AN EXPERIMENTAL STUDY OF THE EFFECTS OF ELECTRICAL STIMULATION ON STRENGTH AND FLEXIBILITY

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Electrical stimulation (ES) in muscles has widely applied in muscle strength training as a training method. It was proven to greatly enhance muscle strength. The purpose of this study was to examine the changes in muscle flexibility in the training of muscle strength with the use of electrical stimulation. The experiment demonstrated that the use of electrical-stimulation in training (EST) could obtain the effects of the improvement in both of muscle strength and flexibility.

KEY WORDS: electrical stimulation, muscle strength, flexibility

INTRODUCTION: The ES approach is believed to be one of the more effect modern training methods. Use of ES for 3~8 weeks can increase muscle strength by 7~58% and can exert a positive influence on the structure of skeleton-muscle. Most of studies on the use of EST were only focused on its effect to increase muscle strength rather than its effect on muscle flexibility. In order for further development and improvement of the ES approach, it is necessary to examine the changes in muscle flexibility while in the process of increasing muscle strength by ES. Combined research on muscle strength and flexibility not only has the potential to raise the training value of the ES approach but also serves to perfect the training methods of muscle strength and flexibility for athletes.

METHODS: Subjects. The subjects selected for this study were 30 males, who had majored in sports training in at the university level. They were divided into three groups.

Table 1 Physical Characteristics of Subjects

	Group I	Group II	Group III
Number	10	10	10
Height (cm)	178.2±4.3	182.4±3.9	176.6±4.1
Weight (kg)	68.7±4.9	72±3.6	71.3±5.9
Age (years)	19.4±1.2	19.8±1.6	20.1±1.2
Training (years)	6.4±1.4	7.1±1.7	6.8±1.6

I ----- subjects with the ES of both hamstring group of muscle and quadriceps femoris
II ----- subjects with the ES of quadriceps femoris
III ----- subjects with the ES of hamstring group of muscle

Design. The experiment lasted for 7 weeks. The 1st and the 7th week were the testing weeks. From the 2nd to the 5th week the EST was conducted. The sessions were as follows: 3 times training per group per week; 3 units each time; 10 EST each unit. Each EST lasts for 15 seconds, with 25-second interval in between.

A T90-1 ES muscle strength trainer was applied, with a carrier frequency of 2500Hz, in 50 pulsed bursts per second. The strength of the electrical charge depends on the amount that the subject can tolerate. The stimulating points were located at each end of the abdominal muscles.

A pulling force sensor was utilized to measure the muscle strength of knee extension and flexion. An electrical goniometer was used to measure knee joint angle and the extension distance of the upper limbs of the same sides (the subject's legs form a right angle).

Data Analysis. Before and after each experiment of each index, analysis was conducted by SPSS Paired-Samples T Test. All statistical procedures were performed at a 0.05 level of significance.

RESULTS: Table 2 lists sebo-thicknesss and thigh girth, comparing pre-test and post-test. The means, standard deviation and percentage of difference in muscle strength of quadriceps femoris and hamstring measured in pre-test and post-test are presented in Table 3. Table 4 presents the means, standard deviations in knee joint angle, the extension distance of the upper limbs, and the percentage difference among groups and between the pre- and post-test.

Table 2 **Pre-test and Post-test, Sebo-thickness and Thigh Girth and their Percentage Difference for Each Group**

		Sebo-thickness	S	Difference (%)	thigh girth	S	Difference (%)
I	1	7.89±1.7	0.75±0.8	9.5	52.5±1.2	0.17±2.1	0.3
	2	7.13±2.0			51.2±1.3		
II	1	8.35±1.8	0.48±0.3	5.7	51.7±0.7	0.91±0.7	1.2
	2	7.85±1.9			50.8±0.8		
III	1	7.65±2.1	0.31±0.4	4.1	54.6±2.4	0.72±0.4	1.3
	2	7.36±1.8			53.9±2.6		

1 - pretest; 2 - posttest

Table 3 **Muscle Strength of Quadriceps Femoris and Hamstring Group of Muscle of Pre- and Post-test**

		Extension (kg)	S	Difference (%)	Flexion(kg)	S	Difference (%)
I	1	29.7±3.3	5.8±2.7	19.5	26.8±0.5	4.2±2.5	15.7
	2	34.5±2.5	**		30.8±7.9	**	
II	1	28.6±3.4	4.7±3.5	16.4	24.2±2.1	2.1±2.8	8.7
	2	33.2±4.9	**		26.6±3.4	*	
III	1	28.2±6.4	3.1±1.8	9.2	23.8±1.8	3.9±1.6	16.4
	2	30.4±2.9	*		27.8±3.4	**	

1 - pretest; 2 - posttest
*P<0.05, **P<0.01

Table 4 **Descriptive Statistics for Pretest and Posttest Flexibility and Percentage Difference**

