GENERAL PATHOLOGY AND PATHOPHYSIOLOGY

New Aspects of the Influence of Quadriceps Femoris Muscle Stimulation Course on Functional Capabilities of the Organism

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We studied the effect of a course of electrical stimulation of the quadriceps femoris muscle with submaximal contraction under biofeedback conditions on functional capabilities of the organism. In addition to the known effects, electrostimulation course modulated the content of intra- and extracellular fluid and increases MDA content and creatine phosphokinase activity, which can be a manifestation of overtreatment. Impairment of body static balance after the course was revealed. Thus, monitoring of the effects of electrostimulation is required during the course.

Key Words: *electrical stimulation; quadriceps muscle; maximal voluntary contraction*

Electrostimulation (ES) is a widely used method of restorative medicine [1].

Hypotrophy of the quadriceps femoris muscle (QFM) in the absence of innervation disturbances after trauma or in knee joint disease is a complex problem of restorative medicine [2]. QFM recovery after traumas and surgeries can take many years, because knee joint pathology of practically any genesis is associated with numerous problems, including reflectory [4,5]. We hypothesized that the analysis of the effects of ES course can reveal additional criteria of impact assessment.

The aim of the study was to reveal the effect of ES course with monitoring of voluntary muscle contraction level on general functional condition in patients with patellofemoral arthrosis.

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MATERIALS AND METHODS

Experiments were conducted on 12 men aging 20-34 years with patellofemoral arhtrosis. Inclusion criterion was the absence of contraindication for ES. The experimental protocol was approved by ethical committee of Institute of Physical Culture and Athletics.

All examinees received a 10-day QFM ES course with a 2-day break in the middle. ES was performed in patients sitting in a chair of an isokinetic dynamometer BioDex, the angle of knee flexion was 45°. Kotz currents were used (pulse duration 10 sec, pause 50 sec, modulation frequency 50 Hz; duration of trapezoid pulse 10 msec; carrier frequency 2500 Hz). The exposure was conducted using Amplidin EST apparatus, EST mode, program P-4. Electrodes (3×10 cm) were fixed on a line between the upper and middle thirds of the stimulated thigh (cathode) and above the patella in the lower third part of the thigh (anode). ES was performed with submaximal current tolerated by the

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examinee. Submaximal current was determined before ES. The patient was asked to toughen QFM during the stimulation during the course of ES to maintain the level previously shown on the display. To this end, biofeedback mode mediated by a hardware-computer complex was used. Before ES procedure, we recorded three maximal voluntary contractions of QFM followed by 10 electric stimulations conducted simultaneously with maximal voluntary muscle contraction. The stimulation was performed on the muscle of the injured leg.

Experimental scheme included control testing of subjects before and after ES course: measurement of ECG, heart rate, blood pressure, anthropometry, psychophysiological testing, bioimpedance measurement, stabilometry, and Biodex isokinetic dynamometry.

On days 1 and 10 of ES, blood samples were collected and MDA content and creatine phosphokinase activity were measured.

Before the start of ES, medical examination and interview for detection of possible contraindications were conducted. Bioimpedancemetry was performed before and after ES course using an ABC-01 Medass analyzer (program ABC-0452, segmental analysis) in hand-leg lead at a frequency of 50 Hz with measurement of active and reactive resistance, phase angle, fat-free weight and fat content, and intracellular, extracellular, and total fluid for the leg segment.

RESULTS

Comparison of morphological indices revealed the absence of significant changes in body weight after ES course.

Analysis of the results of isokinetic dynamometry revealed marked changes of the isokinetic power with significant increase in the peak torque (PT) and PT/kg at medium and high speeds for both legs. At low angular speed, PT and PT/kg on the stimulated leg remained practically unchanged (increase by ~2-3%). At medium angular speed, the positive changes were significant. Power increment at high angular speed was 14% for the stimulated leg.

No significant changes in psychophysiological indices were observed after ES course.

Along with the previously described effects, significant differences in the level of intracellular fluid in the stimulated leg before and after ES were revealed in subjects for the first time (Table 1).

Bioimpedance of the stimulated and non-stimulated legs significantly decreased, reactive (25.58%) and active (15.83%) resistance was more pronounced in the stimulated leg.

Creatine phosphokinase activity was initially within the normal range; single ES procedure did not change enzyme activity in blood serum. However, a course consisting of 10 ES increased creatine phosphokinase activity to 284.3±191.1 U/liter. Moreover, single ES procedure increased MDA concentration from 6.0±1.3 to 7.4±2.6 nmol/ml and significantly increased the basal MDA concentration by the 10th ES procedure (Fig. 1). These results are in line with observed changes in bioimpedance indices, because they characterize changes in the permeability of myocyte membrane in the stimulated group of muscles.

Stabilometry revealed signs of imbalance (increased rate of pressure center displacement and shift of the general pressure center). The 10-day ES course led to body weight redistribution, which primarily manifested in the shift of the position in the frontal plane. In upright standing position on both feet with eyes open, the rate of pressure center displacement was increased.

