

# Preventive Effects to Acute Atrophied Muscles by Therapeutic Electrical Stimulation

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**Abstract--** The spinal cord of injured patients causes muscle atrophy. Therapeutic electrical stimulation (TES) has been performed to increase the force of these muscles, and to prevent muscle atrophy. In this study, we compared the muscle weights of the tibialis anterior (TA) and the extensor digitorum longus (EDL) of rats after stimulation at different frequencies to know the optimal stimulus frequency. The TA and EDL muscles were atrophied through suspension of male Wistar ST rats. Electrodes were unilaterally twisted at the peroneal nerve. The TA and EDL were stimulated for 30 min/day, at either 20, 75, or 100 Hz, for up to 3 weeks. The TA and EDL muscles from both legs were surgically removed and weighed after stimulation. A comparison between stimulated muscle and non-stimulated muscle was done. Those muscles stimulated at 20 Hz were significantly lighter than non-stimulated muscles. There was no significant difference between muscles stimulated at 75 and 100 Hz. These results suggest that high frequency stimulation for acute atrophied muscles may be useful in decreasing muscle atrophy.

**Index terms--** muscle atrophy, therapeutic electrical stimulation, frequency

## I. INTRODUCTION

Electrical activation of the neuromuscular system produces therapeutic effects and is a useful method for restoration of lost or impaired motor function (1). With electrical stimulation it is possible to increase muscle activity to influence their morphological, physiological and biochemical properties. This results in an improvement of muscle strength in healthy subjects or recovery of atrophied muscle due to disuse (2, 3). In order to restore ambulatory function in paralyzed lower limbs, the force of atrophied quadriceps muscles must be increased. Therapeutic electrical stimulation (TES) has been performed to prevent these muscles from atrophying and to increase the force of these muscles. Clinically, we adopt the application of low-frequency stimulation (20 Hz) for atrophied muscles. However the optimal stimulus frequency for TES has not

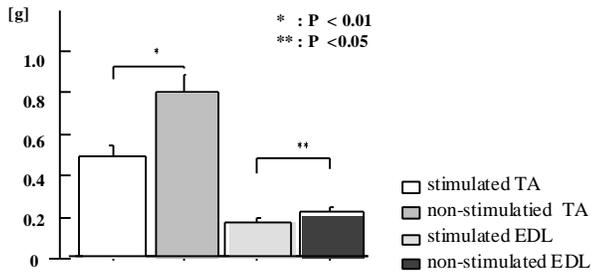
been determined. The purpose of this study is to investigate the difference in preventive effects for acute atrophied muscles after stimulation at different frequencies.

## II. METHODS

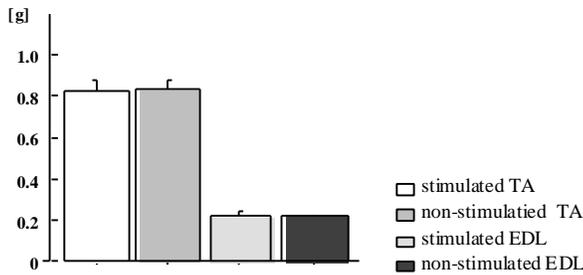
The TA and EDL muscles of sixteen adult male Wistar ST rats were used in this study. During operations rats were deeply anaesthetized with an intraperitoneal injection of 30 mg per 1 kg body weight of pentobarbital sodium. The peroneal nerve of one leg was exposed by incision through the gastrocnemius and soleus, and an electrode was twisted around it. The electrodes led under the skin towards the back of the rats. After the surgical procedure, the rats were suspended by their tails through the Kirschner-wire and their hindlimbs were unweighted to produce atrophied muscles. Then TA and EDL were stimulated for 30 min per day, at either 20, 75, or 100 Hz, for up to 3 weeks. Pulse width was 0.2 ms and constant voltage was adjusted to give maximum contraction force on palpation. After stimulation the TA and EDL muscles from both legs were surgically removed and weighed. A comparison between stimulated muscle and non-stimulated muscle was done.

## III. RESULTS

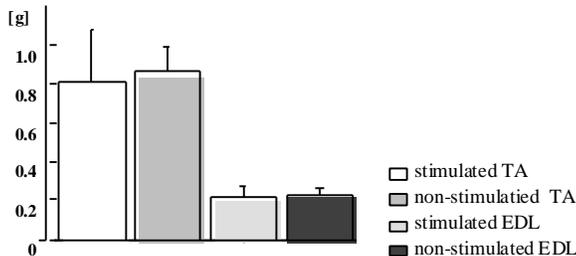
After suspension of their hindlimbs for 3 weeks, the non-stimulated muscle weight was lower than that of non-suspended rats (TA 10 % loss, EDL 12 % loss). The muscle weight of TA non-stimulated was  $0.795 \pm 0.07$  g (mean  $\pm$  SD), TA stimulated was  $0.482 \pm 0.05$  g, and that of EDL non-stimulated was  $0.20 \pm 0.02$  g,  $0.17 \pm 0.02$  g at 20 Hz (Fig. 1), respectively. The muscle weight of TA and EDL stimulated at 20 Hz was significantly lower (TA:  $p < 0.01$ , EDL:  $p < 0.05$ ). There was no significant difference between muscle stimulated at 75 and 100 Hz (Fig. 2, 3).



**Fig. 1 Comparison between stimulated muscle and non-stimulated muscle at 20 Hz. The mean± SD are given for stimulated TA, non-stimulated TA, stimulated EDL, non-stimulated EDL. The muscle weight of TA and EDL stimulated at 20 Hz was significantly lower (TA:  $p < 0.01$ , EDL:  $p < 0.05$ ).**



**Fig. 2 Comparison between stimulated muscle and non-stimulated muscle at 75 Hz. The mean± SD are given for stimulated TA, non-stimulated TA, stimulated EDL, non-stimulated EDL. There was no significant difference.**



**Fig. 3 Comparison between stimulated muscle and non-stimulated muscle at 100 Hz. The mean± SD are given for stimulated TA, non-stimulated TA, stimulated EDL, non-stimulated EDL. There was no significant difference.**

#### IV. DISCUSSION

Electrical stimulation is a useful method for the restoration of lost or impaired motor function and the increasing of muscle force. In this study, the results showed that stimulated muscle weight was reduced at 20

Hz. To our knowledge the only other relevant paper is that of Miyazawa and Rolf Frichknecht et al., who presented a study about the electrical stimulation of innervated muscles (4, 5). They reported that electrical stimulation was not useful to increase the muscle weight of innervated muscles. In our study, the muscle weight of the TA and the EDL stimulated at 20 Hz was lower than that which was not stimulated and there was no significant difference between the muscle weight stimulated at high frequency (75, 100 Hz) and non-stimulated muscle. We suggest that high frequency stimulation for acute atrophied muscles may be useful in decreasing muscle atrophy. Further study includes clinical application of high frequency stimulation for TES.

#### V. CONCLUSIONS

This study showed the muscles stimulated at high frequency (75, 100 Hz) kept their weight, however, those stimulated at low frequency (20 Hz) decreased. This study suggests that high frequency stimulation for acute atrophied muscles may be useful in decreasing muscle atrophy.

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