between the pH-dependencies of Ca^{++} inflow and outflow have been reported in the literature [2, 3, 6]. Comparison of the rate of outflow of Ca^{++} during its transport by SR fragments of the control and experimental animals (Table 1) indicates that the conformation change responsible for the outflow of Ca^{++} takes place more readily in membranes loaded with cholesterol.

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CHANGES IN TISSUE ENERGY METABOLISM IN ANIMALS EXPOSED TO CONTINUOUS AND INTERRUPTED LOW-FREQUENCY VIBRATION

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The action of continuous low-frequency vibration on rats for 1 month caused no changes in the total adenine nucleotides of the brain but led to a marked decrease in the ATP content and total adenine nucleotides in the limb muscles. After exposure to vibration for 3 months considerable exhaustion of the total adenine nucleotides of both muscles and brain was found. In the case of interrupted exposure to vibration the state of the adenine–nucleotide system depended on the duration of the pauses between periods of continuous exposure to vibration. During vibration with the shortest pauses (4 min) between successive periods of 30 min of vibration no changes were observed in the energy metabolism of the muscles and brain. Vibration with pauses of 8 and 15 min was found to be unfavorable for the adenine nucleotides of the muscles and vibration with a pause of 8 min for the brain.

KEY WORDS: adenine nucleotides; brain; muscles; continuous and interrupted low-frequency vibration.

Exposure to vibration causes various functional, structural, and metabolic disturbances in man and animals [4, 7, 9]. The effect of low-frequency vibrations on energy metabolism, however, has been inadequately studied.

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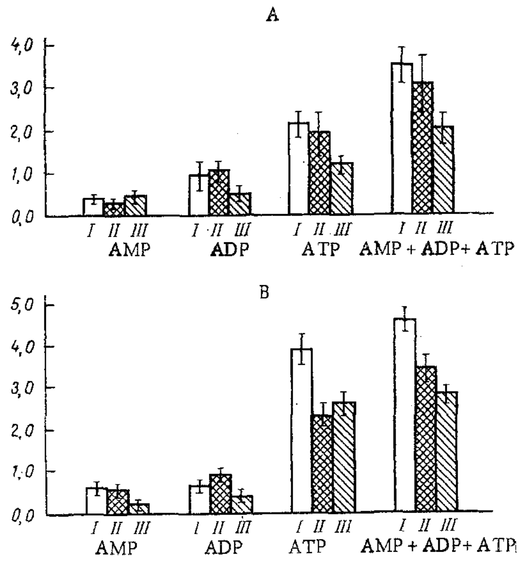

Fig. 1. Concentration of adenine nucleotides (in μmoles/g tissues) in brain (A) and muscles (B) of rats after exposure to continuous low-frequency vibration. I) Control, II) exposure to vibration for 1 month, III) exposure to vibration for 3 months.

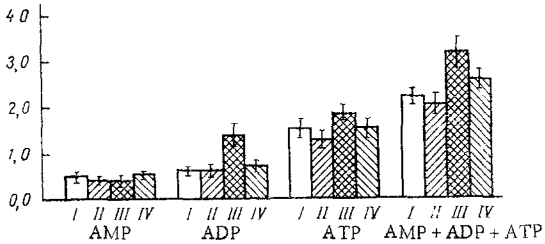

Fig. 2

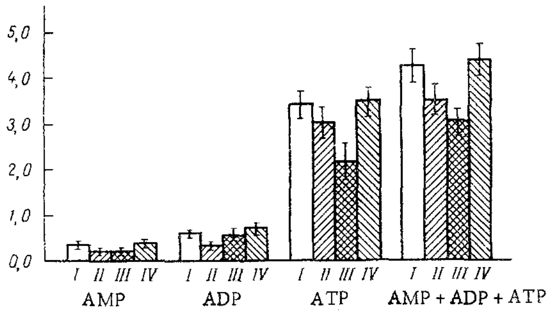

Fig. 3

Fig. 2. Concentration of adenine nucleotides (in μmoles/g tissue) in brain of rats after exposure to interrupted vibration. Here and in Fig. 3: I) control, II-IV) ratio between vibration and pauses 2:1, 4:1, and 8:1 respectively.

Fig. 3. Concentration of adenine nucleotides (in μmoles/g tissues) in muscles of rats after exposure to continuous low-frequency vibration.

The important role of adenine nucleotides as sources of energy for the functions of the body and their participation in many structural and regulatory processes [5], coupled with the absence of information in the literature on their metabolism during exposure to vibration, were the reasons for the study of these compounds in the nervous and muscular system of animals exposed to continuous and interrupted low-frequency vibration.

