FUNCTIONAL STATE OF SOME DEEP BRAIN STRUCTURES DURING ADAPTATION AND DEADAPTATION TO EXERCISE

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Recent investigations have shown that some deep brain structures participate in emotional reactions, in the realization of motor activity, and in the formation of adaptive mechanisms to muscular activity [2, 9]. A special role in these processes belongs to the hypothalamus, the nonspecific thalamus, hippocampus, caudate nucleus, and mesencephalic reticular formation. Recent investigations have shown that the limbic system participates in the formation of adaptive mechanisms for the maintenance of homeostasis [3, 4]. Accordingly in the investigation described below the dynamics of the functional state of deep brain structures was studied during prolonged adaptation and deadaptation of rabbits to exercise.

EXPERIMENTAL METHOD

Experiments were carried out on 35 rabbits with permanently implanted bipolar nichrome electrodes allowing free behavior of the animals. Stimulating electrodes, which also served for recording the local cerebral blood flow (LCBF) were implanted into area CA_4 of the dorsal hippocampus (DH), the mesencephalic reticular formation (RF), the ventromedial thalamic nucleus (VMN), the caudate nucleus (CN), and the anteromedial thalamic nucleus (AMN) in accordance with coordinates taken from the atlas of Fifkova and Marsala [10]. The animals took part in the experiments 15-20 days after the operation. To stimulate the brain structures a two-channel ÉST-12 square pulse generator was used. As indicator of the functional state of the brain structures studied, the level of their excitability and changes in their LCBF were used. The criterion of excitability was the minimal threshold current which, if used to stimulate the brain structures in the animals, induced the motor response of the corresponding behavioral reaction. LCBF was studied by the method of local electroplethysmography [7]. The rabbits were trained by daily exercise of submaximal intensity and duration, consisting of running on a circular treadmill (turning at a speed of 16 m/min). From the 8th day of the experiments the rabbits trained with maximal exertion up to the limit. The experiments included a training program of 120 days and a 30-day period of deadaptation, during which the various indices were recorded daily. After the end of the experiments the location of the electrode in DH (area CA_4), chiefly in the layers of pyramidal cells and their apical dendrites, was confirmed histologically. The electrodes in RF were located in the gray matter of the tegmentum, the head of CN, AMN, and VMN. The experimental material was subjected to statistical analysis by Student's t-test.

EXPERIMENTAL RESULTS

As a result of long-term adaptation of the animals to individually graded submaximal exercise the level of excitability of the deep brain formations changed (Fig. 1A). Two circumstances are noteworthy. First, the greatest fluctuations in functional state were observed in RF and CMN, when the excitability of the structures rose from a level of depressed function (by 10%) in the first 10 days of the experiment by 15-20% above the background level during subsequent days of adaptation. Meanwhile the level of excitability of DH on all days of training remained elevated by from 25 to 63%, whereas the level of excitability of AMN and CN was depressed by 33-52 and 75-180% respectively compared with the background state. Second, starting from the 20th day of the experiments the supposed submaximal exertion led to

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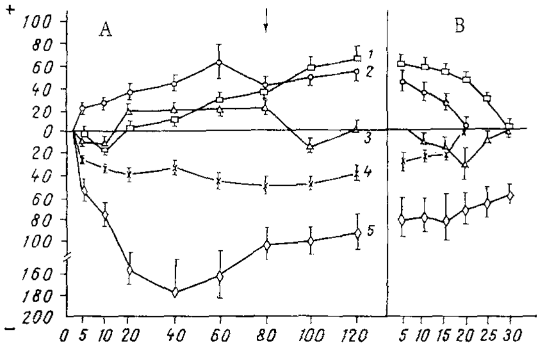

Fig. 1

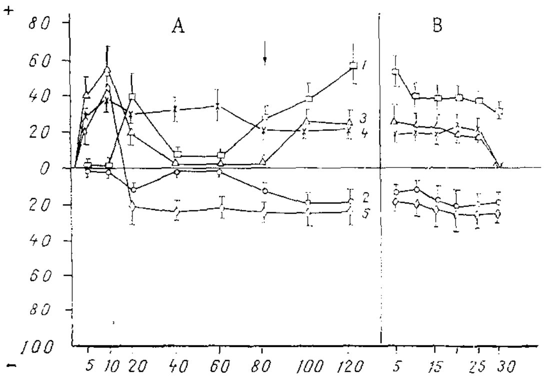

Fig. 2

Fig. 1. Excitability of brain structures at rest during adaptation (A) and deadaptation (B) to physical exertion. 1) Ventromedial hypothalamus; 2) dorsal hippocampus; 3) mesencephalic reticular formation; 4) anteromedial thalamus; 5) caudate nucleus. Abscissa, days of adaptation and deadaptation; ordinate, excitability of structures in % (background excitability taken as 100%). +) Increase, -) decrease in excitability. Arrow indicates beginning of training with maximal exertion.

