INFLUENCE OF ELECTROSTIMULATION ON HUMAN QUADRICEPS FEMORIS MUSCLE STRENGTH AND MUSCLE MASS

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INTRODUCTION:

Among all muscle-development modem methods used in the training of sportmen (Cometti, 1989), electromyostimulation (EMS) is successfull (Delitto, 1989 ; Dudley, 1991). Recently, the improvement of the maximum voluntary dynamic and isometric torques was measured, as well as the decrease of the time taken to achieve peak torque. The sessions using electromyostimulation were carried out on static or dynamic mode (Portmann et al., 1991). Unfortunately, none of them took the morphological changes in muscle into account with as rigorous a tool as the scanner.

This study has two purposes, first to assess the effects of EMS on the maximal concentric torque of knee extension and secondly to measure the influence on the cross-sectional area of the quadriceps femoris muscle.

METHODOLOGY:

Subjects: 20 physical education students divided into two groups. A study group (20.5 ± 1.8 years, 70.9 ± 5.9 kg, 177.5 ± 4.2 cm) trained percutaneously and a control group (22.5 ± 0.5 years, 81.2 ± 5.7 kg, 184.2 ± 4.3 cm) trained by voluntary contraction.

Training : the experiment was conducied over seven weeks. five of which were given over to the strength development cycle. The initial tests preceded the training period by one week and the final tests followed it by one week. The two groups made up of 10 subjects followed a rhythm of 3 sessions per week, making 15 in all.

The control group performed a single series of 30 maximum repetitions (approx. 70 % of one concentric RM) on quadriceps apparatus broken by 15-seconds' rest. The study group used a 4-way stimulator outputting a symmetric orthogonal pulse train lasting 0.1 ms at 60 Hz. The session lasted 10 minutes, contractions being applied to the two quadriceps alternately. Each contraction lasted 5 seconds followed by 15-seconds rest, making 30 contractions for the full session. The working position maintains a 60° leg to thigh angle of flexion, enabling the subject to perform an isometric contraction.

The torque force exerted during each contraction was measured to evaluate relative intensity compared with maximum voluntary contraction. This varied from 25 % to 56 % for the ten subjects. with an average of 44%.

Maximum voluntary isokinetic torque was measured with a Cybex device according to the protocol laid down by Chateris et al. (1982) to ensure identical knee flexion/extension for any subject. Time to reach torque was computed from the angle at which it was attained. The exercise consisted in extending the leg as powerfully as possible twice in succession. The six selected constant angular velocities were tested from fastest to slowest.

X-ray scanning tomography was used to measure the cross-sectional area of the right thigh quadriceps. Digitized scaled images were attained accurate to one square millimeter with a margin of error of 0.5 %. The cross section is 10 mm thick mid-way between the knee cap (patella) and the iliac spine.

Statistical tests : Pre- and post-training mean values were compared within each group using the Wilcoxon non-parametric statistical test. In contrast, variations in results between each strength training method were validated using another non-parametric statistical test, the Mann Whitney U test. For each test any difference in mean is significant if the probability threshold is at least equal to $p \leq 0.05$ (noted: * and ** is $p \leq 0.01$ or *** if $p \leq 0.001$).

RESULTS:

The changes in the Maximum voluntary force torque at different angular speeds depending on the training method means the following facts can be noted:

As can be seen on table 1, significant improvement in torque after EMS only occurs at the two slowest speeds: the mean peak shifts approximately from 235 Nm to 257 Nm which is a gain of 9.4 % ($p \leq 0.001$) at 30°/s. it increases by 5.6 % ($p \leq 0.001$) at 60°/s. Concentric work is more beneficial to the development of maximum concentric force : 11.7% ($p<0.01$) at 30°/s, 10.7% ($p< 0.001$) at 60°/s, 11.2% ($p< 0.001$) at 90°/s and there is even a gain of 8.8% ($p<0.001$) at 180°/s, the first of the fast velocities. If we examine the time to reach the peak torque, which was computed, the increase of the time after concentric work occurs for almost

Explosive Index following Concentric Work

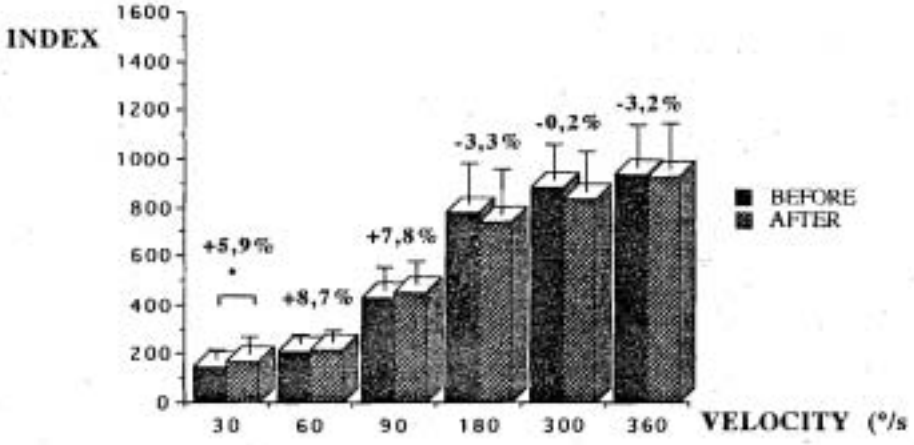

Figure 1.

