as a one-variable function [6]. This system is characterized by two parameters: correlation dimension d and Kolmogorov entropy E. An algorithm for the delayed-coordinate method was adapted to analysis of electromyograms [7]. To obtain fuller characterization of the processes under study, the same electromyograms were in parallel subjected to processing and analysis by the spectral correlation method [8].

The parameters of the delayed-coordinate and spectral correlation methods were calculated when processing the bioelectric data: correlation dimension d, Kolmogorov entropy E, spectral power density, maximal frequency of a spectrum f, intensity of the spectral components of a signal having the amplitude no less than 0.7 of the maximal amplitude $\sum_{i=1}^{n} \frac{S_i}{S_0}$

(S_0- spectral power density over the total frequency range of an electromyogram, Si - spectral power density for the i–th component of an electromyogram; i=1, . . . , n - number of the spectral components having the amplitude no less than 0.7 of the maximal amplitude).

This work presents the results received from analysis of the two types of muscular groups for healthy volunteers.

Phase diagrams of the electromyograms recorded for triceps at the control state () and under a physical load of 7 kg are shown in Fig. 1.

As seen, localization of the phase diagrams is different. With an increasing load of the examined muscle the localization area is growing. The parameters summarized in Tab. 1 and

*E-mail: sidorenkoa@bsu.by

calculated by the delayed-coordinate method are decreasing as the physical load increases, pointing to the reduced number of degrees of freedom for the dynamic system and to its increased stability.

A decrease in the parameters obtained by the spectral correlation method is also observed. A maximal frequency of the spectrum is decreased by a factor of 3, and the spectral power density for the components at a level of 0.7 is reduced by about a factor of 7.

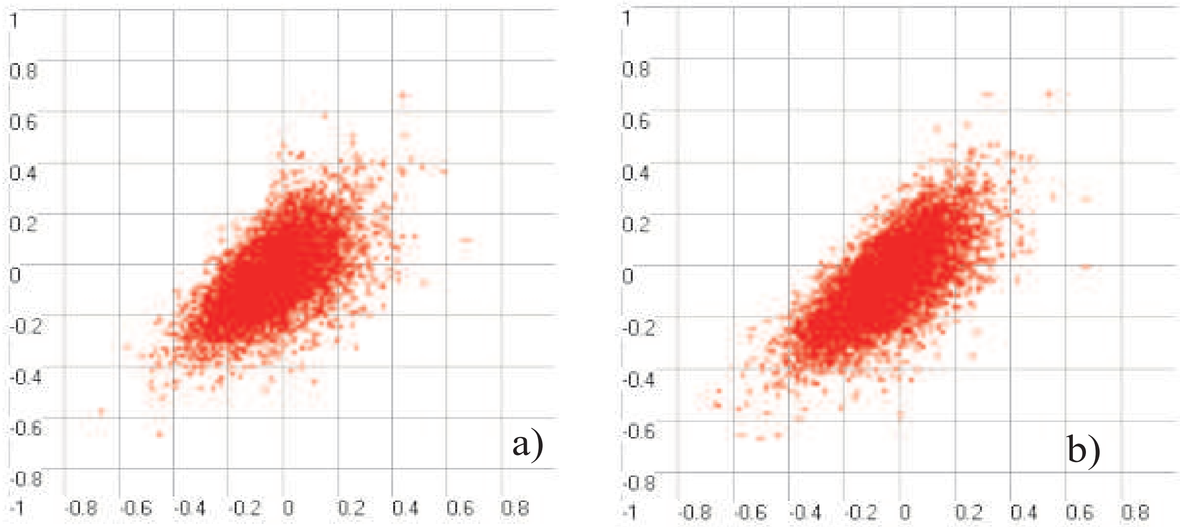

FIG. 1. Phase diagrams of the triceps skin electromyograms of a healthy person without physical load (a) and under a physical load of 7 kg (b).

Table 1: Parameters of interference surface electromyograms recorded for human triceps.

