ELECTRICAL STIMULATION PROTOCOL TO MAINTAIN MASS AND CONTRACTILE FORCE IN DENERVATED MUSCLES

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Abstract--- Due to atrophy, rat EDL muscles denervated for 1 month have a mass of only 38% of contralateral control muscles, and at 2 months it is down to 32%. Likewise, contractile force at 1 month is only 6%, and at 2 months it is down to 2% of control values. Chronic electrical stimulation maintains both the muscle's mass and contractile force at some percent of control values depending on the protocol used. We tested a stimulation protocol resembling the bursts of activity followed by periods of rest observed in animal behavior. We tested 2 protocols producing either 100 or 300 muscle contractions per day. EDL muscles of Wistar rats were denervated and stimulated for 5 weeks. The muscle's mass and force were significantly different between the two groups. The 300 contractions/day protocol maintained both muscle mass and force above 80% of control values, whereas with 100 contractions/day the values did not differ significantly from unstimulated muscles.

I. INTRODUCTION

With denervation, skeletal muscles lose mass and contractile force [1]. For EDL muscles of rats denervated for 1 or 2 months, chronic electrical stimulation resulted in the maintenance of muscle mass up to 100% of control's mass, and contractile force up to 69% [2], by generating single muscle contractions at regular intervals. An animal's natural behavior consists of bursts of activity, followed by rest and sleep. Based on this observation, we hypothesized that a protocol resembling bursts of activity would better maintain mass and force. Moreover, the number contractions produced per day would affect the maintained levels of mass and force.

II. METHODS

Adult, male Wistar rats received a high sciatic denervation [2]. All operations and animal care were carried out in accordance with the guidelines of the Unit for Laboratory Animal Medicine at the University of Michigan. A miniature battery powered stimulator (20x40x8mm) was implanted subcutaneously on the back of the rat. Insulated stainless steel wires were tunneled subcutaneously to the EDL muscle. The bared ends of the wires were looped around each end of the muscle. Five weeks later, both the denervated-stimulated and contralateral control EDL muscles were extracted and placed in an *in vitro* bath for the measurement of maximum isometric force [1]. Specific Force is defined as contractile force multiplied by fiber length divided by muscle mass.

Muscle contractions were generated as follows. Bipolar pulses having a 400μs duration and an amplitude of +/-7V were separated by 10ms (100Hz). One contraction was generated by 20 pulses. A 12 minute Set, defined as 5 contractions (each separated by 30 seconds) followed by 10 minutes of rest, was repeated for 4 hours. Two protocols were tested with either 100 or 300 muscle contractions (C) each day. The 100-C protocol produced 100 contractions/day with the above described 4 hr work period followed by 20 hrs of rest. The 300-C protocol's 24 hr cycle had 4 hrs of work, 2 hrs rest, 4 hrs work, 2 hrs rest, 4 hrs work, and 8 hrs of rest.

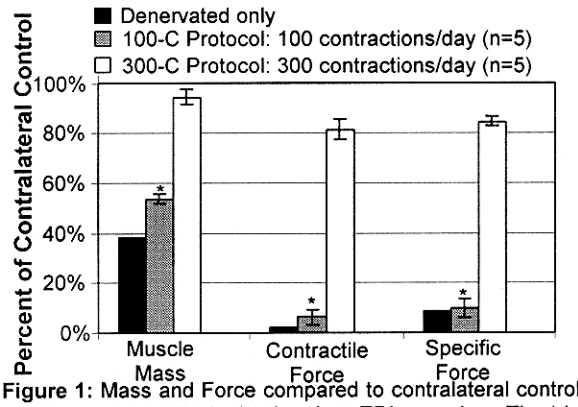

Figure 1: Mass and Force compared to contralateral control values for 5 week denervated-stimulated rat EDL muscles. The * indicates significant difference ($p<0.05$) between the values of the 300 and 100 contractions/day protocols. Error bars are Standard Error.

III RESULTS

According to students t-test ($p<0.05$), the muscle's mass, force, and specific force were all significantly different between the 100-C and 300-C protocols.

IV DISCUSSION

The 300-C group's contractile force of 82% was higher than that for protocols of regular contractions [2]. The 100-C protocol was significantly less effective at maintaining mass and force than the 300-C protocol. A minimum number of contractions/day seems to be required to maintain the mass and force of denervated muscles. For the protocol and type of rats tested, this is between 100 and 300 contractions/day.

V. CONCLUSION

The number of generated contractions per day does affect the maintenance of denervated muscle's mass and force.

REFERENCES

[1] B.M. Carlson, L. Billington, J. Faulkner, "Studies on the Regenerative Recovery of Long-term Denervated Muscle in Rats", Restorative Neurology and Neuroscience, vol. 10, pp. 77-84, 1996.

[2] T. Eken, K. Gundersen, "Electrical Stimulation Resembling Normal Motor-unit Activity: Effects on Denervated Fast and Slow Rat Muscles", Journal of Physiology, vol. 402, pp. 651-69, 1988.