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COLD SHIVERING ACTIVITY AFTER UNILATERAL DESTRUCTION OF THE VESTIBULAR APPARATUS

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Cold shivering is the principal source of regulated heat formation in the organism affected by cold. Central control of cold shivering is carried out by the hypothalamus with participation of stem structures that create muscle tone [5]. As we know, the part played by the vestibulary apparatus in muscle tone regulation is expressed especially by increased extensor activity and depression of the flexor type [4, 7, 10]. It would seem, that the influence of the vestibulary system might have a distinct importance in the formation of cold shivering as well. In this context one must keep in mind, that cold shivering in the extremities arises in the flexor muscles, but not in the extensors [2, 3]. It might be suggested, that exclusion of the vestibular apparatus would have a definite effect on cold shivering in the flexor extremities. /1655*

In the present work there has been a study of bioelectric activity in the muscles of the forelimbs and hindlimbs during cold shivering after unilateral destruction of the vestibular apparatus.

Method

The study was done on 45 cats anesthetized with a chloralose-urethane mixture (50+500 mg/kg) with methacine premedication (2.5 mg/kg). Cold shivering was induced by chilling the entire animal in a thermal chamber kept at 18-20°. The animals, in a free position on its side, was placed on a grill 10 cm above the floor of the chamber in order to insure even cooling. Under these conditions the body temperature of the anesthetized animals dropped and muscular shivering set in. Unilateral destruction of the vestibulary apparatus was done through the round window of a previously opened vesicle with subsequent administration of 1 drop 1% dicaine solution. Due to

*Numbers in the margin indicate pagination in the foreign text.

the possible asymmetrical effect of the vestibulary apparatus on spinal activity [9] the right labyrinth was destroyed in 21 animals and the left in the others. For clarification of total labyrinth destruction created by the present method the operation was carried out under sterile conditions with subsequent observation of the animal's behavior. Following emergence from anesthesia typical symptoms were observed: turning of the head and drooping toward the delabyrinthed side, ocular nystagmus on the healthy labyrinth side. In addition, following the acute experiment there was a histological check showing complete destruction of the laybrinth. /1656

Muscular bioelectric activity was induced by intramuscular bipolar electrodes [1] and recorded with a Medicor M-21 electromyograph. For quantitative assessment of muscular biopotential a Medicor MI-1 myointegrator was used that recorded muscle activity over 30 sec at intervals of 5, 10, 15 and 20 min following delabyrinthization. A study was made of the activity of flexor muscles (humeral biceps, sartorius) and extensors (humeral triceps, gastrocnemius). Destruction of the vestibulary apparatus was carried out while maintaing a relatively stable level of bioelectric activity in each muscle studied. Processing of experiment results took as 100% the initial level of electromyographic activity (integrator impulses over 30 sec) and muscle activity following destruction of the labyrinth was calculated in percent of the initial value.

During the entire experiment rectal and subcutaneous temperature, following preliminary intensification, was recorded on an N-3020-3 automatic recorder.

The Student method was used for analyzing the results of each experiment.

Results of the Study

Before the experiment began the warm animal (rectal temperature 38-39°, subcutaneous above 35°) showed no bioelectric activity in the muscles under study — the flexors and extensors of the extremities. Chilling of the animal in the thermal chamber caused a drop in rectal and subcutaneous temperature and the appearance of cold shivering inthe flexors. At this point not one of the extensor muscles showed bioelectric activity in any experiment. The results of our observations indicated, that the sartorius evinced bioelectric activity when the rectal temperature dropped to $37.9 \pm 0.12°$ and the subcutaneous down to $30.1 \pm 0.54°$. The activity of the humeral

CHANGE IN BIOELECTRIC ACTIVITY OF FLEXOR FORELIMBS AND HINDLIMBS DURING COLD SHIVERING FOLLOWING UNILATERAL DELABYRINTHIZATION

