ARTIFICIAL ADAPTATION TO COLD PRODUCED BY NORADRENALIN

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The state of muscular heat production 2-3 weeks after intravenous injection of noradrenalin was studied during exposure to cold. A single injection of noradrenalin was found to facilitate maintenance of temperature homeostasis for several weeks with a greatly reduced electrical activity of the muscles and before the noradrenalin was given. The phenomenon probably lies at the basis of adaptation of animals to cold.

KEY WORDS: *muscular thermogenesis; noradrenalin; heat production; adaptation; homeostasis.*

Administration of noradrenalin to a cold-adapted animal is known to cause a sharp increase in the body temperature and the total heat production [12-15, 17, 18]. The physiological mechanism of this phenomenon probably consists of a specific increase in the thermogenesis of muscular contraction [3, 5, 6, 11, 12], as a result of which even very slight shivering or thermoregulatory muscle tone can sharply increase the total heat production of the body responsible for its protection against cold.

In this investigation the effect of noradrenalin was studied on the state of muscular thermogenesis in the later period after its intravenous injection into cold-unadapted rabbits. Noradrenalin was injected in doses corresponding approximately to the amounts of mediator entering the animal's blood stream in some stress situations [8, 9].

EXPERIMENTAL METHOD

Chinchilla rabbits weighing 2.5-3.5 kg were used. For several days before the experiment the animals were accustomed to the frame and the experimental situation. The frame restricted the rabbit's movements but enabled it to rest in a comfortable position. The experiments were carried out in a temperature chamber with a capacity of 7 m^3 and at an air temperature of 0°C.

The electromyogram (EMG) was measured and recorded by a UBP-1-01 biopotentials amplifier, using two needle electrodes inserted beneath the animal's skin above the muscles of the upper third of the back at a distance of 2.5 cm apart. The signals from the amplifier terminals were led to the input of an integrator [2]; impulses were recorded at the output of the instrument with a frequency proportional to the integral of the input signal. The rectal temperature at a depth of 6 cm, the temperature of the spinal muscles from which electrical activity was recorded, and the temperature of the chamber were measured by copper–constantan thermocouples, the emf from which was amplified by instruments based on F117 photoelectric amplifiers [1]. The outputs of the photoelectric amplifiers were connected to a type ÉPP-09 MZ 12-channel automatic writer with specially graduated scale. For simultaneous recording of the measured temperatures and EMG (in conventional units) on the potentiometer tape the output of the integrator was connected to the input of a type ISS-3 mean-count rate meter. The oxygen consumption of the animals was also measured by a mask method. Air samples were analyzed with the Haldane apparatus.

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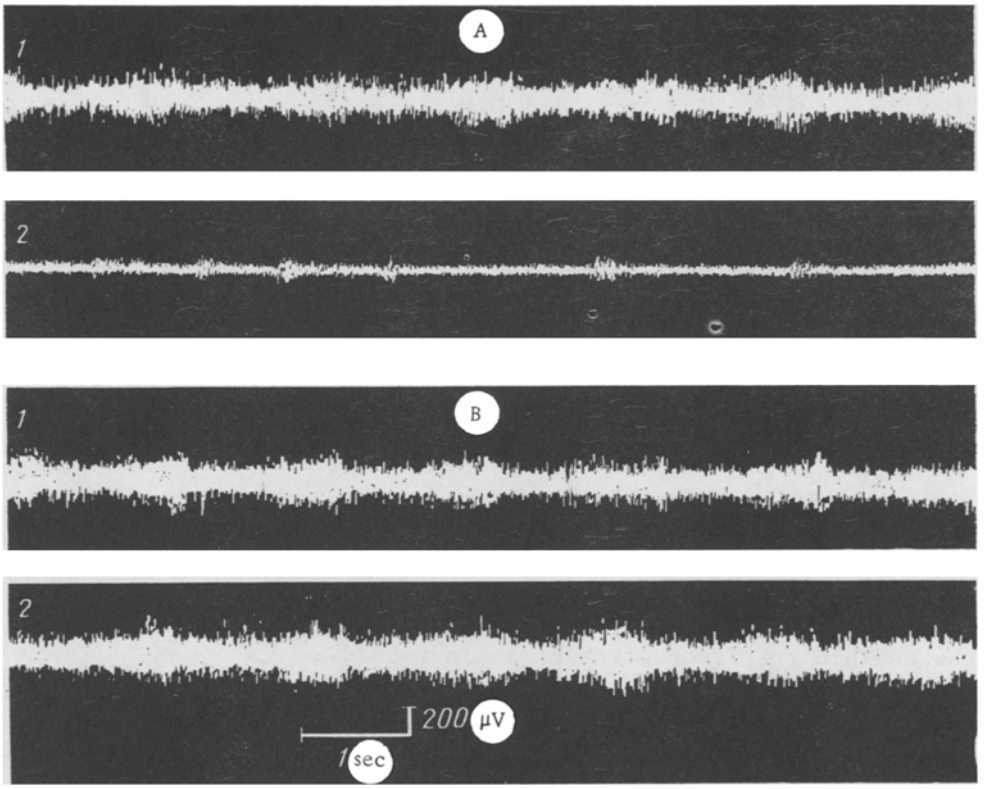

