CHANGES IN TIME AND FREQUENCY RELATED ASPECTS OF MOTOR UNIT ACTION POTENTIALS DURING FATIGUE

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Abstract- **During fatigue the shape of motor unit action potentials (MUAPs) change. Characteristics of the MUAPs described before concern several time related aspects [1,2,3,4]. No attention has been given to the frequency spectrum changes of MUAPS.**
The median frequency of MUAPS has now been determined for motor units in the extensor digitorum longus muscle of the rat. Some examples of the changes are shown during a fatiguing stimulation pattern (250 s of 40 Hz stimulation during one third of each second). In general the median frequency tends to change more quickly than the time characteristics of the MUAPs. The results do not allow to draw yet conclusions about the time and frequency characteristics during fatigue for mechanically identified types of motor units.

I. INTRODUCTION

When it is aimed to prevent fatigue in stimulation controlled muscle activity it is important to have a signal indicating fatigue as early as possible. Fatigue itself is normally quantified with the mechanical behavior, but comes to expression in the electrical signals as well. For action potentials of different types of motor units the time characteristics have been followed during fatigue in animal experiments [1,2,3,4]. In human recordings a lot of attention has been given to the changes in the frequency spectra of the electromyogram [e.g. 5]. In this study we determined both the time and frequency characteristics of action potentials of single motor units during fatiguing stimulation patterns. Such information will support the understanding of surface EMG during fatigue.

II. METHODS

The *in vivo* experiments were carried out on the right M. extensor digitorum longus (EDL) of nine adult, male rats (Wistar). The rats were anesthetized with Nembutal giving some atropine to avoid breathing problems. The experimental procedures met the guidelines established by the Institutional Review Board for the care and use of laboratory animals.

The length of the muscle was about optimal twitch length. The temperature of the muscle and the N. peroneus was 308 ± 2 K by moistened airflow. Very thin parts of the peroneal nerve were stimulated with a bipolar Pt-Ir hook electrode. It was carefully tested that only one motor unit was activated. The action potentials were recorded with 8 Ni-Cr (25 μm diameter) wires embedded in needle shaped epoxy within 1.5 mm. The force was recorded with a two range force transducer enabling easy switching between recording motor units and muscle.

For each motor unit twitch, tetanus (50 Hz during one s) and fatigue (during 250 s each s a burst of 13 pulses at 40 Hz) were recorded.

The median frequency and other MUAP characteristics were determined per action potential. For the fatigue patterns the obtained values were averaged for the action potentials per second.

III. RESULTS

Data of about 28 motor units was obtained. Single fibre components were sometimes clearly visible in the MUAPs. Nevertheless the MUAP characteristics at the different channels of the multielectrode changed similarly. In this report we give two representative examples of simultaneous changes in the median frequency (starting values ranged from 300 - 910 Hz), the action potential top-top time (starting values 0.3 - 1.7 ms) and the maximum force per second (starting values 7 - 64 mN). In nearly all cases the median frequency decreased from the start of the fatiguing pattern (fig. 1 upper plots). The steepness of the change was variable and was already high at the start. The top-top times (fig. 1 middle) in consecutive seconds showed more variation than the median frequencies. Quite often the top-top time started with decrease; thereafter or already from the start this time increased and reached sometimes a constant level. The time at which the top-top time switched from decreasing to increasing was sometimes linked to changes in the mechanical behavior (fig. 1 lower plots). During the 250 s fatigue patterns the MUAP top-top time and the force showed more different time courses than the median frequency.

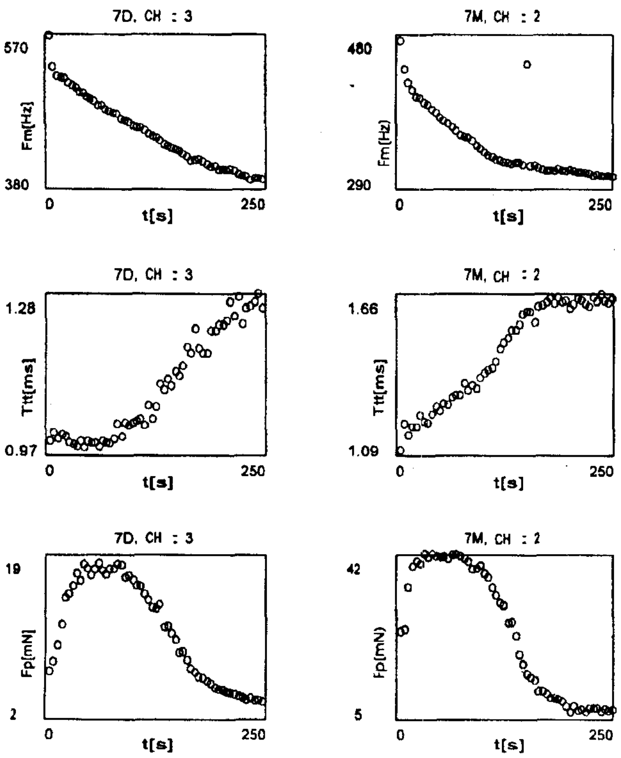

Fig. 1. Data of two motor units during 250 s fatiguing stimulation.
On the abcis the time 0-250 s. From above to below:
- the median frequency, Fm (in Hz)
- the top-top time of the MUAP, Ttt (in ms)
- peak force in a one second pattern, Fp (in mN).

IV. DISCUSSION

Application of sag and fatigue index according to [2,4] did not enable reliable classification of fast fatiguing, fatigue intermediate and fatigue resistant motor units in our rat EDLs. We noted that the motor unit characteristics in our research varied considerably within a category. None of the motor units showed the slow motor unit pattern.

In general the transients of top-top time and MUAP duration were comparable, but the derivation of the top-top time was easier. The increase in the MUAP duration and of the top-top time was of the same order as for cat motor units [resp. 1 and 3]. The amplitude of the MUAP showed more variable patterns than described for motor units in rat plantaris [2].

A direct comparison with human data with comparable stimulation patterns is not possible. A decrease of 50% of the unfatigued median frequency during stimulation is quite normal for action potentials in human muscle [5] and animal motor unit [this study].

V. CONCLUSIONS

The median frequency of MUAPs starts to decrease very early in fatiguing contractions of motor units. The value of the median frequency appears to be less sensitive for disturbances than the time characteristics. The transient in it offers an additional possibility to follow fatigue. It has to be studied in more detail whether the shift in this frequency characteristic offers special advantages above the time pattern characteristics for detection of fatigue and application in fatigue prevention.

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VI. REFERENCES

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