CONTRACTION OF SMOOTH MUSCLES OF THE CAT SKIN ON COOLING

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Cooling of an isolated area of cat's skin is accompanied by considerable contraction of the skin, with relaxation on a return to the normal temperature. The strength of contraction is directly dependent on the temperature level. Temperature changes can be used as a direct stimulus for the smooth muscles of the skin. Suggestions are made regarding the role of the skin collagen in the contractile process, the direct mechanism of thermoregulation of the cooled area of skin, and the possible role of mechanoreceptors in the transmission of temperature stimulation.

Investigations of the effect of lowering the skin temperature in cats on work of the mechanoreceptors have revealed a decrease in the frequency spectrum in Aδ fibers [1]. This fact may be connected with changes in the visco-elastic properties of the skin during contraction of the pilomotor muscles. In man, cooling of the skin is accompanied by contraction of the pilomotor muscles [12, 13], but this has not been found in cats [7].

In the investigation described below, the effect of changes in temperature on the smooth muscles of the cat skin was studied.

EXPERIMENTAL METHOD

Cats were anesthetized with urethane and an area of skin dissected in the region of the knee joint, placed on a moist, thermostatically controlled bed, and fixed to a myograph to measure the strength of contractions. The nerve supply, blood supply, and original dimensions of the area of skin were preserved. The temperature of the bed was varied by means of water from TS-15 thermostats. Changes in skin temperature were measured with a TÉMP-60 electrothermometer. The strength of contraction of the pilomotor muscles of the skin was recorded with a photodiode. Changes in the skin temperature and in the strength of contraction of the pilomotor muscles were recorded on an N-102 loop oscillograph. In some experiments, activity was recorded from the patellar branch of the saphenous nerve by platinum electrodes through a type UBP1-01 amplifier.

EXPERIMENTAL RESULTS

Electrical activity recorded from the patellar branch of the saphenous nerve and the strength of contraction of the piece of skin in response to a decrease in temperature are shown in Fig. 1. Low-voltage spikes and definite contraction of the skin can be seen. The rate of change of skin temperature was nonlinear. The strength of contraction of the skin varied in different experiments from 6 to 25 grams force (Figs. 2, 3).

The graph in Fig. 2 (curve A) shows the relationship between strength of contraction of the skin and changes in temperature. With a decrease in temperature the skin developed a contraction strength of up to 20 grams force. As the temperature returned to normal, the skin relaxed beyond its original level.

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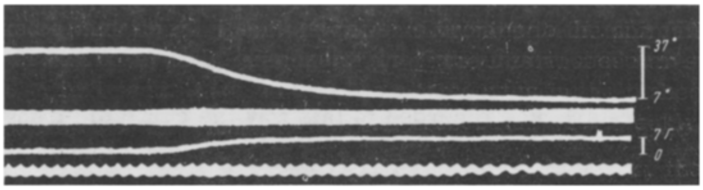

Fig. 1. Contraction of smooth muscle of skin and afferent activity in cutaneous nerve on lowering skin temperature. From top to bottom: change in temperature, activity of cutaneous nerve, strength of contraction of smooth muscle of skin, time marker 1 sec. Calibration of temperature and strength of contraction on right.

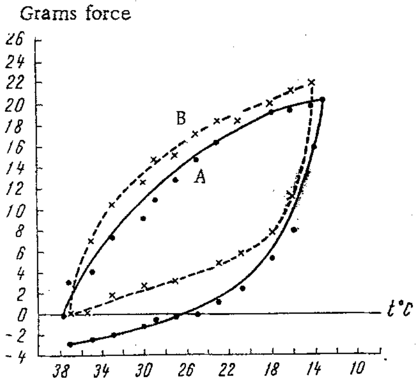

Fig. 2

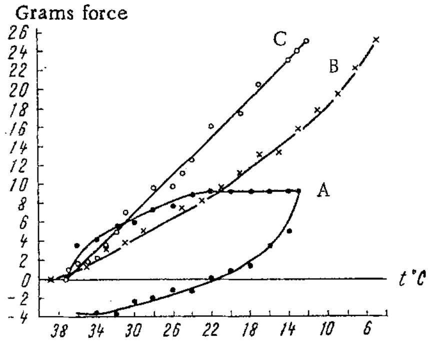

Fig. 3

Fig. 2. Strength of contraction and relaxation of smooth muscle of an area of skin during change in temperature: A) first measurement; B) measurement taken immediately after first.

Fig. 3. Strength of contraction of smooth muscle of skin during change in temperature: A) area of preliminarily denervated skin; B) sensor of electrothermometer placed between thermostatically controlled bed and skin; C) slow lowering of skin temperature, at 1 deg/min.

A second change in skin temperature immediately after the first always led to a stronger contraction than the first time, and on rewarming to body temperature, the skin relaxed to its initial level (Fig. 2, curve B).

