HUMERAL MECHANISMS OF REGULATION OF WORKING HYPERTHERMIA

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Progress in the identification of substances playing the role of "working factor" in the regulation of body temperature has recently been noted. For instance, a whole group of natural steroids (etiocholanolone, pregnenolone) and other biologically active substances have been shown to have a pyrogenic action, and the pyrogenic action of estrogens also has been confirmed [5, 6]. The intracerebral calcium ion balance has been shown to be a most important component of the regulatory mechanism of working hyperthermia [4].

A wide range of hormones, secretion of which increases with the commencement of muscular work, deserves attention. These hormones support the increased demand made on the autonomic component of motor activity, and at the same time many of them induce a pyrogenic side effect [2].

Recent research has shown that with the commencement of muscular work cells of the phagocytic system become activated and secrete several biologically active substances into the medium; leukocytic pyrogen is one of these substances which has received the closest study. Under its influence a chain of reactions is triggered, leading to an increase in the adhesive properties of the endothelial cells, increased permeability of the tissue-blood barriers, activation of glial cells, and changes in levels of neurotransmitters, hormones, and neuropeptides in the internal medium of the brain. These changes lead to the restructuring of specialized temperature-sensitive nerve cells, and to the triggering of effector temperature-regulating reactions aimed at increasing the heat content of the body. Exactly the same phenomena also are observed during the development of febrile reactions, aimed at maximal mobilization of the defensive forces of the body [1, 3, 4, 7].

A correct understanding of the initiating stage of mechanisms of thermoregulation is not only of theoretical, but also of considerable practical importance for the physiology of work and sport. In this connection we have undertaken a series of experimental studies with the aim of improving our understanding of some aspects of the mechanism of thermoregulation, that are of great importance in the practice of sport.

Considering that the "work factor" accumulates in the blood plasma, we attempted to prove its existence and the time course of its action on the body by observing reactions of the temperature-regulating system to injection of blood plasma of a working animal into the vascular system of a resting recipient.

EXPERIMENTAL METHOD

A sample of blood was taken from the external marginal vein of a rabbit, which had worked on a treadmill for at least 20 min, and after centrifugation for 10 min the plasma (5 mm^3) was injected into the marginal vein of a rabbit sitting motionless in a special frame. The rectal temperature of the two rabbits was measured.

EXPERIMENTAL RESULTS

The results in Fig. 1 show that injection of plasma from the working donor caused an initial fall of the core temperature of the recipient, which lasted about 10 min. In some experiments this amounted to 0.9°C. After about 90 min, wavelike oscilla-

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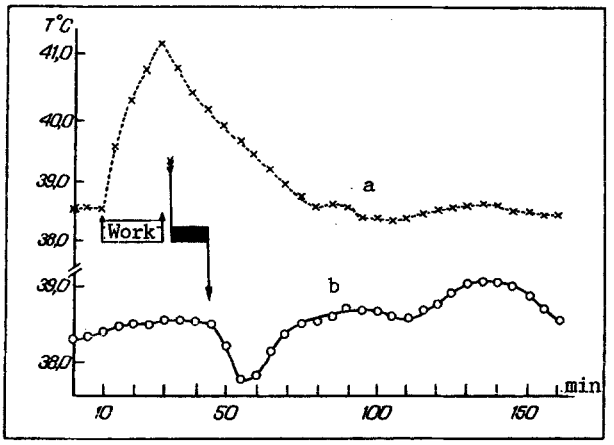

Fig. 1. Changes in core body temperature of rabbits: a) donor at test, during work, and in recovery period; b) recipient, at rest. Arrows indicate time of working, taking blood, centrifugation, and injection of plasma into recipient.

tions of the recipient's core temperature with an amplitude of not exceeding 0.8°C were observed. In control experiments the temperature fell after injection of the foreign plasma, but did not rise during the subsequent 2.5 h of observation.