Type of muscle reaction	Number of experiments			
	Sartorius		Humeral Biceps	
	side of vestibular destruction	side opposite	side of vestibular destruction	side opposite
Appearance or increase of activity	38	30	29	22
Average percent increased activity	131.9±5.6	120.8±3.8	149.9±10.8	126.5±6.7
No activity changes	7	13	5	8
No noticeable activity	0	0	11	11
Decrease in activity	0	2	0	4
Total experiments	45	45	45	45

biceps usually appeared later at a lower rectal and subcutaneous temperature of 37.4±0.16 and 27.8±0.62° respectively. We executed unilateral destruction of the vestibular apparatus following further decrease in temperature, rectal to 35.7±0.31° and subcutaneous to 26.4±0.84° during a period of stable bioelectric muscle activity. It should be noted, however, that in standardizing the temperature conditions at which delabyrinthing was done we were compelled in some of the experiments to destroy the labyrinthine structures of animals that were cold but not shivering. Thus in 13 out of 45 experiments at the moment of delabyrinthing there was an absence of cold shivering in the sartorius and in 19 experiments in the humeral biceps.

Unilateral destruction of the vestibular apparatus carried out under the conditions described did not produce in a single experiment any bioelectric activity phenomena for extensor muscles.

The results of our observations in respect to change in the bioelectric activity of extremity flexor muscles during cold shivering under conditions of unilateral delabyrinthization are presented in the Table. /1657

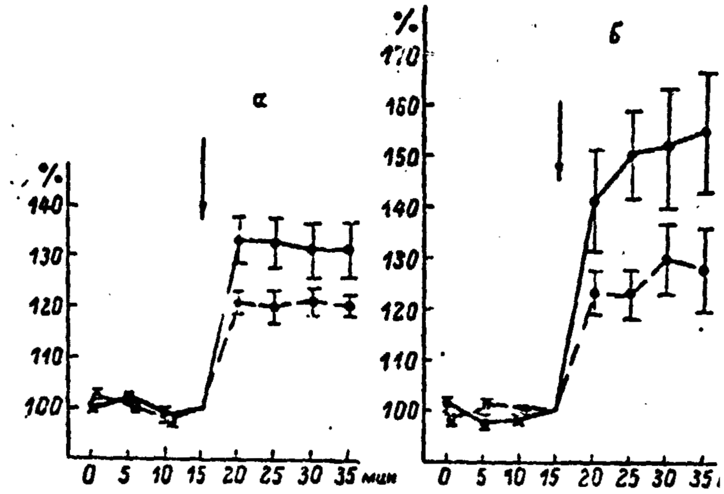

Fig. 1. EMG changes in muscle activity induced by unilateral destruction of the labyrinth during cold shivering. a - sartorius, b.- humeral biceps. Solid line - on the side of labyrinth destruction, broken line - on the opposite side. Arrow indicates moment of delabyrinthization. x axis - time in min, y axis - EMG activity of muscles based on integrator indications in % of initial value.

Activity of the sartorius located on the side of the destroyed vestibulary apparatus increased in 38 of 45 animals. Intensified activity showed itself both through its increase in 25 shivering animals and by its appearance in all 13 non-shivering animals previous to the cats' delabyrinthization (fig. 2, 3). Increase of bioelectric activity ($p < 0.05$) of the sartorius muscle on the ipsilateral side averaged $131.9 \pm 5.6\%$ as compared with the initial value and was fairly constant over the entire recording period (Fig. 1a). In only 7 animals was there no change in the activity of the sartorius muscle on the ipsilateral side following delabyrinthization.

Bioelectric activity of the sartorius on the contralateral side also increased in most (30 out of 45) experiments; in 13 the unilateral delabyrinthization resulted in the appearance of bioelectric activity of the sartorius in cold but not shivering animals and in 17 experiments it led to the increase of initial bioelectric activity (Fig. 2, 3). Increased activity of the sartorius on the contralateral side was less than on the ipsilateral and averaged $120.8 \pm 3.8\%$ compared with the initial level (Fig. 1a). In the remaining experiments the initial bioelectric activity of the sartorius following delabyrinthization either did not basically change (13 animals) or went down slightly (2 animals).