Fig. 2. Dynamics of local cerebral blood flow at rest during adaptation (A) and deadaptation (B) to exercise. Ordinate, change in blood flow in % (background level of LCBF taken as 100%). Remainder of legend as in Fig. 1.

relative stabilization of functional activity of DH, RF, AMN, and CN. However, starting from the 20th day of training the excitability of VMN increased. A marked increase in function of VMN observed when maximal physical exertion was included in the training, when excitability increased from 28 to 50% after the 80th day compared with the background level, will be particularly noted in Fig. 1A. In addition the maximal exertion used on subsequent days of the experiment changed the functional state of RF and DH. For instance, the level of excitability of RF fell whereas activity of DH rose. Meanwhile the functional activity of CN and AMN showed no significant change. Investigation of the functional state of the structures after the end of the training program showed (Fig. 1B) that excitability of DH and AMN was restored by the 20th day of deadaptation, and that of VMN and RF by the 30th day. Meanwhile functional activity of CN remained depressed by 70% throughout the period of deadaptation.

During prolonged physical training characteristic changes were observed in LCBF. The dynamics of LCBF during adaptation and deadaptation to exercise is shown in Fig. 2A, B. During the first 10 days of the experiment the greatest changes in LCBF were found in RF, CN, and AMN; the blood flow in these structures was increased on average by 35-58% compared with the background level. As Fig. 2A shows, during this period LCBF in DH and VMN did not change significantly, but on the next days of the experiment (until the 20th day) the blood flow in VMN increased by 25%, whereas in DH and CN, on the contrary, it fell on average by 18% compared with initially. Starting with the 40th day of the experiment LCBF was restored in DH, RF, and VMN, but physical exertion to the limit caused a fresh increase in the blood flow in RF and VMN, a decrease in DH, and small fluctuations of LCBF in CN and AMN. More intensive exercise evidently caused the greatest increase in LCBF in VMN toward the end of the experiment. During deadaptation (Fig. 2B) LCBF was restored by the 30th day only in RF and AMN, and in the remaining structures the blood flow remained increased by 30-50% in VMN and reduced by 15-22% in CN and DH.

Starting with the 20th day of training, the deviations in functional activity of the structures studied, except VMN, were thus stabilized, a phenomenon which can be regarded as an adaptive reaction to the supposed individually graded submaximal physical exertion. However, the use of a physical factor with stronger action, in the form of compelling the rabbits to run up to the limit, changed the character of functional activity of DH and VMN and, in particular, of RF, but without causing any significant changes in AMN and CN. During deadaptation, excitability of DH and AMN was restored soonest of all. It is an interesting fact that after the end of training, excitability of RF continued to fall and it was not restored to its initial level until the 30th day.

The state of LCBF as described above during adaptation to physical exertion corresponds on the whole to the dynamics of changes in the thresholds of stimulation of the various structures, as confirmed by investigations showing close correlation between the functions of nerve cells and the circulation [1, 7, 11, 12].

During deadaptation, however, this rule could not be confirmed for DH and VMN. It has recently been shown that during the development of adaptation, changes in functional systems and in the formation of the response reaction of the body are rhythmic in character [5, 6, 8, 13]. The results of the present experiments show that during adaptation to exercise rhythmic changes also are observed in the functional activity of deep brain structures.

LITERATURE CITED

1. I. G. Demchenko and D. I. Paikin, Zh. Vyssh. Nerv. Deyat., No. 5, 1006 (1971).
2. V. G. Zilov, in: Problems in Physiology of the Hypothalamus [in Russian], No. 12, Kiev (1978), pp. 34-41.
3. O. I. Kamaev, in: Stress and Adaptation, Kishinev (1978), p. 318.
4. I. I. Leshchinyuk and O. V. Zaitseva, in: Stress and Adaptation [in Russian], Kishinev (1978), p. 32.
5. F. Z. Meerson, The General Mechanism of Adaptation and Prophylaxis [in Russian], Moscow (1973).
6. F. Z. Meerson, Adaptation, Deadaptation, and Failure of the Heart [in Russian], Moscow (1978).
7. Yu. E. Moskalenko, G. B. Vainshtein, I. G. Demchenko, et al., Intracranial Hemodynamics [in Russian], Leningrad (1975).
8. A. P. Sorokin, G. V. Smel'nikov, and A. N. Vazin, Adaptation and Regulation of the Properties of the Organism [in Russian], Moscow (1977).
9. K. B. Shapovalova, Role of Cortical and Subcortical Structures in Sensomotor Integration [in Russian], Leningrad (1978).
10. E. Fifkova and J. Marsala, in: Electrophysiological Methods of Investigation, J. Bures, M. Petran, and I. Zachar, eds. [Russian translation], Moscow (1962), p. 384.
11. M. Baldy-Moulinier and D. Ingvar, Brain Res., 5, 55 (1968).
12. D. Ingvar, M. Baldy-Moulinier, I. Suly, et al., Acta Neurol. Scand., 14, 179 (1965).
13. R. Metze, P. G. Linke, and E. Mantel, Med. Sport, 11, 327 (1971).