PHYSIOLOGY

Effect of Tonic Activity and Physiological Tremor on Evoked Auxotonic Muscle Contractions

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Electrically evoked auxotonic muscle contractions may be used as a functional test to investigate the spinal control of muscle activity. It is demonstrated that physiological tremor facilitates evoked auxotonic synergist contractions to a greater extent than tonic activity. It is assumed that tremor activates fast motoneurons under their forced recruitment. Amplitude of evoked auxotonic contractions is modulated due to discrete involvement of muscle units into activation. Static tension diminishes the amplitude of evoked contractions and prevents their development. Removal of static tension results in postactivation potentiation.

Key words: *spinal motoneurons*; *tonic influences*; *physiological tremor*; *auxotonic contractions*

Physiological tremor in its initial stage and muscle tone have similar mechanisms and EMG characteristics [2,3]. Taking into consideration this similarity, one can suppose that tremor can activate motoneurons under conditions of excessive emotional or physical effort and contribute to preparing to the movement.

The aim of this study was to evaluate the role of tonic and synchronized activities in the movement initiation and facilitation and to study their effect on the contraction force.

In order to investigate spinal motor control, we used auxotonic muscle contractions evoked by threshold or suprathreshold electrical stimuli (ES). This functional test is based on the assumption that external pulses propagating via the nerve and muscle fibers (MF) produce a summation effect [4]. In this case, an external pulse applied to MF mimics the nerve command spike coming from a spinal motoneuron. Thus, the motor unit premovement activity and some components of the motor act can be quantified by parameters of MF contraction in response to external stimulus.

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MATERIALS AND METHODS

Tests were performed repeatedly on a healthy volunteer.

In series I we recorded EC in the soleus muscle under ideomotor fictive movement during preparation to locomotion, and during tonic tension and relaxation. The subject sitting on a chair contracted thigh muscles simulating the standing up movement. Then, during several seconds, he strongly contracted thigh muscles in a static effort, stood up, and sat down again on the chair.

In series II, EC were recorded in the contralateral muscles under conditions of complex coordination synergy. In order to fix the contralateral crus out of locomotion, a support was placed under the lower third of the thigh near the knee. The subject sitting on the chair contracted extensor muscles of the active leg with a maximum effort. In the contralateral leg, the crural muscles were relaxed, while the thigh muscles reflectively contracted during this maneuver. EC were recorded both in contracted thigh muscles and in relaxed crural muscles of the contralateral leg.

In series III, EC amplitude variability was investigated under conditions of tonic contractions of varying

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intensity. To this end, EC were recorded in the soleus muscle during contraction of homolateral muscles and during alternating flexion-extension of the ankle joint with or without supporting the foot.

EC were recorded using a stimulating impedance myography technique [1]: electrical stimuli were applied via a needle electrode inserted into the muscle and evoked contractions were recorded near the tip of the electrode. The stimuli of suprathreshold intensity (0.01 or 1 msec duration) were delivered at a frequency of 1 Hz.

EC were recorded with a pen recorder on the thermopaper at a speed of 5 and 50 mm/sec. A few MF can be recorded when threshold or suprathreshold stimuli were applied. In all experiments, EC of the soleus muscle were recorded from ipsi- and contralateral legs with respect to the contracted one. The common electrode was fixed on the upper side of the immobilized crus. For better conductance, a piece of gauze soaked with electrolytic gel was put under the electrode.

The results were statistically analyzed by the χ^2 test.

RESULTS

The amplitude of EC decreased in muscles that were contracted or stretched during ankle joint flexion (Fig. 1, *3*; 2, *3*). A marked postactivation potentiation of the muscle response was observed during relaxation after the isometric tonic contraction accompanied by a decrease in EC amplitudes.

EC reflect the intermittent activity of muscle fibers. The amplitude of EC varies due to involvement or drop out of the high amplitude contractions and depends on nervous regulatory influences and mechanical interactions in the muscle (Fig. 2).

Ideomotor movements and isometric contraction during preparing to the movement occurring without tremor were characterized by a slight increase in the EC amplitude irrespective to the origin of tonic influences (Fig. 3).

Physiological tremor characteristic of maximum muscular contraction significantly increases EC amplitude in relaxed muscles in the immobilized segment of the contralateral leg. The amplitude of EC increases in parallel with the tremor amplitude (Fig. 1, *1*).

EC are generated due to compliance of series elastic muscle components adjacent to the contraction point. During coordinated synergy, the amplitude of EC in contracting thigh muscles of the contralateral leg drastically decreased. At the same time, synaptic transport to the muscle is enhanced, which leads to excitation of fast MF.

