COOLING RATE AND THRESHOLD OF METABOLIC AND HEAT LOSS RESPONSES BEFORE AND AFTER ADAPTATION TO COLD

T.V. Kozyreva

Institute of Physiology, Novosibirsk, Russia

INTRODUCTION

It is generally believed that the central and peripheral thermoreceptors are the structures forming the thermoregulatory sensory network. Our previous experiments have demonstrated that cold adaptation results in change in the functioning of the central and the peripheral skin receptors, Adaptation to cold result in a decrease in number of the hypothalamic neurons sensitive in the range of low brain temperatures. Also, in the range of low skin temperatures, decreases (2, 6, 7). The dynamic response of the majority of the skin cold receptors to cooling also decreases twofold (4). Cold receptors in control animals at slow skin cooling (less than 0.01°C/sec) virtually show no dynamic activity. At fast cooling, dynamic activity appears and increases with cooling rate up to a certain limit at which saturation is reached (1, 9). The importance of the dynamic activity of the skin cold receptors to the triggering of the metabolic response and heat loss has been demonstrated at fast cooling (3, 5, 8). Hence, to follow the course of changes of the thermoregulatory responses to fast and slow cooling during cold adaptation and to attempt to relate the adaptive changes in the thermoreceptive structures with the shift in the thermal thresholds of the cold defense responses are of importance.

MATERIALS and METHODS

For six weeks prior experimentation the control rats were kept at 20-22°C, and the cold adapted rats at 3-5°C of ambients. The experiments were performed on male rats slight anaesthetized by urethane. A part of the abdomen 20-22 cm , which was depilated, was cooled with a thermode. Cooling rates ranged 0.0025 to 0.1°C/sec. Intracutaneous temperature of the cooled surface of the abdomen, rectal temperature, total oxygen consumption (the metabolic response), and intracutaneous temperature of the thigh were continuously recorded. Thigh temperature (the measured area was heat isolated from the body and environment), permitted the estimation of changes in the tone of the skin vessels, i.e. heat loss.

RESULTS

The formation of the thermoregulatory response proceeds differently for slow cooling. when the thermoreceptors show no dynamic activity, than for fast cooling, while dynamic activity was exhibited in both control and cold adapted rats. During fast cooling, the metabolic response was triggered before rectal temperature started to fall. Only after a rectal temperature fall (by 0.3±0.14°C in control and 0.13±0.05°C in cold adapted) heat loss started. During slow cooling, heat loss is initially reduced as a result of the response of the skin vessels; then, only after a considerably lowered rectal temperature (by 0.7±0.15°C in control and 1±0.17°C in cold adapted rats), metabolic rate increases. This evidences for the importance of the dynamic activity of thermoreceptors to the sequential triggering of the thermal defense responses. There was a similarity between the general sequence of the development of responses to cooling with different rates in control and cold adapted rats. However, the two groups were found to differ, when their parameters of the thermoregulatory responses were compared. At slow cooling, the lower the cooling rate, the lower was rectal temperature and the higher was the skin temperature at which the metabolic response was triggered (Fig. 1). At fast cooling, the metabolic response was triggered in the absence of changes in rectal temperature regardless the state of adaptation. However, Fig. 1 shows that, after cold adaptation, all the curves for the threshold temperature are shifted to the range of higher cooling rates. In the controls, the metabolic response was triggered without change in rectal temperature, when cooling rate exceeded 0.013°C/sec, after cold adaptation, cooling rate had to exceed 0.033°C/sec to achieve this effect. Furthermore, in all the ranges of cooling rates, the metabolic response after cold adaptation appeared at lower skin temperature, while in the slow cooling range it appeared also at a greater rectal temperature fall than before adaptation (Fig. 1). The threshold shifts of the thermoregulatory responses after cold adaptation can be explained by the functional characteristics of changes in both the peripheral and central thermoreceptors. At slow cooling, both the peripheral and central thermoreceptors are presumably involved in triggering of the metabolic response. A shift of the threshold of the response may be related to a decrease in the amount of hypothalamic and skin thermoreceptors functioning in the range of low brain and skin temperatures, as well as to a decrease in the level of the static activity of most cold skin receptors (2, 3, 5). At fast external cooling, the dynamic activity of the skin cold receptors seems to acquire primary importance. After adaptation to low temperatures, the dynamic activity of the bulk of the skin cold receptors decreases, and this is reflected in change of the thermoregulatory metabolic response. The dependence of the metabolic response on cooling rate decreases. The patterns of slow cooling in cold adapted animals spreads over a wide range of cooling rates to 0.033°C/sec. In the controls, the patterns of fast cooling appeared early at 0.013°C/sec. The threshold of rectal temperature fall did not change significantly after adaptation to cold in the case of the response of the skin vessels at both types of cooling. Only at slow cooling, the values for threshold skin temperature of the vascular response was lower in the cold adapted (32.4±0.63 °C) than in control rats (35.6±0.29°C). This may be also