For monitoring of the efficacy of ES effect, the maximal voluntary force (including the dynamics of

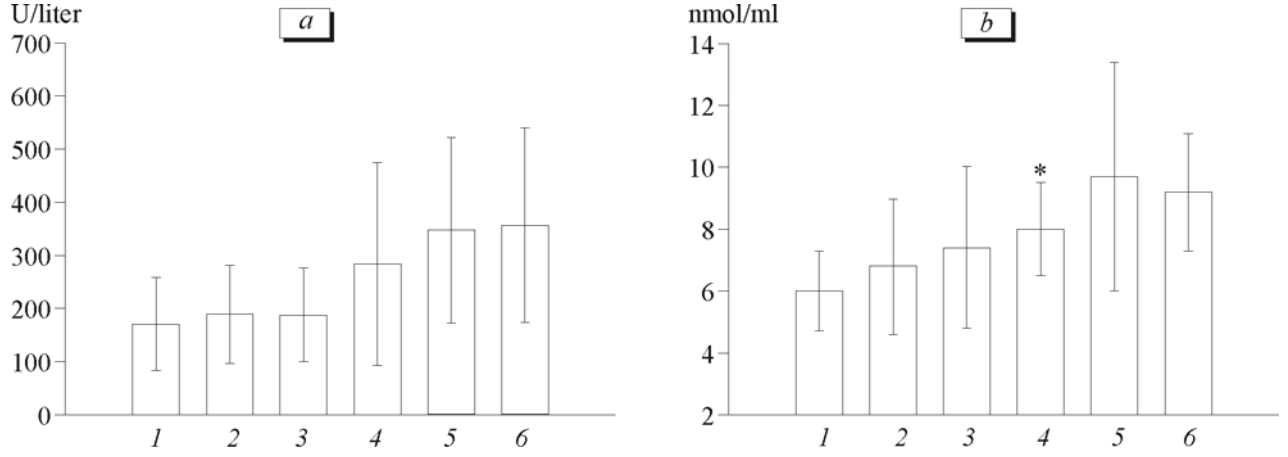

Fig. 1. Effect of stimulation on creatine phosphokinase activity (*a*) and MDA concentration (*b*). *1-3*: on day 1 of ES course: *1*) before ES; *2*) immediately after ES; *3*) 30 min after ES; *4-6*: on day 10 of the course: *4*) before ES; *5*) immediately after ES; *6*) 30 min after ES. *Difference is significant at $p<0.05$.

TABLE 1. Impedance Characteristics of Stimulated and Non-Stimulated Thigh in Patients before and after ES Course ($\bar{X}\pm\sigma$)

Index	Before ES	After ES	Δ	%Δ
Stimulated thigh				
Active resistance, Ω	55.43±16.03	46.65±5.10	-8.78	-15.83
Reactive resistance, Ω	16.13±4.20	12.00±2.75	-4.13	-25.58*
Intracellular fluid, liters	5.06±0.51	4.96±0.25	-σ0.10	-1.98*
Non-stimulated thigh				
Active resistance, Ω	49.38±6.92	47.50±5.37	-1.88	-3.8
Reactive resistance, Ω	14.80±2.03	12.93±1.33	-1.88	-12.67
Intracellular fluid, liters	5.07±0.41	4.99±0.42	-0.08	-1.58*
Rate of pressure center displacement, mm/sec				
right leg	31.54±7.92	1.47	4.87	
left leg	30.83±6.00	32.61±6.17	1.77	5.75
open eyes	7.47±2.19	9.17±2.09	1.70	22.73
closed eyes	11.81±3.24	11.97±2.41	0.16	1.31

Note. *$p<0.05$.

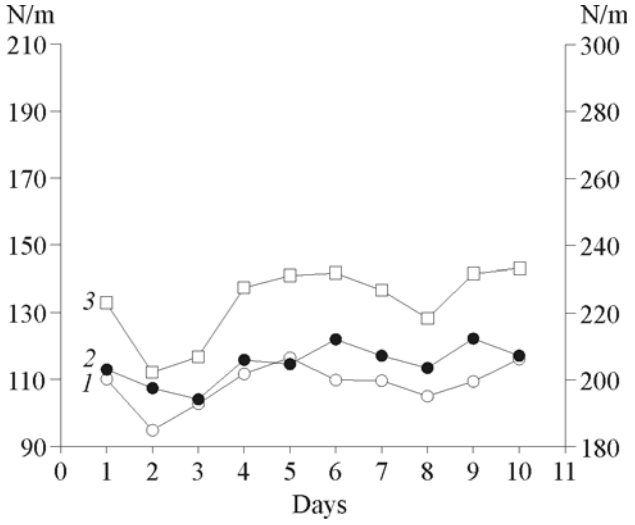

Fig. 2. Daily dynamics of maximum voluntary force (*1*), maximum voluntary force upon simultaneous ES impulse (*2*), total power (*3*). Left ordinate for *1* and *2*, right ordinate for *3*.

three maximum static tensions, mean voluntary tension during ES, and total work) was daily measured.

The dynamics of total work tended to increase with peak achievement and maintenance on days 5-6 of the course (increase by 21.7 N/m and 22.9% compared to day 2 of ES), a decrease on days 7-8, and subsequent increase on days 9-10 to the level attained on days 5-6 (Fig. 2).

Thus, apart from expected increase in power capabilities (maximal voluntary force and dynamic force upon isokinetic testing at medium and high speeds), the following effects were revealed: decrease in intracellular fluid content, increase in reactive resistance, elevation of MDA content, impairment of body static balance, and attaining force maximum on days 5-6.

The increase in MDA level against the background of the decrease in intracellular fluid content can be indicative of overtreatment [3]. Impairment of the static balance is probably associated with unilateral application of ES procedures. Attaining of the maximal force on day 5-6 of ES course can attest to body adaptation to the treatment (decrease of response to ES) and to the necessity of revision of the number of procedures in the course. Monitoring of the contraction level is necessary for determination of the required number of procedures or for revision of the exposure parameters. Similarly as any other treatment, ES should be strictly dosed and given depending on initial functional body state and should be adjusted to changes of current state.

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