ELECTRICAL STIMULATION OF THE TRICEPS SURAE FOR MUSCULAR STRENGTH IMPROVEMENT IN VOLLEYBALL PLAYERS.

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INTRODUCTION

Beside the studies carried out at "Centro Scoliosi" of Istituto Ortopedico "Gaetano Pini" about idiopathic scoliosis pathogenesis (Dacquino et al., 1970) and its treatment using the electrical stimulation (Crivellini and Divieti, 1972, 1975; Crivellini et al., 1976, 1979; Divieti, 1979), an experiment was carried out to analyze the muscular strength increase, obtained by means of the same stimulation procedure for the scoliotic patients. The triceps surae muscle was chosen because of its size and accessibility. The electrical stimulation was performed on a group of subjects not involved in any sporting activity by Caiulo et al., 1980b. This study has shown that electrical stimulation increased the maximum spontaneous force (31.9%), the jumping index (23.7%) measured with the Abalakov method (Kots and Xvilon, 1971; Kots et al., 1971), and the maximum limb circumference (6%) measured near the belly of the stimulated muscle. Moreover this experience has shown that the stimulation of the whole gastrocnemius muscle, with well tolerable current values, causes not only the contraction of the triceps surae muscle but also the contraction of the posterior tibialis muscle, normally quite difficult to stimulate because it is deeply positioned under the soleus muscle. In this work the force of the triceps surae was transduced by means of a particular experimental device . The force of this muscle is measurable considering the action of the foot during the flexion movement. The same experiment was repeated on a group of athletes of a volleyball team in order to compare the results. It is important to note that the electrical stimulation first recruits the big superficial motor units that are the last activated in maximal voluntary contractions.

METHODOLOGY

Electrodes

The electrodes consisted of sheets of silver in a 4 x 4 cm rectangle, 1 mm thick. The electrodes were put in suitable flannel covers that were soaked in water. The skin was cleaned with ether before the electrodes were placed on it so as to improve conductivity. The electrodes were placed just above and below the belly of the muscle 4 to 5 cm apart according to the size of the muscle (Figure 1a). In every case the electrodes were so placed as to ensure maximum contraction.

Stimulator and stimulation parameters

The frequency of the current controlled voltage output was fixed at 2500 Hz. The following stimulation pattern was adopted: 10 s stimulation followed by a 50 s pause for 20 minutes each day for 15 consecutive days. A four channel stimulator was used. It was designed at the Istituto di Elettrotecnica ed Elettronica (now the Dipartimento di Bioingegneria) at the Politecnico di Milano and it was built by C.E.I.P. s.r.l. in Piacenza (Figure 1b). Particular care was paid to subject and operator safety in the design of the stimulator. The four channels are activated in sequence one by one for 10 s each. Then the stimulator keeps on standby status for 20 s and then restarts the cycle. The output voltage assumes values between 0 and 100 V (peak to peak). The value of the output peak current appears on a digital display. Each output channel is current controlled and the maximum peak current value is limited at 150 mA.

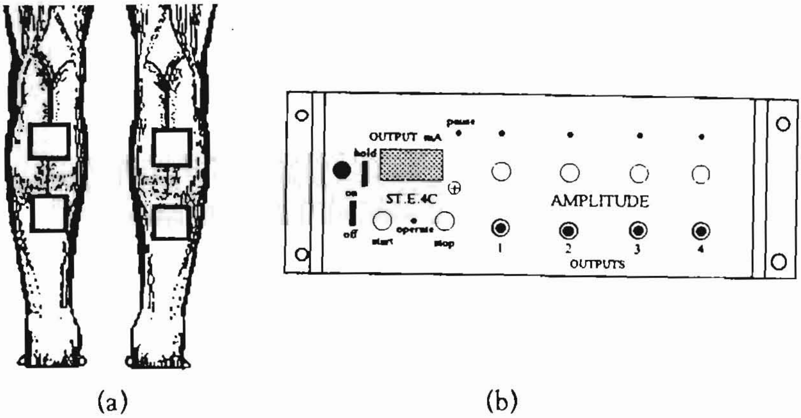

Figure 1. a) Positioning of the electrodes on the triceps surae muscle; b) electrical stimulator ST.E.4C.

Device for spontaneous force measurement

In order to transduce the maximum spontaneous force developed by the triceps surae a special bed, adjustable in length, was built. The subject rests in prone position on the bed with the knees on adjustable supports to maintain the legs in maximal extension position. The action of the gastrocnemius muscle is at its best when the tibia and the femur are aligned. The feet of the subject rest on movable pedals mounted on the bed. The support of the pedals rotates around an axis coincident with the rotation axis of the foot. Behind each pedal a small hollow cylinder was suitably shaped and a strain gauge, working in bridge type configuration, was fitted to the pedal to transduce the axial force in isometric conditions. The strain gauges were connected to a pair of extensometric devices mod. GA 101 built by A.N.N.A. soc. in Milan and calibrated so as to indicate directly the values of the force (kg).

Subjects

This experiment was carried out on a group of five volleyball players from the age of 17 to 21 during the championship. The mean age was 18.6 years. The results were compared with a previous experiment carried out on a group of six young healthy people, from the age of 21 to 27 who were not involved in any sporting activity. All the subjects were treated by means of electrical stimulation of the triceps surae of both legs to increase muscle strength and to check variations in jumping ability. The triceps surae is one of the main muscles activated for jumping and its main action is plantar flexion of the foot.