Elevation of the recipient's temperature 90 min after injection of plasma from a working rabbit, continuing on average for about 30 min, is evidence that certain biologically active substances, capable of initiating a rise of temperature in a nonworking animal, are present in it. The temporal characteristics of the response are in agreement with data in the literature, such as, for example, after injection of pyrogenal. Unlike the action of pyrogenal, in the present experiments a relatively small rise of the core temperature was observed. The small rise of temperature can easily be understood, using the following simple calculation: the concentration of "work factor" in the donor's blood was such that it caused the temperature to rise by 3°C. We took 1/10-1/15 of the blood and injected it into a recipient, thereby reducing the concentration of the factor approximately 15-fold. In response, a rise of temperature of a few tenths of a degree would be expected, and that indeed was obtained in the present experiments. We concluded from the results of this series of experiments that the "work factor" might be found more clearly if its concentration in the plasma was made much higher. Under experimental conditions this meant either complete replacement of the recipient's blood or injection of plasma directly into the space surrounding the temperature regulating center.

The next series of experiments accordingly consisted of recording changes in the temperature regulating system during perfusion of plasma from a donor in a state of muscular hyperthermia through the third ventricle.

Jointly with colleagues at the A. N. Sysin Institute of Communal Hygiene, we developed and tested a method of implanting a guiding cannula into bone above the third ventricle, by means of which thermodes, electrodes, or cannulas for perfusion of any liquid through it, into bone above the third ventricle. The guiding cannulas had strictly parallel walls and their configuration was such that the cannulas could be securely fixed by means of lugs to a layer of acrylic glue on the miniature screws to the bone surface (the cannulas and miniature screws were designed and made at the Second Moscow Clock Factory). The cannulas were implanted by means of a stereotaxic apparatus (Hungary) and with the aid of a stereotaxic atlas. Of all the rabbits undergoing the operations, four were fit for the experiments after 3 weeks. Needles of microsyringes, through which the perfusion was carried out, were inserted into the cannulas. The measuring junction of thermocouples for measuring brain temperature was introduced. After the experiments, the site of the needle of thermocouple was identified histologically.

Both in the experiment and in the control, in response to perfusion of the third ventricle with plasma, a sharp rise of the core temperature by 0.8-1.1°C was observed (after a latent period of not more than 15 sec), which lasted more than 5 min. In the control experiments the core temperature of the rabbit fell in the course of 15-20 min to its initial level or below. By contrast with this, in experiments with perfusion with plasma of a working animal, a new rise of core temperature began after 17-20 min and lasted about 40 min (Fig. 2). The amplitude of the second rise of the rectal temperature in the experiment was 0.7-0.9°C, the donor's temperature being 41.2°C (with a rise of temperature of 2.8°C). The temperature readings in the third ventricle were synchronized with readings of the rectal temperature, but were 0.15-0.20°C higher than the latter.

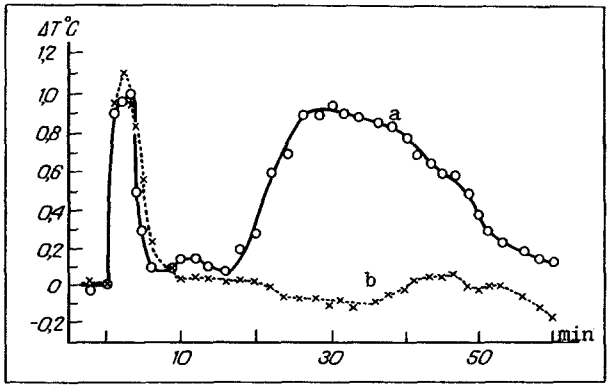

Fig. 2. Graph of changes in core temperature of rabbits after injection of plasma from a rabbit working on a treadmill (a) and from a control rabbit at rest (b), into the third ventricle.

The experimental results demonstrate that the important mechanisms in the development of work hyperthermia are chemical, enabling nervous mechanisms of regulation to be activated. Thus the first rise of temperature in both control and experiment was clearly neurogenic in nature, with a short (for autonomic responses) latent period (up to 15 sec), and a short duration with a steep leading and linear trailing edge. The second rise, which was observed only in the experiment and not in the control, was evidently triggered chemically: the long latent period, the linear leading edge and the exponential trailing edge. The experiment showed that nervous influences raise the body temperature (considering the difference in weight between laboratory animals and man) by 1.0°C possibly in the course of 3-8 min. However, in actual muscular work hyperthermia develops in accordance with different laws, similar to those operating in the model described in this paper. This suggests that a complex of chemical substances, accumulating and formed during muscular work, is the initiating principle, maintaining and developing work hyperthermia.

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