Observation of the bioelectric activity of the humeral biceps on the ipsilateral side indicated, that activity changes occurred in 29 experiments out of 45, whether they appeared as intensified in the case of the shivering animals or in the display of biopotentials in the animals that were cold but not shivering. Thus, in animals in which unilateral delabyrinthization was done against a background of cold shiver-

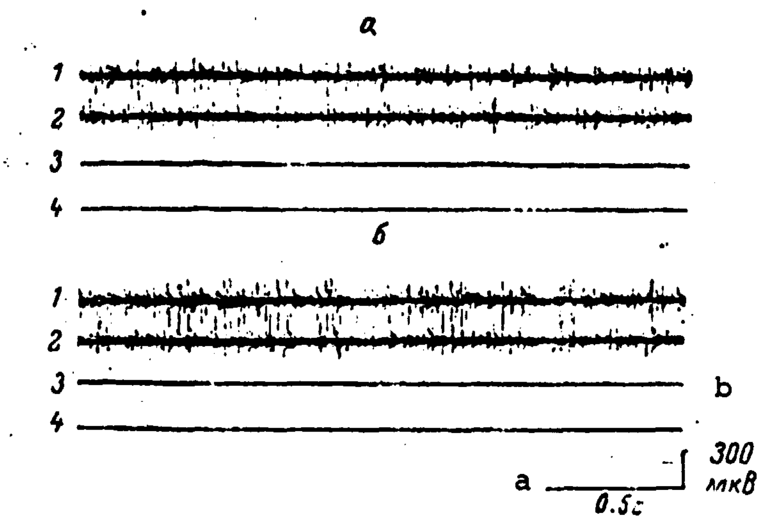

Fig. 2. Change of bioelectric activity in hindlimb muscles following unilateral delabyrinthization during cold shivering. a - initial activity, b - activity 10 minutes after delabyrinthization. EMG: 1 - sartorius muscle on ipsilateral side, 2 - sartorius on contralateral side, 3 - gastrocnemius on ipsilateral side, 4 - gastrocnemius on contralateral side.
Key: a. Seconds. b. Microvolts.

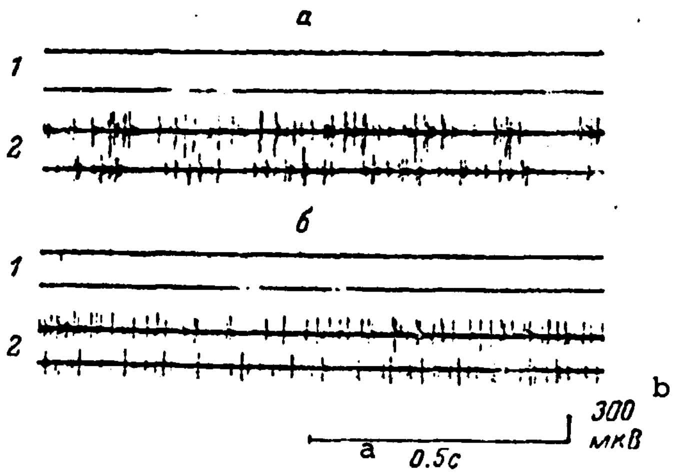

Fig. 3. Effect of delabyrinthization on EMG of muscles of flexor extremities in cold non-shivering animals. a - sartorius, b - humeral biceps, 1 - initial record, 2 - record 10 minutes after delabyrinthization.
Key: a. Seconds. b. Microvolts.

ing of the humeral biceps (21 experiments), there was a substantial increase in shivering ($p < 0.05$). At the 10 min point following delabyrinthization muscular activity was 150.4±9.1% and at the end of the observation period 155.2±12.0% as compared with

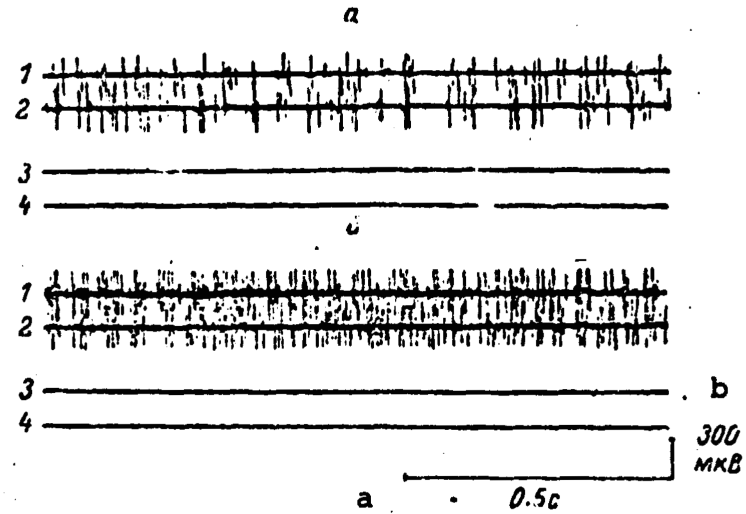

Fig. 4. Change of bioelectric activity of forelimb muscles following unilateral delabyrinthization during cold shivering. a - initial activity, b - activity 10 minutes after delabyrinthization. EMG: 1 - humeral biceps on the ipsilateral side, 2 - same on the contralateral side, 3 - triceps on the ipsilateral side, 4 - same on the contralateral side.
Key: a. Seconds. b. Microvolts.