Loading, kg	Correlation dimension, d	Kolmogorov entropy, E	Spectral power density, $\sum_{i=1}^{n} \frac{S_i}{S_0}$	Maximal spectral frequency, f, Hz
Subject 1				
Control	2.6119±0.077	0.02481±0.002	0.0700±0.01	101.3±3.1
1	2.5952±0.061	0.0193±0.002	0.0585±0.01	73.6±2.3
3	2.5801±0.064	0.0087±0.01	0.0241±0.01	50.1*±2.1
7	2.5524±0.060	0.0074*±0.002	0.0124±0.01	33.4±2.0
* Error probability$p \leq 0.05$				

The phase diagrams obtained when processing the biceps electromyograms recorded for one of the examined subjects are demonstrated in Fig. 2.

As seen from the phase diagrams, with the load increasing from 1kg (Fig. 2a) to 6kg (Fig. 2b) the localization area is also increased. With further increase in the load from 6kg (Fig. 2b) to 16kg (Fig. 2c), the prevailing muscle-weariness effects lead to changes in the form of the phase- portrait localization area.

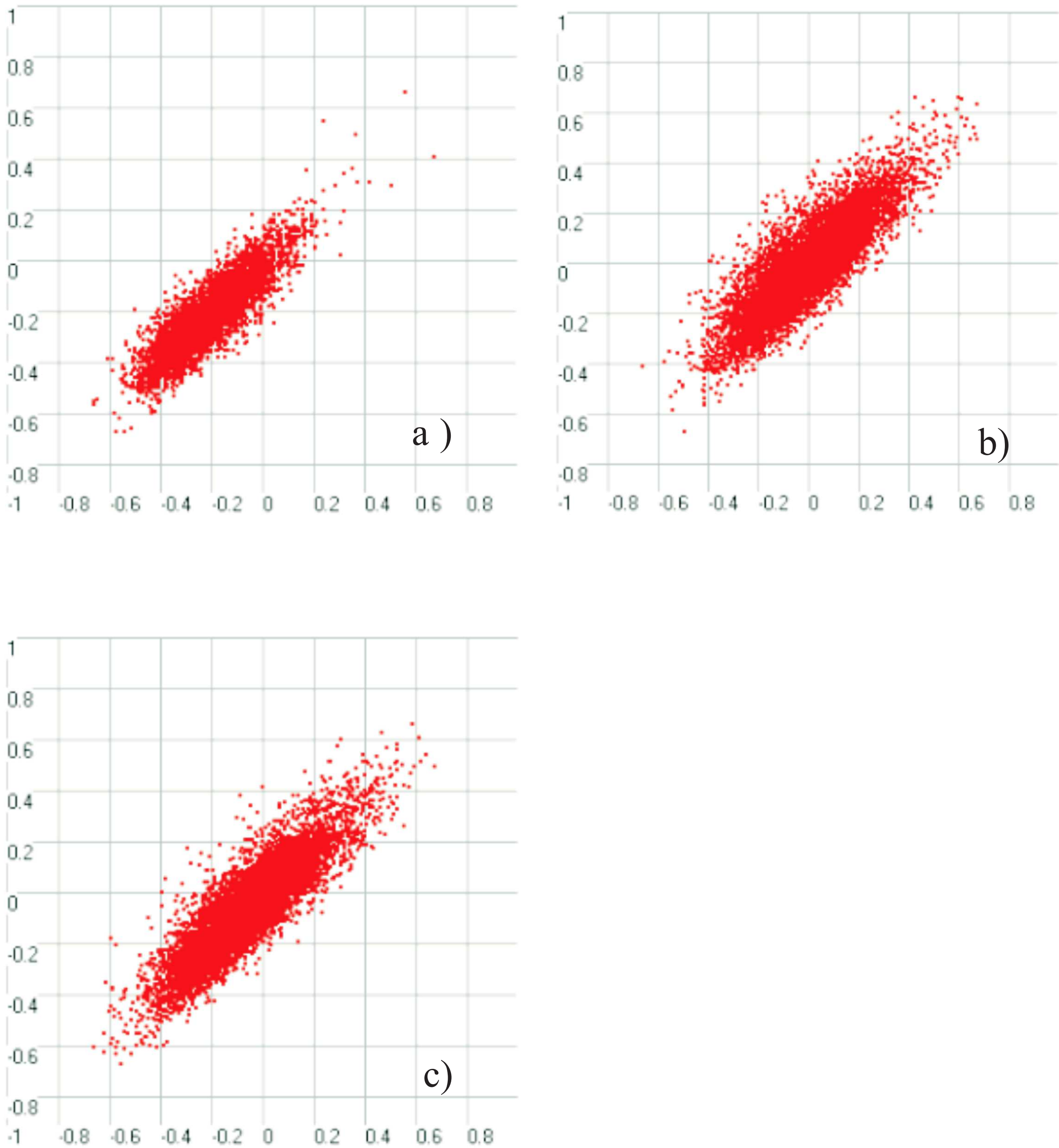

FIG. 2. Phase diagrams of the biceps skin electromyograms recorded for a healthy person under a physical load of 1kg (a), 6kg (b), and 16 kg (c).

It is seen in Tab. 2 that with increasing physical load of biceps from 1kg to 16kg the correlation dimension d of the analyzed electromyograms is decreased as well as the value of Kolmogorov entropy E.

The data demonstrate that the dynamic system undergoes the transition to a more stable state with less degrees of freedom.

The electromyogram parameters obtained by the spectral correlation method, including the spectral power density of the components at a level of 0.7, indicate a decrease as the physical load increases from 1kg to 16kg (Tab. 2)

As demonstrated by analysis of the parameters of interference skin electromyograms recorded for biceps and triceps, the processes in the muscles due to an increased physical load result in lower nonlinear dynamics (correlation dimension d and Kolmogorov entropy E) and in decreased values of the parameters (maximal frequency of a spectrum and spectral power density of the

Table 2: Parameters of interference surface electromyograms recorded for biceps.

Load, kg	Correlation dimension, d	Kolmogorov entropy, E	Spectral power density, $\sum_{i=1}^{n} \frac{S_i}{S_0}$	Maximal spectral frequency, f, Hz