Fig. 1. Changes in muscle electrical activity 2-3 weeks after injection of noradrenalin: A) noradrenalin, B) physiological saline; 1) spontaneous EMG at 0°C; 2) EMG at 0°C 2-3 weeks after injection of noradrenalin (A) or physiological saline (B).

The order of the experiment was as follows: After fixation of the sensors the air temperature in the chamber was lowered by means of a refrigeration system to 0°C. At this temperature the EMG, rectal temperature, and muscle temperature were recorded and the oxygen consumption determined for 1.5-2 h. Noradrenalin was then injected intravenously into the animal through a cannula inserted previously into the marginal vein of the ear, at a rate of 4 μg/kg body weight/min in 30-40 min. The total dose of noradrenalin given was thus about 500 μg per animal. In agreement with data in the literature, this dose is approximately equal to the amount of noradrenalin which enters the animals' blood stream in some stress situations (for example, if the animal is placed in an unfamiliar environment, such as an airtight chamber) from the sympathetic nerve endings and chromaffin tissue [8, 9].

In supplementary experiments the animal's arterial blood pressure was measured during injection of the above-mentioned dose of noradrenalin: the blood pressure rose to 160 mm Hg, remained at that level for only 1-2 min, and then fell rapidly, so that throughout the experiment it exceeded its initial value by only 8-10 mm Hg. The doses of noradrenalin injected can be taken to be commensurate with the amount entering the animals' blood stream under natural conditions.

After injection of noradrenalin the animals were kept under ordinary animal house conditions in an ambient temperature of 16-18°C.

The EMG, rectal temperature, and oxygen consumption were recorded and measured again 2-3 weeks after the injection of noradrenalin, also in the chamber at a temperature of 0°C. Observations by many workers have shown that this period is commensurate with the duration of cold adaptation, signs of which (reduced muscle electrical activity in the EMG accompanied by high heat production) can be manifested during repeated exposures to cold 2-3 weeks after the first such exposure [4, 7, 16].

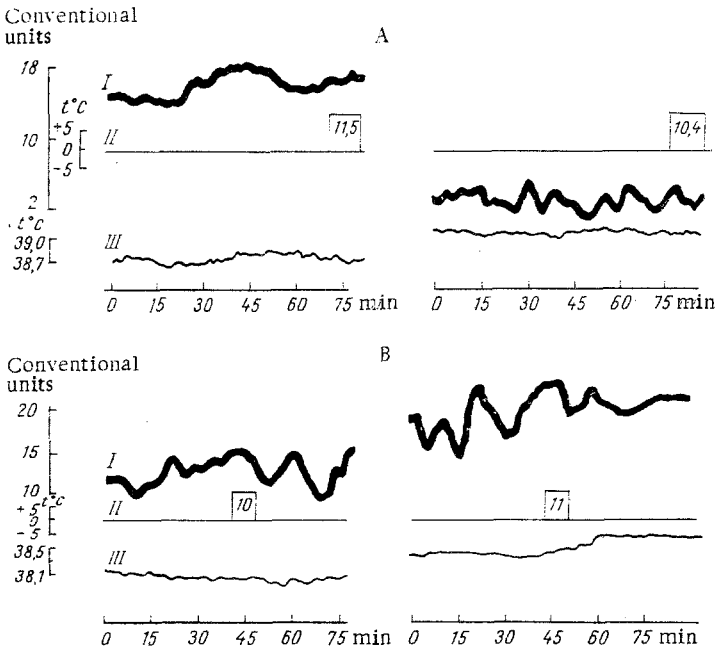

Fig. 2. Changes in muscle electrical activity, rectal temperature, and oxygen consumption 2-3 weeks after injection of noradrenalin: A) noradrenalin; B) physiological saline; I) muscle electrical activity; II) air temperature in chamber; III) rectal temperature. Numbers in boxes show animals' oxygen consumption (ml/kg/min).