Tests and measurements

Subsequent to the beginning of the stimulation cycle, after nine days and after 15 days the following measurements were performed on both legs:

1) maximum spontaneous force
2) jump index using the Abalakov method

3) maximum circumference of the limbs in relaxed state
4) maximum circumference of the limbs at maximum spontaneous contraction.
The maximum spontaneous force was measured isometrically with the equipment previously described. In the Abalakov jump test we measured the difference between the static height, the highest point that the subject can reach with his finger tips in standing position with both feet and heels on the ground, and the jump height, the highest point that the subject can reach with his finger tips jumping with a take-off of both feet. For both maximum spontaneous force and Abalakov test measurements the best result obtained in three trials was taken into account.

RESULTS AND DISCUSSION

During the stimulation cycle the maximum stimulation current tolerated without pain increased for all the athletic subjects by 45.7% from the first to the last day of stimulation. The value of the stimulation current was fixed by the subject himself. The current values for the right leg were greater than those for the left leg. The stimulation was performed isometrically, blocking the movement due to the induced contraction of the triceps surae muscle. The results and those obtained from previous work on the normal subjects are summarized in Table 1. The mean increment of the maximum spontaneous force after nine days of stimulation was 7.9 % and after 15 days was 17.8% (minimum final increment=5.6%, maximum final increment=28.3%). The mean increment of the Abalakov jump index after nine days was 9% and after 15 days 12.1% (minimum final increment=7.7%, maximum final increment=14.4%). The leg circumference after nine days increased 0.6% (relaxed muscle) and of 0.8% (contracted muscle); after 15 days the increment was 1.4% (relaxed muscle) and 1.5% (contracted muscle). The trend of the maximum spontaneous force is shown in Figure 2 for the right and the left leg. The effect of muscular strength increase on the asymmetry between the force of the two legs was also analyzed. The maximum force of the right triceps surae was greater than the left by a mean value=23.6 kg. (mean=23.1%, minimum=7.5%, maximum=34.3%). A similar asymmetry in the circumference was not appreciably different. The asymmetry index is computed as:

$$A\% = \frac{| F_{dx} - F_{sx} |}{\min(F_{dx}, F_{sx})} * 100$$

$$A_{absolute\ value} = | F_{dx} - F_{sx} |$$

where F_{dx} is force of the right leg and F_{sx} is force of the left leg. After nine stimulations the asymmetry index became greater not only absolutely (28.0 kg) but relatively (25.9%). At the end of the cycle the absolute asymmetry value was 36.8 kg (30.8%).

Table 1. Incremental changes in the experimental parameters following the stimulation cycle.

Mean % Increments	After nine days		After 15 days	
	Athletes	Normal	Athletes	Normal
Max. spontaneous force	7.9%	25.7%	17.8%	31.9 %
Abalakov test	9.0%	17.7%	12.1%	23.7%
Max. circumference (relaxed)	0.6%	5.2%	1.4%	6.3%
Max. circumference (contracted)	0.8%	4.5%	1.5%	5.7%

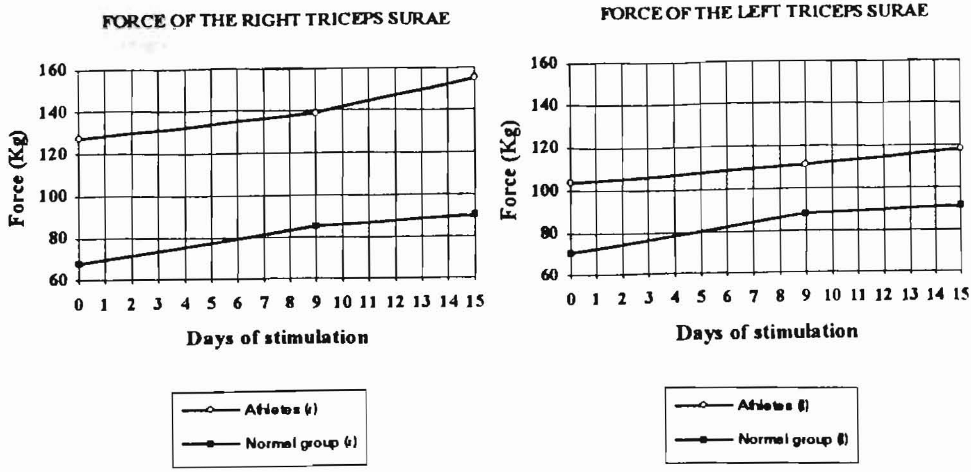

Figure 2. Trend of the maximum spontaneous force of the triceps surae for the right and the left leg.

CONCLUSIONS

This study showed the effect of electrical stimulation in improving muscular strength even on athletes produces good results. The increments for the athletes were lower than those of the normal subjects but even for the athletes the increments were enough to improve sport performance. The minimum result in the Abalakov index obtained with the electrical stimulation is only achievable through three months training jumping with an additional load on ankles and hips. In the athletes an asymmetry in the force of the two legs was present even before the stimulation. This was due to the particular sport considered and to the specific training. In the normal group the asymmetry index $A_{\%}$ was 5.2% ($F_{dx} - F_{sx}$=3.2 kg) before the stimulation. After the stimulations the asymmetry decreased (3.7% after nine days and 3.0% after 15 days of stimulation). This fact showed that the electrical stimulation has a decreasing effect on the small asymmetry, like that present in the normal group. On the contrary, for a greater asymmetry due to a different functionality of the two legs, as happens for the volleyball players, the electrical stimulation leads to an increase of the initial asymmetry. This consideration is useful when applying the electrical stimulation to those subjects affected by pathologies that cause asymmetry in gait and posture. In those cases a monolateral stimulation of the hypotrophic limb is preferred in order to avoid a further increase of the initial asymmetry. This paper shows how the study of the behavior of the athletes leads to a more complete knowledge of the analyzed system, that can be useful for the application of electrical stimulation in pathological subjects.

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