Patient 1				
Control	2.6421±0.082	3.06*±0.68	0.09863±0.02	54.1±2.1
1	2.6266±0.079	2.32±0.72	0.09526±0.02	48.0±1.9
6	2.6200±0.076	0.00572±0.002	0.0912±0.01	40.8*±1.8
16	2.5543±0.083	0.000694*±0.0002	0.07245±0.01	36.3±1.6
*Probability error $p \leq 0.05$				

components at a level of 0.7) obtained by the delayed-coordinate method. This suggests that with increasing physical load there is a tendency to the involvement of less motor elements in the formation of a skin electromyogram.

In conclusion it may be inferred that the quantitative data on nonlinear dynamics (correlation dimension d and Kolmogorov entropy E) determined by the delayed-coordinate method may be accepted as a criterion for estimation of a functional state exhibited by the human nervous - muscular system.

References

[1] Grigoriev Yu. G., Stepanov V. S. Electromagnetic human safety. - .: Russian National Committee on Non-Ionizing Radiation Protection, 1999. – 150 p.

[2] Sidorenko L. V. thods of information analysis of bioelectric signals. – insk.: Belarusian State University, 2003. – 189 .

[3] Andreeva +. L., Chutorskaya +. +. Spectral method of the muscle electric activity analysis. – .:Nauka, 1987. – 105 p.

[4] ntsev V. N., Zabolotnych. The Methodic Basis of Clinical Electromyography. – S.-Peterburg, 2001. -230 p.

[5] Sidorenko L. V., Solonovich N. L., Selitsky L. P. Information-Measuring System for Estimation of the Brain and Heart Dynamics Functional State // Biomedical Technologies and Radioelectronics. – 2005. – 10. – P. 65 – 70.

[6] Sidorenko L. V., Chodulev V. I., Selitsky L. P. Nonlinear Dynamics of Electromyograms // Biomedical Technologies and Radioelectronics. – 2005. – 11. – PT. 53 – 59.

[7] Sidorenko L. V. Nonlinear Analysis of Interference Electromyograms of Human in Norm and Pathology.// Electronics. – 2006. – 8. – P. 62 – 63.

[8] Sidorenko L. V., Chodulev V. I., Selitsky L. P. Ponomarev V.V. Neuromedium treatment of compression-ishemya nueropathy of radiate nerve by using nonlinear electromyogram analysis// dical panorama. – 2006. – 6. – P. 46 – 49.