Cross Effect of Electrostimulation of Quadriceps Femoris Muscle during Maximum Voluntary Contraction under Conditions of Biofeedback

V. V. Arkov, T. F. Abramova, T. M. Nikitina, D. A. Afanasjeva, D. V. Suprun, O. N. Milenin, and A. G. Tonevitsky

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny,* Vol.149, No. 1, pp. 101-103, January, 2010
Original article submitted September 22, 2009

We describe cross effect of enhancement of muscular power and electrical activity during electrical stimulation. Due to the use of electrostimulation method with biological feedback and effort visualization for the examinee, its expression on non-stimulated leg by some indices approached that on the stimulated leg.

Key Words: *electrical stimulation; quadriceps muscle; isokinetic dynamometry; maximum voluntary contraction; cross effect*

Speed and power properties of muscles are important components in the evaluation of functional state of the body, individual groups of muscles, and overall physical condition and special training of an athlete. Cross effect is a phenomenon, when regular muscular activity of one limb induces similar changes in the homologous muscles on the contralateral side of the body. Increase in dynamometry indices was revealed in the course of one standard electrostimulation (ES) procedure: increment of isokinetic moment on non-stimulated limb was about 5% from the baseline [5]; 4-week ES course resulted in isokinetic moment increase up to 10%; 8-week ES course produced a 20% increase [2].

During power training, the cross effect on homologous muscles of contralateral limb is about 10-15% [1].

The aim of the study was to estimate the effect of ES course with biofeedback on the power of non-stimulated leg.

MATERIALS AND METHODS

Experiments were conducted on 12 men (age 23-34 years) with unilateral patellofemoral arhtrosis. Inclusion criterion was the absence of contraindication for ES. Experimental protocol was approved by ethical committee of Institute of Physical Culture and Athletics.

All subjects received a 10-day course of ES of quadriceps femoris muscle (QFM) with a 2-days break after 5 days of stimulation. ES was performed in patients sitting in the chair of isokinetic dynamometer BioDex, knee flexion angle was 45°. Kotz currents were used (10 sec pulse duration, 50 sec pause, 50 Hz modulation frequency; duration of trapezoid impulse 10 msec; carrier frequency 2500 Hz); the exposure was conducted using Amplidin EST apparatus, EST mode, program P-4. The electrodes (3×10 cm) were fixed on the line between the upper and middle third parts of stimulated thigh (cathode) and above the patella in the lower third part of the thigh (anode). ES was performed at submaximal current level tolerated by the subject. Submaximal current rate was determined before ES. The patient was asked to strain QFM during the stimulation impulse and to maintain the level displayed on the screen in the course of ES. In order to help the patient to maintain the level of muscle tension, we used biofeedback mode mediated by a hardware-software complex consisting of volume sensor fixed in the middle of the thigh (inflation up to 45 mm Hg), polygraph device, and computer with

Institute of Physical Culture and Athletics, Moscow, Russia. ***Address for correspondence:*** afanasjevada@gmail.com. D. A. Afanasjeva

0007-4888/10/1491-0093

Neocortex software allowing real-time visualization of volume sensor readings. In the beginning of ES procedure, three maximum voluntary QFM contractions were recorded with subsequent 10 electric stimulations conducted simultaneously with maximum voluntary muscle contraction. The stimulation was performed on the muscle of the bad leg.

Before and after ES course, isokinetic testing of leg flexor and extensor muscles was performed using BioDex dynamometer at angular speeds 60, 180 and 300 sec^{-1} with estimation of peak torque (PT) and its relative value (PT/kg).

RESULTS

After a 10-day course of ES, the following changes in isokinetic power were revealed in the group (Table 1). At low angular speed, changes of PT and PT/kg in the stimulated leg were almost absent. At medium angular speed, the power increment in the stimulated leg was 19.10 N/m (16.6%) and in non-stimulated leg 17.95 N/m (14.21%). At high angular speed, the power increment in stimulated leg was 12.57 N/m (14.25%), and in non-stimulated leg 18.33 N/m (23.88%).

The cross effect, revealed in the test groups (up to 23.88% at high speed) during quite a short (2 weeks) ES course can be explained by specific feature of ES procedure. Voluntary maintenance of the required effort and its visualization, probably, involve all CNS regions. During maximum voluntary contraction of QFM on the stimulated leg, simultaneous work of other groups of muscles is observed. It was previously shown that the power increment on non-stimulated leg in the course of stimulation does not exceed 10% after 4-week ES course [5] and 20% after 8-week ES course [2].

It is known that after usual training, the power obtained by the contralateral limb is on average 60% from the power increment on the trained limb [6].

In the applied method, when the examinee directly observed the level of contraction, the cross effect of power increase at high testing speed was stronger on non-stimulated leg, than on stimulated leg. This effect can be associated with complicacy of strengthening of weak QFM in patients with patellofemoral arthrosis on the affected side [4]. The obtained effect can be used for ES method development.

Thus, as a result of ES course conducted according to the method with visual feedback and submaximal voluntary contraction, there occurs an increase of QFM dynamic force in the group of patients at medium and high speed of isokinetic dynamometry on stimulated (16.6 and 14.25%) and non-stimulated (14.21 and 23.88%) legs. We demonstrate a strong cross effect of non-stimulated muscle of thigh expo-

TABLE 1. Time Course of Isokinetic Dynamometry before and after ES Course in Groups of Subjects

Angular speed, sec^{-1}	Index	Stimulated thigh						Non-stimulated thigh					
		before ES		after ES		Δ	%Δ	before ES		after ES		Δ	%Δ
		$\bar{X}$	σ	$\bar{X}$	σ			$\bar{X}$	σ	$\bar{X}$	σ		
60°	PT	189.50	69.21	194.65	72.11	5.15	2.72	200.27	39.85	225.97	44.54	25.70	12.83
	PT/kg	238.77	93.82	244.88	94.74	6.12	2.56	242.28	43.52	271.72	42.27	29.43	12.15
180°	PT	115.73	42.85	134.83	40.00	19.10	16.60*	126.33	12.89	144.28	16.20	17.95	14.21*
	PT/kg	140.22	49.04	162.35	42.36	22.13	15.79*	154.28	25.60	174.73	17.81	20.45	13.25*
300°	PT	88.18	26.23	100.75	31.72	12.57	14.25*	76.78	13.29	95.12	9.67	18.33	23.88*
	PT/kg	106.85	30.30	121.02	32.99	14.17	13.26*	93.87	21.08	115.48	14.70	21.62	23.03*

Note. *Values are significant at $p<0.05$.

sure, which appears upon 10-day ES course and opens up new possibilities for ES methods development. In particular, this effect is specifically important for stimulation of a limb, which is currently immobilized.

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