		Knee angle(°)	S	Difference (%)	Distance (cm)	S	Difference (%)
I	1	66.3±4.2	8.2±4.7	12.4	18.8±4.0	2.4±3.8	12.8
	2	58.3±4.9	*		21.2±4.2	*	
II	1	74.8±9.1	5.3±10.1	7.1	19.5±8.4	2.8±6.7	14.4
	2	69.5±8.6			22.6±8.0	*	
III	1	61.2±8.8	7.4±6.8	12.1	15.1±4.7	1.7±4.6	11.3
	2	53.8±5.7	*		16.4±4.9	*	

1 - pretest; 2 - posttest
*P<0.05, **P<0.01

DISCUSSION: The results of analysis showed that increase in strength was found in quadriceps, femoris and hamstring muscle. Both of quadriceps femoris and hamstring muscle were given electrical-stimulation simultaneously (Goup I). The strength of quadriceps femoris was raised by 19.5% (p<0.05) and the hamstring muscle strength was also increased by 15.7% (p<0.01). When only quadriceps femoris was exposed to ES (Group II) there was an increase in strength of 16.4% ($p<0.05$) while hamstring muscle's strength increased only 8.7%($p<0.05$). When only the hamstring muscle was treated (Group III), quadriceps femoris' strength improved by only 9.2% ($p<0.05$), and the hamstring muscle improved by 16.4% ($p<0.01$).

Physiological studies found that most muscle spindles were controlled by two sensory nerve fibers. One was primary afferent fiber, accept for stretching temporary and degree, Another was secondary afferent fiber, accept for stretching degree, stimulate r-neuron to induce muscle spindle contraction, and connected with a motorneuron which control extra-spindle muscle to lighten stretching. The reason of enhancing strength by executing electric-stimulation to quadriceps femoris or hamstring muscle might be related to body's conductive function. When quadriceps femoris is executed electrical-stimulation, hamstring muscle also accept stimulation; similarly, when hamstring muscle is executed training, quadriceps femoris also trained. Along with increasing the electric current intensity, antagonists muscles nervous degree significantly increased. Thus when agonists muscle is executed electrical-stimulation, antagonists muscles contracted and improved in strength. On the other hand, one to the training is executed in static state the stimulated quadriceps femoris make the leg stretch, while hamstring muscle contracted to impress the leg stretch. Under the action of extensor and flexor simultaneously, the subjects' lower extremities were in the balance of static, thus the antagonicsts muscle strength increased also.

The results showed that sebo-thickness decreased 9.5% and thigh girth decreased 0.3%. The subjects of group II decreased 5.7%, and 1.2% respectively, Group III reduced 4.1% and 1.3% (Table2). The results showed that electrical—stimulation training increased the flexibility of quadriceps femoris by 12.4% ($p<0.05$), and that of hamstring muscle increased 12.8% ($p<0.05$). When both quadriceps femoris and hamstring muscle were executed electrical—stimulation (group I). Only quadriceps femoris was executed electrical stimulation (group II), its flexibility improved 7.1% ($p<0.05$) and hamstring muscle's improved 14.4% ($p<0.05$); Only hamstring muscle was executed electrical stimulation, (Group III), quadriceps femoris flexibility was improved 12.1%($p<0.05$), hamstring muscle's improved 11.3% ($p<0.05$).

Flexibility reflects the extent of joint activity and elasticity and extending ability of ligament, muscle, tendon, skin, etc which across the joint. It includes two meanings. One is extent of joint activity, the other is extending ability of muscle, tendon, ligament around the joint. Flexibility is affected by the properties of the tissues, such as muscle, ligament and muscle tendon, and joint construction, tissues around the joint, age sex, temperature, and tiredness, etc.

This study showed that the muscle strength and flexibility both increased by ES training. Electrical—stimulation can reduce muscle sebo-thickness Both quadriceps femoris and hamstring muscle were executed electrical—stimulation, sebo-thickness reduced 9.5%; Only quadriceps femoris was executed, sebo-thickness reduced 5.7%; Only hamstring muscle was executed electrical—stimulation, sebo-thickness reduced 4.1%. The surface of myofibrils and muscle cell covers a thin fat tissue. Electrical—stimulation not only reduced sebo-thickness, but also consumed fat tissue covered on the surface of myofibrils and muscle cell, so that it reduced muscle adhesive Therefore, It increased muscle strength and flexibility.

ES could decrease significantly thigh girth also reduce contraction of soft tissue that may be one reason of flexibility improvement. On the other hand, ES can repress muscle stretch reflex The receptor of muscle's length and tension can activated or impede muscle contraction, perhaps when the muscles is stretched, its antagonist muscles will deter its length, therefore ES can improves muscle inflexibility.

CONCLUSION: ES can significantly improve strength of antagonists muscles, so that it makes agonists muscle and antagonists muscle synchronize development. ES can significantly improve flexibility of agonists muscle and antagonists muscle at same time. ES can make strength and flexibility development synchronize and coordinately.

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