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ROLE OF THE VESTIBULAR SYSTEM IN THE REGULATION OF COLD TREMOR

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The main source of heat production in homoiothermic animals is cold tremor (CT). Central regulation of CT is effected by the hypothalamic center, with the participation of brainstem systems forming postural muscular activity [5-7, 10]. It is natural to suggest that these systems may also have a definite influence on activity of the muscle during CT.

In the investigation described below the role of the vestibular component of the postural control system in the regulation of CT was studied.

EXPERIMENTAL METHOD

Experiments were carried out on 132 cats anesthetized with a chloralose-urethane mixture (50 and 500 mg/kg, respectively). During the experiment the animals were kept in a constant temperature chamber (temperature 18-20°C) in a frame, fixing them in a "standing" posture, or they lay freely on their side. Activity of the limb muscles (flexors: biceps brachii, sartorius; extensors: triceps brachii, triceps surae) and the dorsal cervical muscles (trapezius, rhomboideus) was investigated. Methods of derivation of muscle potentials and of stimulation and destruction of the vestibular system were described by the writers previously [1, 2]. To analyze changes in muscle electrical activity during CT evoked by stimulation of the vestibular system, the function of motor units (MU) of the ipsilateral sartorius muscle was investigated before and 5 and 10 min after destruction of the labyrinth by the method in [4]. Throughout the experiment the rectal and subcutaneous temperature was recorded continuously on the N-3020-3 automatic writer.

EXPERIMENTAL RESULTS

In anesthetized animals in an ambient temperature of about 20°C the subcutaneous and rectal temperature fell, with the subsequent appearance of bioelectrical temperature-regulating activity in the muscles (CT). Muscular activity developed in the limb flexors and neck muscles. It was absent in the limb extensors. Stimulation of the vestibular system was applied during CT against the background of a stable integral electromyogram (EMG).

The investigation showed that during unilateral stimulation of the vestibular system by a pulsed current and also during caloric stimulation a bilateral decrease or cessation of electrical activity took place in the neck muscles and limb flexors. During stimulation of the labyrinth no evoked responses were observed in the limb extensors. In the cervical muscles suppression of activity predominated on the contralateral side relative to the side on

KEY WORDS: cold tremor; vestibular system; motor units.

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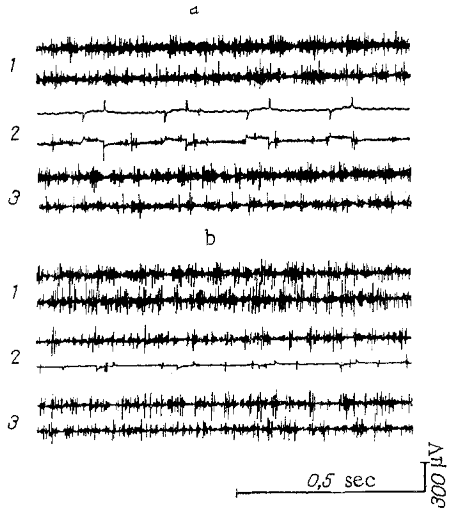

Fig. 1

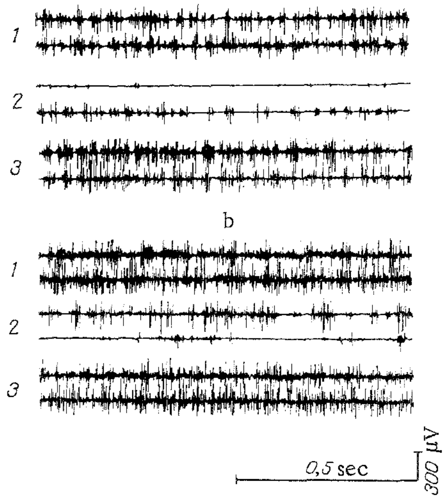

Fig. 2

Fig. 1. Activity of limb flexor muscles and neck muscles during CT and electrical stimulation of vestibular system. a, b) EMG of sartorius and rhomboideus muscles, respectively. Top beam — EMG of ipsilateral muscles, bottom beam — EMG of contralateral muscles. 1) Initial activity; 2) activity during action of stimulus; 3) activity after cessation of stimulation. Stimulation artifact can be seen in traces 2a and 2b.

