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PHYSIOLOGY

Motor Function Disturbances: Contralateral Effects

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Electromyography methods were employed to examine the mechanisms underlying changes in the functional state of the contralateral neuromotor apparatus of rat gastrocnemius muscle during unilateral limitation of the hind leg motor function. Elimination of one hind leg from the total pattern of motor activity affected the state of contralateral neuromotor apparatus via changing the properties of motoneurons in the corresponding spinal motor center resulting mostly from activation of the bilaterally acting spinal mechanism.

Key Words: *functional motor limitation; contralateral changes; electromyography*

Under conditions of functional motor limitation caused by damage to peripheral axons and/or tendons, or during immobilization of the extremity, the ipsilateral neuromotor apparatus demonstrates similar changes: atrophy of the muscle fibers [12], transformation of muscle phenotype [7], sprouting in the end-plates [9], and down-regulation of the lipoprotein lipase activity [5]. The disturbances in various elements of neuromuscular apparatus modify the functional state of not only the damaged motor systems, but also of the symmetrical structures that had not been traumatized [3,10]. The data on possible origin of the contralateral transformations and the changes in the related structures are mostly inconsistent and contradictory [2,8].

This work was designed to study the mechanisms of the changes in the functional state of contralateral neuromotor apparatus in rat gastrocnemius muscle (GM) caused by unilateral limitation of the motor function of a hind leg.

MATERIALS AND METHODS

Experiments were carried out on outbred rats weighing 130-150 g. All experimental procedures were carried out in accordance to humanistic principles specified in Helsinki Declaration on Protection of Vertebral Animals (1975) and approved by Committee on Bioethics of Kazan (Volga Region) Federal University.

The state of the neuromotor apparatus of rat GM was assessed by electromyographic (EMG) methods in control animals and in two experimental groups. In experimental group 1 (n=8), the rats were narcotized with ether and Achilles tendon was isolated under aseptic conditions at the site of its attachment to the foot. A 2-3-mm fragment of this tendon was excised and the wound was cleansed and sutured. In experimental group 2 (n=7), the rats were similarly narcotized. Their spinal cord was cut at segments T_{III}-T_{IV}, the wound was cleansed and sutured layer-by-layer. Then Achilles tendon was cut as in group 1 rats. The control rats (group 3, n=5) were not subjected to traumatic procedures.

In groups 1 and 2 rats, electrical potentials in the contralateral gastrocnemius muscle (CLGM) evoked by stimulation of sciatic nerve with single rectangular pulses were recorded in 5 days after surgery. The amplitude of these pulses varied from 0.1 to 30 V, duration being 0.5 msec. To generate electrical pulses as well as to amplify and record the muscle responses, a custom-made setup was employed, which combined an MG-42 Electromyograph (Medikor), Pentium-based PC, and Miograf software.

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The reflex excitation of spinal motoneurons was assessed by testing the monosynaptic H-reflex, which reported the response of the motor center to afferent stimulation. In addition, we recorded motor M-wave that reflects electrical response of the muscles to stimulation of the efferent fibers. The threshold and maximum amplitude of these potentials were determined, thereupon the ratio of maximal amplitudes of the reflex and motor responses were calculated as (H_{max}/M_{max}) in percentage to the control value. To limit the total motor activity during recording of EMG parameters, groups 1 and 3 rats were spinalized 2 h prior to EMG recording.

The data were processed statistically with the routine methods.

RESULTS

The unilateral tenotomy produced no immediate and significant effect on the reflectory and motor responses of CLGM. However, in 5 days after tenotomy, H_{max}/M_{max} increased to 145±13% ($p<0.05$).

The data on CLGM neuromotor apparatus obtained in group 1 rats after unilateral tenotomy attested to enlargement of motoneuron pool in spinal motor center, which responded to afferent stimulation and to corresponding shrinkage of the Sherrington's "subliminal fringe". It is a common knowledge that the nervous system can adapt to limitation of motor activity [1]. Obviously, this process is triggered bilaterally. It had been shown that unilateral denervation of GM changes excitability of the motoneurons in the ispi- and contralateral motor systems [4].

The possible reason of the contralateral transformations can be activation of the reflex arcs, those of the cerebral motor centers included. However, the data obtained in group 2 rats showed that elimination of the supraspinal control influences did not prevent the transformations in functional state of CLGM motor apparatus. Really, in 5 days after preliminary surgery, the threshold of H-reflex in CLGM decreased to 64±10% ($p<0.05$) while its amplitude increased to 163±11% ($p<0.05$). To this time, H_{max}/M_{max} increased to 160±4% ($p<0.05$). The threshold of M-wave decreased to 81±5% ($p<0.05$), while its amplitude did not significantly change (95±10%).

The data obtained indicate enhancement of excitability of the motoneurons in CLGM spinal motor center determined by the parameters of H-reflex. Enhanced reflex excitability of the motor centers attests to the development of a certain stage of the restorative process, which involves activation of these centers. The observed transformations cannot result from the cut of the spinal cord, because during 14 post-spinalization days, the amplitude parameters of the neuromotor responses in rat GM did not exceed the control values, although the threshold of H-reflex expectedly increased [1]. It should be remembered that the spinal motor centers of the leg are affected by the inhibitory supraspinal influences, whose down-regulation can be one of the reasons of the pronounced changes in the parameters of H-reflex observed in group 2 rats.

The influences originating from the motor neurons shape the parameters of sarcolemma and sarcoplasmic reticulum, enzymatic activity, the composition of enzymatic cocktail of energy metabolism, the moiety of isoforms of contractile and regulator proteins, and other properties of muscle fibers. Probably, the observed decrease of the threshold of M-wave can be related to the changes in the functional state of motoneurons in the spinal motor center, which in its turn determines the features of the peripheral elements of the motor apparatus.

The mechanism recruiting the contralateral motor systems in the processes of motor reorganization is probably located at the level of spinal motoneurons. Transmission of the signals to contralateral motoneurons is secured by corresponding propriospinal connections, which functionally integrate the both halves of the spinal cord [8]. It is of importance that some afferent fibers originate from the contralateral side, where they form the synapses with the contralateral neurons [6]. Activation of the intraspinal connections is also evidenced by CLGM responses recorded after compression of the sciatic nerve and evoked by stimulation of the ipsilateral afferent fibers at the proximal region of this nerve [4].

Thus, elimination of one leg from the total pattern of the motor activity affects the state of the contralateral neuromotor apparatus by changing the properties of the motoneurons in the corresponding spinal motor center. The major reason of these transformations seems to be activation of a bilaterally operating mechanism located at the spinal level.

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