The postactivation potentiation observed during relaxation of muscles in the active leg indicates the existence of a latent muscle activation. In this case, EC amplitude can increase 2-fold, which implies the involvement of phasic extrafusal fibers in the previous

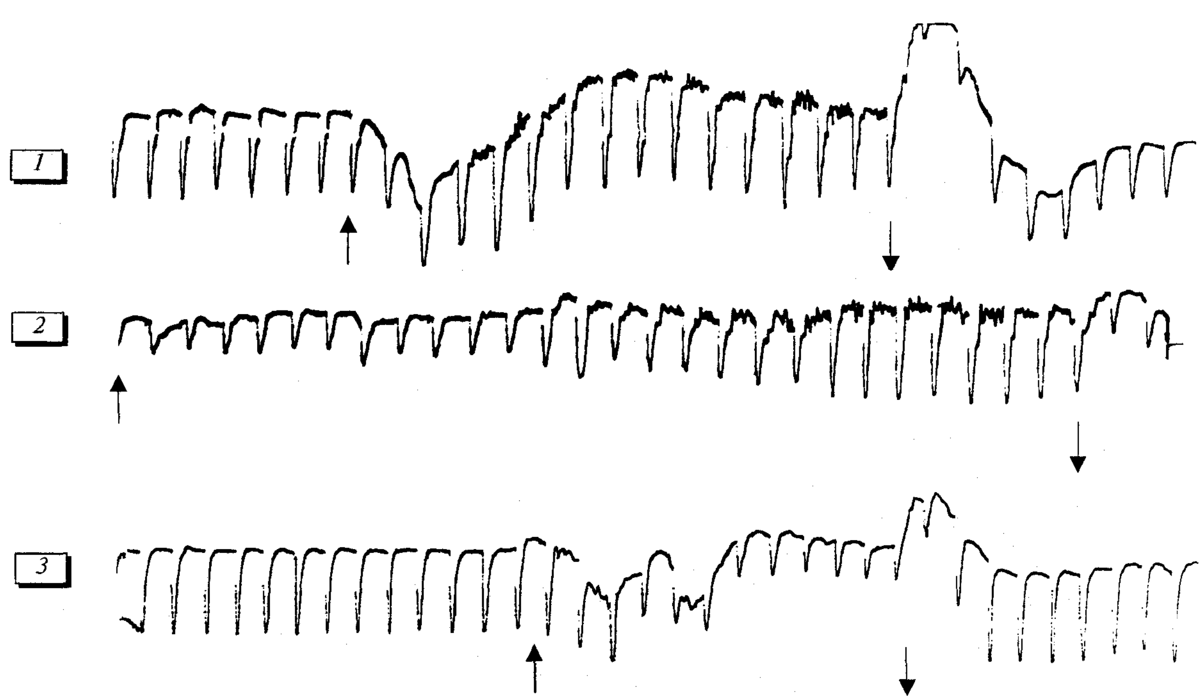

Fig. 1. Amplitude of evoked contraction in the soleus muscle of the immobilized segment (*1*, *2*) and in the musculus rectus femoris (*3*) of the contralateral leg during voluntary contraction of extensors of the active leg. *1*, *2*: tremor at 6-8 Hz on the baseline and on contraction response curves; *3*: increase of amplitude during extensor relaxation. Arrows indicate the start and finish of leg contraction.

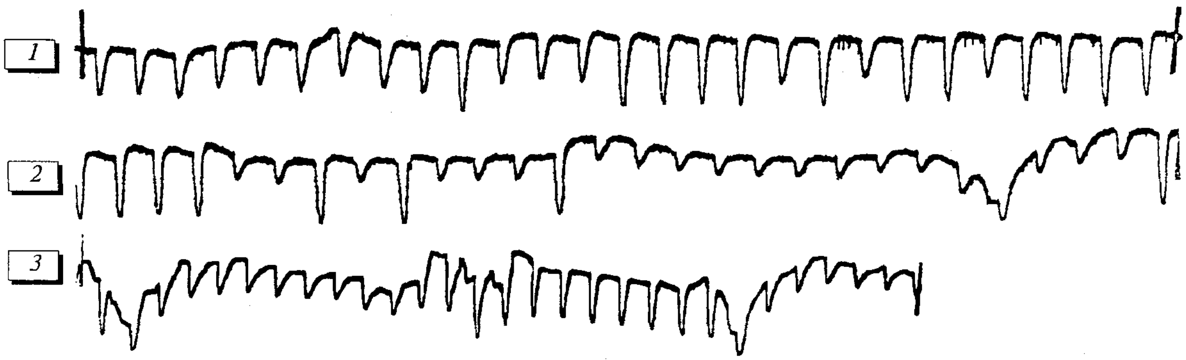

Fig. 2. Evoked contraction amplitudes in the immobilized segment during muscle contraction in the contralateral leg (*1*) and in the soleus muscle during the body weight movement in the saggital plane (2,3). *2)* alternating amplitude during intermittent MF activity. *3)* amplitude decreases in stretched muscle during forward inclination, reaches its maximum when the body is vertical, and remains elevated in the non-stretched muscle during dorsal inclination.

