EFFECT OF ADDITIONAL ELECTRICAL STIMULATION OF MUSCLES ON MAXIMAL FORCE PRODUCTION

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INTRODUCTION

There are two neural mechanisms controlling the maximal voluntary contraction (MVC): motor units recruitment and their firing frequency. To attain the absolute force of the muscle all of its motor units should be activated with the maximal firing frequency. Belanger and McComas (1981) provided evidence suggesting the possibility of complete activation of the muscle during MVC. On the other hand a strength deficit was introduced (Massalgin and Uschakow, 1979) to describe a disability for complete activation of the muscle. The difference between the MVC force and absolute muscle's force is interesting as a measure of the muscle's utilization as well as a possible mechanism for force gains during additional reflex activation of the muscle. The objective of the study was to assess the force gains over the MVC force level as a function of the duration of additional electrical stimulation (ES) of quadriceps femoris muscle (QF).

METHOD

Subjects. Eight male sport subjects (age 21.4 ± 0.7 yrs, weight 71.8 ± 8.2 kg, height 174.6 ± 4.9 cm), all in good condition, participated in the study. All of them gave their informed consent. All testing procedures were approved by the state medical ethic commission.

Procedure. The effects of additional ES of QF on force production were studied with the subjects laid in a dorsal position on a bank with full extension in hips. The dominant leg was fastened with the knee angle of 135 degrees (180 deg. full extension) and connected to the strain gauge. The nondominant leg was left passive aside. After the warm up procedure subjects performed maximal voluntary extensions in knee joint of the dominant leg. They were asked to reach their MVC level and keep it during the ES. ES of QF consisted of the trains of impulses, which differed in their durations: single impulse, 5 ms, 10 ms, 15 ms, and 20 ms. In all conditions the frequency and the current amplitude remained the same. Frequency was set to 100 Hz, the length of the impulse to 0.3 ms, and the current amplitude just under the threshold of the discomfort. The current amplitude setting procedure was conducted at the train duration of 20 ms. Sponge electrocles (40 cm square) were placed distally and proximally over the vastus lateralis and vastus medialis muscles. Trains were delivered 2-3 seconds after the signal for the start of contraction. At every single contraction only one train was employed. Trains of impulses were applied in random order individualized for every single subject. Every single train duration was applied twice. The isometric force-time curve was established during MVC and additional ES. As a variable served a ratio between the peak force during additional ES and force level at MVC, The ratio from the attempt with higher MVC force at the same train duration was used for further statistical procedures. For ES of QF a custom made programmable four channel (electrically separated) electrical stimulator was used (University of Ljubljana, Faculty of Sport, Slovenia).

Statistics. Mean value and stantlard error of ES-MVC ratio were calculated for every single train duration.

RESULTS

Ration between force during additional ES and MVC force level varied in proportion to the changes in train durations inside the first 10 ms, when the peak ratio was achieved (Fig. I). It was maintained at the same level for all further train durations. Same tendencies were seen in all subjects, although at different ratios.

DISCUSSION

Results show that QF was not completely activated during MVC. Already 10 ms long train of impulses was sufficient to draw out the absolute force of QF. In some other reports, the absolute force for leg extensors was assessed to be between 10 and 25 % over the maximal isometric force (Schmidtbleicher, 1987), what is in a good agreement with these results. In extreme cases the force during ES may run more than 70 % over MVC force level (own observations). But there should be drawn a difference in mechanisms involved in a force production between both methods. During a stretching of an active muscle beside reflex activation, a viscosity and stiffness of different tissues as well as a short range stiffness occur. This is not a case during isometric contraction with additional ES, though some rearrangement inside the muscle due to tendon compliance may be involved. There were no problems reported about discomfort during additional ES. Since the current amplitude was set at the train duration of 20 ms, all shorter trains were more comfortable. In very short trains, e.g. twitch, the amplitude to get the maximal force response is considerably higher than in longer trains.

For examination of the influence of the additional ES on force production during MVC trains of impulses should last at least 10 ms to get the maximum. From different reasons (fatigue, muscle fibre types etc.) the train duration should be longer than that when used in regular examination. In practice times about 0.8 second seem to be appropriate (Strojnik, unpublished).

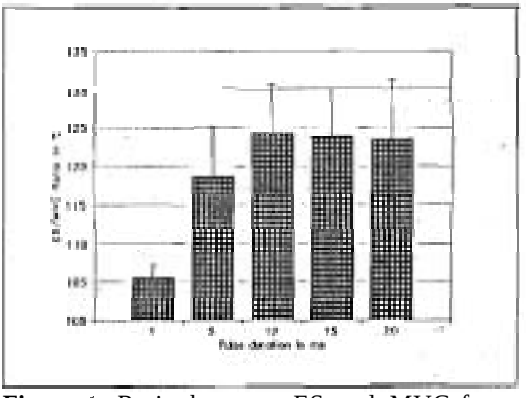

Figure 1. Ratio between ES and MVC force levels expressed in percents of MVC force level.

With tetanic nerve stimulation it is hard to obtained higher forces than during MVC since the inter-muscular coordination is not the same. Voluntary action is more complex and involves also synergists which may help to stabilize the position or give other kind of support to agonists. The same nerve (e.g. peroneal nerve) may also supply antagonists. Thus it seems that additional ES, applied directly to the muscle, gives better possibilities to study muscle's utilization because of preserving the complexity of the action. The method may be used in different arrangements (Strass and Strojnik, 1991).

Myoelectrical potentiation plays important role in stretch-shortening cycle exercises (Schmidtbleicher et al., 1978, Wosco et al., 1982). Low muscle utilization during MVC may be one of the prerequisites for mechanical benefit in concentric phase to which reflex activity should be addressed. The difference may he even more important since the nonactivated motor units are usually bigger and faster ones. Most studies about the mechanical effects of the reflex

activation were conducted on decerebrated animals (Nichols and Houk, 1976). Quantifying an EMG trace in a mechanical sense during eccentric-concentric movement in individuals in vivo is almost impossible. Information about the electro-mechanical delay at MVC conditions for a subject may be of help. It depends on direction and speed of contraction (Nichols and Houk, 1976) and should be measured according to this. The other information gap concerns the muscle mass that may be additionally activated (or was previously activated) and the effect of duration of the reflex activation on the muscle utilization.

CONCLUSIONS

Since voluntary contraction is very complex in terms of inter-muscular coordination, it seems that additional ES, which preserves the activation of not stimulated muscles, is more comfortable and perhaps more valid method for the muscle activation assessment than indirect nerve stimulation. With certain procedural rearrangements it is possible to obtain some informations that may be vital for EMG assessment in mechanical sense.

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