Explosive Index following Electromyostimulation

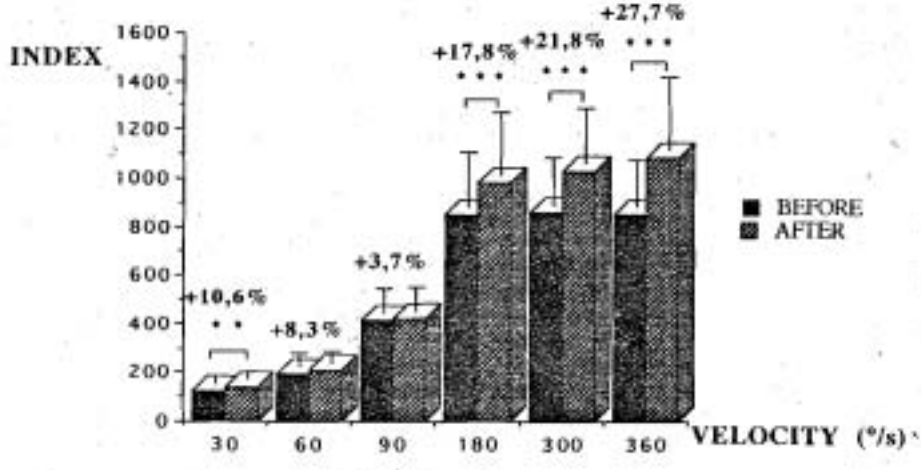

Figure 2.

	30°/s	60°/s	90°/s	180°/s	300°/s	360°/s
Torque after Ems	+9,4% ***	+5,6% ***	+1,9%	+2,5%	+0,2%	+3,3%
Torque after C W	+11,7%**	+10,7%***	+11,2%***	+8,8% ***	+3%	+0%
Time to peak Ems	-5,6%	-2,3%	+ 6,6%	-11,9% **	-18,9%***	-24,6%***
Time to peak CW	-0,4%	+2%	+5%	+15% **	+4,8%	+5,8%

Table 1 : Influence of training on Maximal Concentric Torque and Time to Peak

all velocities. But it's only significant at 180°/s with 15% ($p<0.01$). It was expected that the improvement of maximum torque shapes the time taken to achieve the peak.
On the contrary, training using EMS has made the time to peak significantly decreasing for the 3 fastest velocities : nearly 12 % ($p < 0.01$) at 180°/s, - 18.2 % ($p < 0.001$) at 300°/s and - 24.6 % ($p < 0.001$) at 360°/s.
In order to relativize this fact by the improvement of maximum torque, we propose a comparison of the ratio peak torque over time to achieve it : this is the explosive index.
In terms of explosive power strength development, the voluntary contraction of a concentric work seems to be effective only for very slow velocities (figure n°1): + 5.9 % ($p < 0.05$) at 30°/s. The explosive index would decrease at high velocities but not significantly. Unlike this traditional method, EMS seems to be the most effective work to improve the explosive power skill (figure n°2) : + 10.6 % at 30°/s ($p<0.01$), + 17.8 % at 180°/s ($p<0.001$), + 21.8 % at 300°/s ($p<0.001$) and + 27.7 % at 360°/s ($p<0.001$). However, the Mann whitney test shades this hypothesis because of the fact that concentric work would increase the explosive index at low velocity in a significant manner. At last, we must point out that the computed tomography of the cross-sectional area shows a significant and substantial hypertrophy : 8% using EMS versus only 2% using C.W.

DISCUSSION

Maximum force test results show that voluntary contraction is more effective at low speeds. It should be stressed that the control group trained at about 70 % of its maximum voluntary isometric strength. While the EMS group, whose contractions ranged between 25 % and 56 % of the maximum voluntary isometric force, had a group average of around 44 %. Compared with earlier studies, it is likely that this low level of work is one cause of lack of progress in terms of strength which can and should be improved on in future. However, the weakness of quadriceps contractions in electrically stimulated subjects did not prevent sizeable hypertrophy being measured for fifteen sessions spread over five weeks. It can be considered that the training load of voluntary contractions and stimulation current parameters were not aimed at exhausting muscle resources and so enhancing muscular mass. For high speed measurement the trend is reversed. Here the increased effectiveness and value of electrical stimulation is shown. So much so that there would seem to be, in the ratio improvement of the maximum torque variation/time to maximum torque variation, a valuable method for expressing and controlling the explosive strength sought in some disciplines: this is the explosive power factor.

CONCLUSION

To sum up the essence of this work, it can be claimed that the significant results of the experiment point to the use of electrical stimulation for sports training if it is decided to increase overall muscle mass while considerably enhancing explosive strength. This suggests it is an excellent method for body building or other activities where it is difficult to reach this objective during certain training periods. While awaiting fundamental data that would better explain such phenomena, further studies are needed to explore parameters for getting the most out of EMS in terms of hypertrophy and secondly, above all developing eccentric training on top of EMS-induced maximum contraction.

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