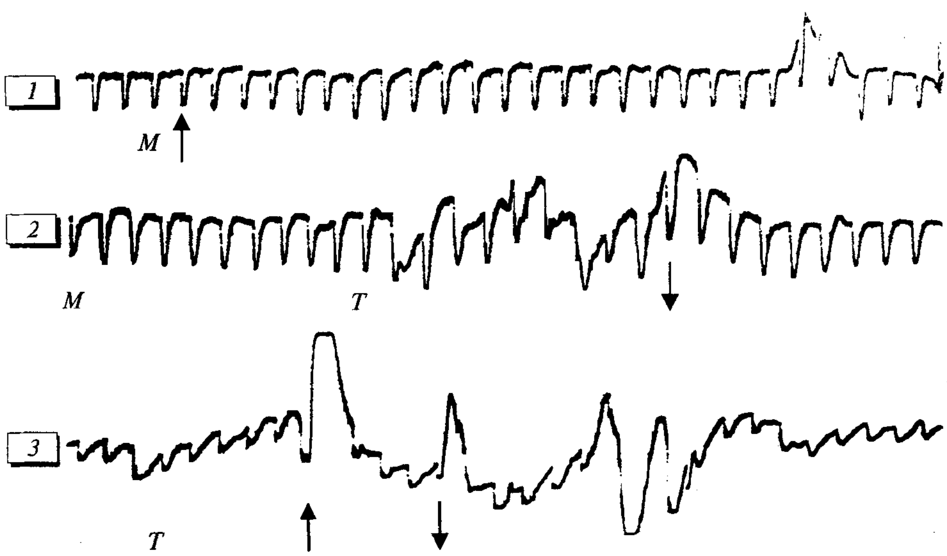

Fig. 3. Evoked contractions in the soleus muscle of the homolateral femur. *1*: ideomotor simulation of contraction (*M*) and fictive standing up (arrow); a slight increase in amplitude; *2*: ideomotor simulation of contraction (*M*), muscle tonic contraction (*T*) and relaxation (arrow); an increased muscle tone is sometimes accompanied with tremor; *3*: tonic contraction (*T*) in standing (up arrow) and sitting (down arrow) positions; tremor is absent, amplitude is stable; slow waves of impedance variations.

contraction. On the other hand, the amplitude of EC in the extensor muscles of the immobilized crus, increased during contraction in parallel with that in active leg. Proprioceptive signals were not generated in the relaxed muscles of immobilized leg. Hence, additional tonic influences from spinal motoneurons do not involve the proprioceptive loop, but result from either generalized supraspinal control or contralateral tonic extensor reflex.

The amplitude of EC depends on both synaptic flow received by the muscle and the mechanical factors related to contraction. With near-threshold external stimulating currents it was clearly seen that the variations of EC amplitude were due to intermittent activity of single MF which, probably, belonged to different motor units. An external stimulus evoked contractions of MF in the state of subthreshold activation. The basic activity represented by low-amplitude EC could be joined with high amplitude contraction responses. At the same time, the high-amplitude EC dropped out of contraction first of all. To some extent, high amplitude reactions bring to light the sequence of motoneuron involvement into contraction (the amplitude principle). In patients with myasthenia gravis, we observed a preferential disappearance of the high-amplitude EC during rhythmical muscle stimulation, which indicates the presence of a nerve-synaptic component in the intermittent MF activity.

In our experimental conditions, the role of proprioceptive loop was strongly diminished if not excluded in tremor initiation in the immobilized part of the leg. It is likely that the mechanisms responsible for tremor in this case are the generalized bilateral reticulo- and vestibulospinal influences on the spinal interneurons, which can excite synchronized activation of motoneurons.

It was shown that a significantly greater activation of motor units could be reached by the high-amplitude "activated" tremor rather than by tonic tremor-free activity. Such tremor is triggered in emergency case, which needs involvement of fast motor units.

REFERENCES

1. V. I. Babinkov, A. P. Abul'khanov, and V. N. Yakovenko, *Byull. Eksp. Biol. Med.*, **100**, No 9, 375-376 (1985).
2. V. S. Gurfinkel', Yu. S. Levik, and M. A. Lebedev, *Neirofiziologia*, **21**, No 3, 343-351 (1989).
3. Yu. V. Lupandin, A. Yu. Meigal, and L. V. Sorokina, *Thermoregulating Activity of the Locomotor System in Humans* [in Russian], Petrozavodsk (1995).
4. A. I. Shapovalov, *Cell Mechanisms of Synaptic Transmission* [in Russian], Moscow (1986).