the initial level (Fig. 1b, 4). In fact unilateral destruction of the labyrinth in 9 cold animals in the absence of biceps activity resulted in the appearance and stable maintenance of such activity in 8 experiments (Fig. 3b). In 5 delabyrinthed /1658
animals the biceps activity was the same as at the start.

Increase in humeral biceps activity on the contralateral side following unilateral destruction of the vestibulary apparatus was observed in 22 experiments. In 14 of these increased activity took the form of growing activity in shivering animals, although the increase was less than in the biceps on the ipsilateral side that by the end of the observation period amounted to $128.0 \pm 8.7\%$ as compared with the initial (Fig. 1b, 4). Unilateral delabyrinthization carried out in the absence of biopotentials recorded for the humeral biceps on the contralateral side in the same 19 chilled animals resulted in their appearance only in 8 experiments. In 12 experiments activity either was not really different from that in the beginning (8 animals) or even went down slightly (4 animals).

Evaluation of Results

Results of the experiments conducted indicated, that unilateral dropout of ves- /1659 tibulary impulsation in anesthetized animals favors facilitation of cold shivering manifested both in its intensification and in its appearance in animals that are cold but not shivering. The results obtained may be explained on the basis of literature data on the inhibiting effect of the vestibulary apparatus on activity of the flexor extremities [4, 7, 10]. It may be supposed, that removal of the downward effect of the vestibulary apparatus on spinal activity facilitates the functioning of flexor motoneurons participating in cold shivering. The effect of facilitation of cold shivering following unilateral delabyrinthization was most clearly expressed in muscles located on the side where the vestibulary apparatus had been destroyed. This is evidenced by the number of experiments where facilitation of cold shivering in muscles on the ipsilateral side (Table) was observed as well as a greater increase in their bioelectric activity (Fig. 1).

Changes in the bioelectric activity of the sartorius muscles differed from activity changes in the humeral biceps. Thus, the increase of activity in flexor muscles of the forelimbs was larger than that of flexor muscles of hindlimbs both on the ipsilateral and contralateral side. At the same time unilateral delabyrinthization done on cold but not shivering animals usually resulted in the appearance of cold shivering in the sartorius muscles, while this happened to the humeral biceps in only some of the experiments. There may be two explanations for this effect. First of all, the absence in some of the experiments of bioelectric activity in the humeral biceps following delabyrinthization may be associated with later involvement of these muscles in cold shivering. Probably the removal of the inhibiting effects of the vestibulary apparatus on motoneurons of the flexor forelimbs was in some of the experiments insufficient to cause the appearance of cold shivering. Secondly, the reason for some differences in the reactions of the sartorius and humeral biceps to delabyrinthization may possibly be connected with the well known difference in the organization of vestibulary control of the activity of motoneurons in the forelimbs and hindlimbs. In accordance with the data in the literature these motoneurons in the cat are connected in various ways with nuclei of the vestibulary complex. The motoneurons of the lumbar regions are connected with the Deiter nucleus through the /1660 homolateral vestibulospinal tract. Vestibular influences on the motoneurons of the forelimbs are not limited to the Deiter tract; fibers from the medial vestibulary nucleus included in the makeup of the medial vestibulary longitudinal fasciculus and connected with the motoneurons of the forelimbs but not of the hindlimbs [11, 12].

In about half the experiments the facilitation of cold shivering following unilateral delabyrinthization had a dual character that may be explained in terms of literature data on the bilateral effect of the vestibulary apparatus on spinal activity [6, 8].

The demonstrated effects of the vestibulary apparatus on the course of cold shivering should be regarded as participation in the supersegmentary mechanism of the facilitation and inhibition of motoneuron activity.

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