In the control series of experiments physiological saline was injected in the same volume instead of noradrenalin. Otherwise the experimental conditions and management of the animals were identical with those in the experiments in which noradrenalin was given.

Altogether 20 animals were used, nine in the control experiments and 11 in the experiments with noradrenalin.

EXPERIMENTAL RESULTS AND DISSCUSSION

At 0°C the animals developed intensive cold shivering. Continuous administration of noradrenalin in the above-mentioned dose for 30-40 min caused no changes in the EMG or rectal temperature during this time. Injection of physiological saline in the control experiments likewise caused no changes. Electrical activity of the muscles 2-3 weeks after intravenous injection of noradrenalin at an ambinet temperature of 0°C was much lower than before injection of noradrenalin (Fig. 1). The rectal temperature at 0°C remained the same after injection of noradrenalin as before, and in some animals it was actually higher. No significant change took place in the animals' oxygen consumption (Fig. 2). Additional measurements of the temperature of the spinal muscles likewise revealed no decrease in the muscle temperature compared with that at 0°C before injection of noradrenalin.

In the control experiments no statistically significant change in muscle electrical activity was observed 2-3 weeks after intravenous injection of physiological saline (Fig. 2) but the rectal temperature, just as after injection of noradrenalin, was a little higher than initially. No statistically significant differences likewise were found between the rectal temperature after injection of noradrenalin and after injection of physiological saline.

The experiments thus showed that noradrenalin can induce a specific shift in the mechanisms of muscular thermogenesis up to 2-3 weeks after a single injection. This shift is reflected in the fact that cold shivering of much lower intensity enables the body to maintain temperature homeostasis during exposure to low ambient temperatures. A similar decrease in the intensity of shivering on account of its increased thermal efficiency takes

place during prolonged adaptation of animals to cold [3, 4, 5, 6]. These results are in agreement with the observations of Slonim and Shvetsova [10], who found a long aftereffect following a single exposure to cold accompanied by lowering of the body temperature to 30°C. This aftereffect was characterized by great stability of the "core" temperature to cooling, reduced muscle electrical activity, and increased oxygen consumption.

The results of the experiments with noradrenalin indicate prospects for artificial pharmacological methods of increasing the resistance of the body to cold.

LITERATURE CITED

1. I. M. Bakhilina, Fiziol. Zh. SSSR, No. 1, 119 (1967).
2. S. R. Gutman, in: Electronic Apparatus for Electrophysiological Research [in Russian], Moscow (1969), pp. 18-23.
3. K. P. Ivanov, Bioenergetics and Temperature Homeostasis [in Russian], Leningrad (1972), pp. 32-64.
4. K. P. Ivanov and D. A. Rashevskaya, in: Physiological Adaptations to Heat and Cold [in Russian], Leningrad (1969), pp. 126-129.
5. K. P. Ivanov and A. D. Slonim, Fiziol. Zh. SSSR, No. 12, 1828 (1970).
6. K. P. Ivanov, E. Ya. Tkachenko, and M. A. Yakimenko, Fiziol. Zh. SSSR, No. 10, 1438 (1970).
7. L. A. Isaakyan, The Metabolic Structure of Temperature Adaptations [in Russian], Leningrad (1972), p. 83.
8. P. Clegg and A. Clegg, Hormones, Cells, Organism [Russian translation], Moscow (1971), pp. 148-150.
9. A. F. Maslova, Pat. Fiziol., No. 2, 57 (1966).
10. A. D. Slonim and E. I. Shvetsova, Fiziol. Zh. SSSR, No. 8, 1262 (1973).
11. E. Ya. Tkachenko and K. P. Ivanov, Fiziol. Zh. SSSR, No. 1, 111 (1973).
12. E. Ya. Tkachenko and M. A. Yakimenko, Fiziol. Zh. SSSR, No. 10, 1540 (1973).
13. J. Chatonnet, J. Physiol. (Paris), 51, 319 (1959).
14. W. Cottle and L. Carlson, Proc. Soc. Exp. Biol. (New York), 92, 845 (1956).
15. F. Depocas, Canad. J. Biochem., 38, 107 (1960).
16. J. S. Hart, Fed. Proc., 19, Suppl. 5, 15 (1960).
17. O. Héroux, Canad. J. Biochem., 39, 1829 (1961).
18. L. Jansky, R. Bartinkowa, and R. Zeisberger, Physiol. Bohemoslov., 16, 306 (1967).