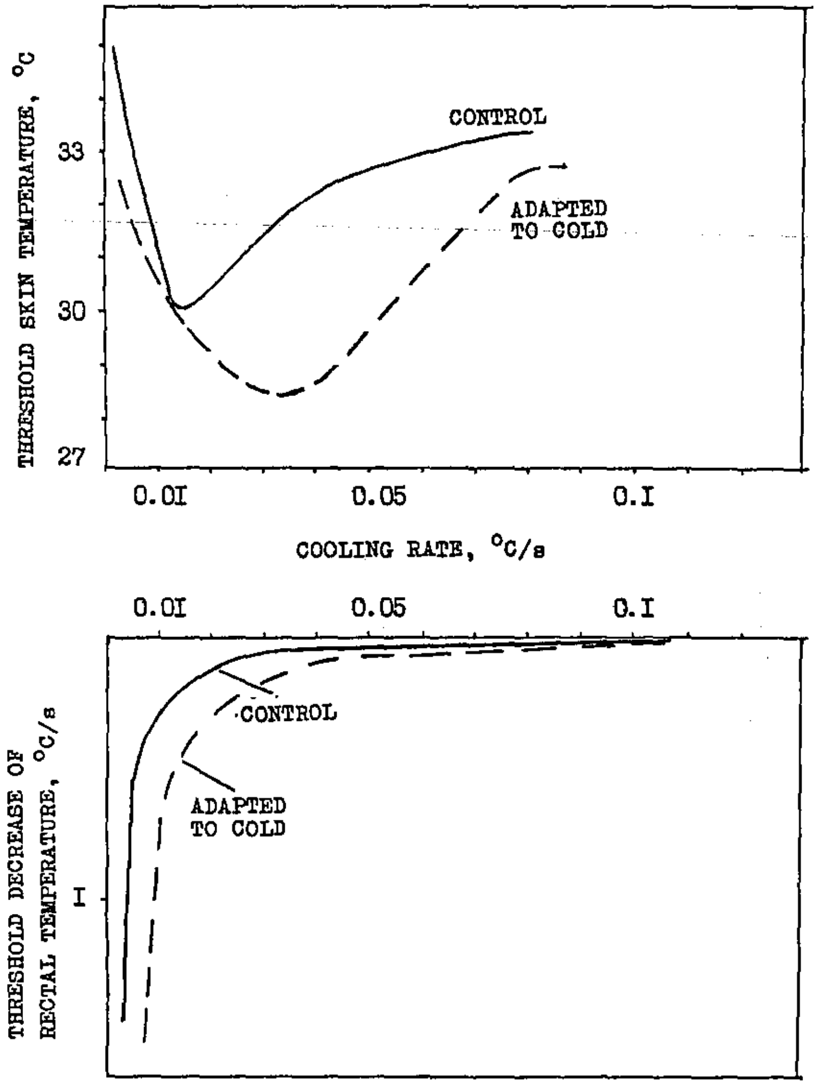

Fig. 1. Threshold skin temperature (top) and theshold rectal temperature (bottom) for metabolic response in dependence on the cooling rates in control and cold adapted rats. ($P < 0.01$ for all curves.)

related to a decrease in the static activity of the peripheral and central thermoreceptors in the range of low temperatures.

CONCLUSION

The results demonstrated that at fast and slow cooling the triggering sequence of the metabolic and heat loss responses are different. This evidences the influence of the dynamic activity of the cold skin receptors on the thermal thresholds of the metabolic and heat loss responses. An increase in the dynamic activity of the cold skin receptors at higher cooling rate produces a lower thermal threshold of the metabolic response and a higher threshold of heat loss response. A decrease in the dynamic activity of the skin cold receptors after adaptation to cold weakens the dependence of the metabolic response threshold on cooling rates. As a result, the patterns of slow cooling spread over a wider range of cooling rates to 0.033°C/sec in rats adapted to cold compared to not adapted (0.013°C/sec). A rise in the thresholds of the thermal defensive responses in the cold adapted rats in the slow cooling range, when the skin thermoreceptors are only statically active, is, obviously, related not only to a decrease in the activity of the skin cold receptors. It is also related to a decrease in the thermosensitivity of the hypothalamic neurons in the low temperature range, thereby conditioning low sensitivity to cold. The data may evidence for the important role of the peripheral thermoreceptors in the maintenance of adaptive reorganizations, concomitant with the role played by central thermoreceptors.

REFERENCES

1. Davies S.M., Goldsmitt G.E., Helllon R.F., Mitchell D. 1983. Facial sensitivity to rates of temperature change: Neurophysiologacal and psychological evidence from cats and humans. J. Physiol. 344 (1), 161-175.
2. Hensel H., Schafer K. 1982. Static and dynamic activity of cold receptors in cats after long-term exposure to various temperature. Pflug. Arch. 392 (3), 291-294.
3. Kozyreva T.V., Pierau F.-K. 1994. Effect of cold adaptation and noradrenaline on thermosensitivity of hypothalamic neurons studied *in vitro*. Neurofisiology. 64 (3),172-176.
4. Kozyreva T.V., Verkhogliad L.A. 1989. The functional role of the dynamic activity of cold cutaneous receptors. Fisiol. Zh. SSSR. 75 (1), 117-123.
5. Kozyreva T.V., M.A.Yakimenko. 1979. The effect of adaptation to cold on skin thermoreceptor activity. Fisiol. Zh. SSSR. 65 (11), 1598-1602.
6. Mekjavic I.B., La Prairie A., Burke A., Lindborg B. 1987. Respiratory drive during sudden cold water immersion. Respir. Physiol. 70 (1), 121-130.