Fig. 2. Electrical activity of limb and neck muscles during CT and caloric stimulation of vestibular system. a) Electrical activity of biceps brachii; b) of trapezius muscle. Remainder of legend as in Fig. 1.

which the vestibular system was stimulated, whereas in the limb flexors depression of activity was more marked in muscles on the ipsilateral side (Figs. 1 and 2).

Unilateral destruction of the labyrinth during CT led to an increase in electrical activity of the neck muscles and limb flexors. Activity was absent in the extensors both before and after labyrinthectomy. The increase in activity in the limb flexors was bilateral, with predominance of the ipsilateral side. Electromyographic activity of the ipsilateral and contralateral sartorius muscle increased to 131.1 ± 5.5 and 120.8 ± 3.8%, respectively ($P < 0.05$) relative to the initial level. Electrical activity of the biceps brachii increased to 149.4 ± 10.8 and 126.5 ± 6.7% ($P < 0.05$) on the ipsilateral and contralateral sides, respectively. The increase in activity in the neck muscles after labyrinthectomy took place only on the ipsilateral side. The new level in the trapezius muscle was 152.6 ± 10.2% relative to its initial value ($P < 0.05$) but on the contralateral side activity either was unchanged or was reduced (to 79.3 ± 6.0%; $P < 0.05$). A similar unilateral effect also was observed in the rhomboideus muscle.

The increase in the integral EMG during CT after removal of vestibulospinal influences was due both to an increase in discharge frequency of active MU and to recruiting of previously "silent" MU. The mean discharge frequency of 24 MU tested (in 12 experiments) was between 5 and 9 Hz. After labyrinthectomy 10 of the 24 MU increased their discharge frequency (Fig. 3). Before labyrinthectomy, for instance, the interspike interval of MU active during CT was 142.2 ± 5.7 msec, falling to 121.3 ± 4.4 msec ($P < 0.05$) 10 min after the operation. Besides the increase in discharge frequency, variability of interspike intervals also decreased. Before labyrinthectomy the standard deviation of interspike intervals of MU was 26.8 ± 2.5 msec, but 10 min after the operation it was 15.4 ± 1.1 msec. As a rule, after labyrinthectomy recruiting of new MU took place (Fig. 3). In two experiments in which destruction of the vestibular system did not change the electrical activity of the sartorius muscles, MU discharged with the previous frequency and variability.

The investigations thus showed that the vestibulospinal component of brain-stem control of muscle tone participates in the regulation of CT, the main source of heat production during exposure to cold. For instance, loss of vestibulospinal influences had a facilitatory action of CT of the neck muscles and limb flexors, whereas strengthening of vestibular impulsa-

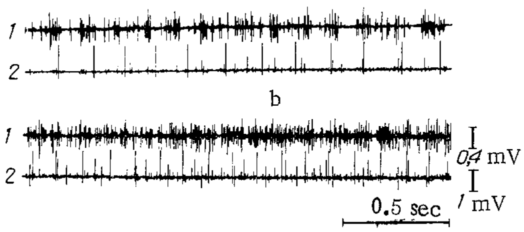

Fig. 3. Activity of MU and EMG of sartorius muscle after unilateral destruction of the vestibular system: a) initial activity; b) 10 min after labyrinthectomy; 1) global EMG of sartorius muscle; 2) activity of MU. Trace 2b shows recruiting of MU.

tion depressed CT. This may probably be explained by the character of descending influences of the vestibular system aimed at maintaining the antigravity responses of the body through facilitation of extensor and inhibition of flexor motoneurons [8, 9]. Involvement of the neck muscles and limb flexors in temperature-regulating activity (in the absence of activity in the extensors), together with an increase in heat production, led to the formation of a posture reducing the heat-emitting surface (adduction of the shoulder girdle and limbs to the trunk). Previously [3], with respect to limb muscles, the writers showed that involvement of the limb flexors exclusively in CT is linked with selective activation of flexor motoneurons by impulses from peripheral temperature receptors. Considering the "functional topography" of the muscles active during CT, and also the character of descending influences of the vestibular system, it can be tentatively suggested that vestibular impulsation not only participates in the regulation of CT but also modifies the responses of the body to cold, aimed at formation of a posture reducing the heat-emitting surface.

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