The object of the present investigation was to study the effect of continuous and interrupted vibration on energy metabolism.

EXPERIMENTAL METHOD

Male rats weighing 180-220 g were exposed to continuous vibration with a vibrational velocity within the 2 Hz octave frequency band and with an intensity of 130 dB. In the case of interrupted exposure the approximate ratios between the duration of action of vibration and the intervening pauses were: a) 2:1 (30 min vibration and 15 min pause), b) 4:1 (30 min vibration and 8 min pause), and c) 8:1 (30 min vibration and 4 min pause).

Interrupted vibration in all the experiments was characterized by vibrational velocity within the 2 Hz octave band and an intensity of 144 dB.

The total duration of exposure to vibration was 3 h daily. Exposure to continuous vibration lasted 1 and 3 months and to interrupted vibration 1 month. Intact animals were used as the control. Each group consisted of seven to nine rats.

The concentrations of adenine nucleotides were determined by high-voltage electrophoresis on paper, using the basic methods described by Voskoboinikov [2] and Sato et al. [13], with subsequent spectrophotometry at wavelengths of 260 and 290 nm. Differences between mean values were assessed by the t-test [11].

EXPERIMENTAL RESULTS

Exposure of the rats to continuous vibration for 1 month caused no change in the content of total adenine nucleotides in the brain. As a result of exposure for 3 months to vibration the ATP and ADP concentrations were reduced by almost half compared with the control and the total adenine nucleotides were reduced by 41% compared with their level in the control rats (Fig. 1A).

In the limb muscles a significant decrease in the ATP level and total adenine nucleotides was observed after exposure to vibration for 1 and 3 months (Fig. 1B). The changes in the adenine nucleotide system were intensified by lengthening of exposure to vibration: The metabolism of ATP precursors was disturbed (the AMP concentration was reduced by two-thirds compared with the control, the ADP level showed a tendency to decrease).

Despite different times of onset of the changes, the response of the total adenine nucleotides of the brain and skeletal muscles to continuous vibration was thus similar and consisted essentially of a fall in their concentration. Considering the role of ATP as the source of energy for the activity of the CNS and muscles [1], the decrease observed in its level must be regarded as highly unfavorable.

The decrease in the concentration of adenine nucleotides in the muscles after exposure to low-frequency vibration for 1 month and the appearance of disturbances in the brain only after such exposure for 3 months indicate that the muscular system is more sensitive than the brain to the action of this vibration.

Denervation of skeletal muscles leads to a disturbance of their energy metabolism, and the changes produced are similar to those found in the present experiments [3]. On the other hand, according to data in the literature structural disturbances are observed in nerve endings in the neuromuscular synapses as a result of exposure to vibration [8, 1]. This may perhaps account for the earlier fall in the level of adenine nucleotides in the muscles under the influence of low-frequency vibration.

The balance of adenine nucleotides in the brain was found to be significantly disturbed after exposure to interrupted vibration under certain conditions. For instance, if the ratio between vibration and the intervening pauses was 2 : 1 (alternation of 30 min vibration and 15 min pause) no significant changes were found in the adenine nucleotide system of the brain, but if the ratio between vibration and pause was 4 : 1, the ADP concentration was more than doubled compared with its level in the control animals, the total adenine nucleotides increased significantly, and the ATP concentration showed a tendency to increase (Fig. 2). If the duration of the pauses was later reduced from 8 to 4 min (so that the ratio between the time of vibration and pause became 8 : 1) no significant changes were observed in these parameters.

Certain changes in metabolism of adenine nucleotides were found in the muscles after exposure to vibration even interrupted by relatively long pauses (15 min), i.e., when the ratio between vibration and pause was 2 : 1. Under these circumstances the ATP concentration did not differ from the control, but there was a significant decrease in the AMP and ADP concentrations, and the total adenine nucleotides showed a tendency to fall (Fig. 3). A significant decrease in the concentrations of ATP, ADP, and total adenine nucleotides was found only if the pauses were shortened to 8 min (ratio of vibration to pause 4 : 1).

The results suggest that changes in the energy metabolism of the brain and muscles of rats exposed to interrupted vibration depend on the duration of the pauses between periods of continuous exposure to vibration. The shortest intervals were found to be more favorable than pauses of 8 or 15 min for muscles, and for pauses of 8 min for the brain. The absence of any marked effect of interrupted stimuli with pauses of 5 min duration by comparison with longer pauses has been described in the literature for auditory sensation under the influence of noise [11].

One reason for the suggested dependence of energy metabolism in the tissues on the duration of the pauses between exposure to vibration may be the fluctuating character of restoration of the sources of energy that is a characteristic feature of energy metabolism [6].

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