This difference can be explained by the existence of a constant contractile tone of the skin, which was partly lost during contraction of the pilomotor muscles when recorded under isometric conditions. The loss of this tone resulted from the visco-elastic properties of the skin. Because of it, the strength of contraction of the skin in response to the first application of cooling was less than to the second. After 30-40 min the contractile tone of the skin was restored. Similar effects also were observed in specimens of cat's skin completely isolated from the animal.

Rapid cooling of a nerve is known to induce impulse activity in its fibers [4]. Presumably during cooling of the skin the rapid change of temperature causes excitation in efferent fibers, thereby causing contraction of the pilomotor muscles. To test this hypothesis the saphenous nerve was divided 13-15 days beforehand, so that all its fibers would have degenerated. Cooling the skin denervated in this manner showed that the curve of strength of contraction versus temperature was indistinguishable in character from the curve obtained in experiments with innervated skin (Fig. 3A) and was convex in shape. The nonlinear character of the curve depended on other causes. One such cause could be delay in recording the true temperature of the layer of skin containing the pilomotor muscles by the electrothermometer. To determine if this was the true cause of the nonlinear character of the curve of contraction strength of the skin versus change in temperature, the electrothermometer sensor was placed between the thermostatically controlled bed and the skin. In the case, the skin temperature readings would be obtained first and the shape of the curve would correspond to the mirror image of the curve in Fig. 2A.

In fact, when the temperature was recorded in this way the curve of strength of skin contraction versus decrease in temperature was concave in shape (Fig. 3B). In this case the anticipation of the skin temperature readings was much less than the delay when temperatures were measured from the skin surface, since the curve was almost a straight line.

To avoid any discrepancy between the electrothermometer readings and the skin temperature, the skin was slowly cooled (at about 1 deg/min). It was assumed that during this time all the layers of the skin would have reached the temperature of the bed. Figure 3C shows a graph of the strength of skin contraction in response to a slow decrease in temperature. In this case the strength of contraction of the smooth muscles of the skin was directly dependent on temperature.

The smooth muscle of the internal organs is known to be very sensitive to changes in temperature [5, 9]. The effect of contraction of the smooth muscles of the human skin (the appearance of "goose flesh") on cooling has been observed in denervated skin [12]. It can be assumed that in man cooling of the skin causes contraction of the pilomotor muscles and of the diagonal muscle bundles whose function is not connected with erection of the hair [10]. The cat's skin is very richly supplied with smooth muscle, which is connected with the hair follicles and is concerned with erection of the hair [8, 14].

The present experiments demonstrated contraction of the smooth muscle of the cat's skin in response to cooling. Chronic denervation experiments have shown that contraction of the pilomotor muscles of the skin takes place in response to the direct action of cold on the smooth muscles. It is possible that collagen plays a role in the contractile response of the area of skin to local cooling. The structure of the collagen molecule is known to be extremely sensitive to temperature changes [3, 15]. The cause of differences in the strength of contraction of the skin in this experiment was not investigated.

The hypothesis that the smooth muscle of the skin plays a definite role in temperature sensations was put forward by Häggquist [6]. In his histological investigations of "cold" spots of the human skin, instead of the hypothetical specific encapsulated cold receptors he found a large collection of smooth muscle fibers. Conceivably the mechanoreceptors located in these points become excited as the surrounding tissues are displaced in response to contraction of the smooth muscles during exposure to cold. The hypothesis has been put forward that smooth muscles of the cutaneous muscular system play a role in temperature reception [11], which is based on the great sensitivity of the smooth muscles of venules and arterioles of the skin to temperature changes. The proposers of this hypothesis considered that there is one adequate stimulus for the receptors of the skin, namely movement. In response to cooling the smooth muscles of the vessel walls contract, causing movement of the surrounding tissues and thus exciting the receptors.

Investigations of cold receptors of cutaneous vessels [2] revealed a connection between contraction of the smooth muscles of the vessel wall and excitation of the receptors. It was considered that these receptors are receptors of tone of the cutaneous vessels. The resulting vasoconstriction arrests the circulation in that part of the skin and reduces the heat loss.

It can be concluded from the present experiments that not only the smooth muscles of the vessel walls can produce vasoconstriction, but also the smooth muscles and, possibly, the collagen of the skin itself, which, by their contraction, make the skin tight and close its capillaries sooner than the smooth muscles of the cutaneous vessels can do so themselves. Under these conditions impulses are generated by the skin mechanoreceptors, and subsequently by mechanoreceptors of the blood vessels. This argument concerning the order of contraction of the smooth muscles is supported by experiments in which the temperature of the skin was changed from its surface and from below. The delay in temperature measurement depended on the poor thermal conductivity of the skin. This shows that during exposure to low external environmental temperatures, cooling of all layers of the skin takes place with a high gradient.

It can thus be postulated that the thermoreceptors of the skin can act as its mechanoreceptors, and that the initial component of the thermoreceptor is the smooth muscle.

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