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Effect of Thermal Acclimation on the Stress−induced Elevation of Core Temperature in Rats

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Abstract; Elevation of core temperature during the loose restraint by the small cage suspended in the air of the climatic chamber in cold−acclimated rats (C−rats, reared at 10℃), heat−acclimated rats (H−rats, at 30℃) and control (N−rats, at 22～24℃) were compared. In Experiment A, rats were restrained at the temperature at which they were reared. Mean Tre during the restraint in C−, H− and N−rats were in the order C−rats >N−rats > H−rats, while tail skin temperatures were nearly the air temperatures, which indicates the vasoconstriction in the tail. In the Experiment B, rats of the three groups were restrained at the standard temperature of 25℃, there were small differences between elavated rectal temperatures of the three groups. Mean differences between the tail skin temperature and the air temperature, which are indices for the tail vasodilation, were in the order C−rats > N−rats > H−rats. From these results it is suggested that not only brown adipose tissue but also peripheral vasoconstriction contributes to the elevation of the core temperature during the loose restraint in rats.

Key words: Core temperature, Loose restraint, Thermal acclimation, Brown adipose tissue, Tail vasomotion

It is well known that core temperature in rats is elevated by the psychological stress, such as handling and loose restraint and so on, and this phenomenon was called "Emotional hyperthermia". It has been suggested that thermogenesis in brown adipose tissue (BAT) plays an important role for this response. Recently Kluger *et al.* (1987) suggested that "stress-induced hyperthermia may be a stress-induced fever". In this study, in order to know the role of thermogenesis in BAT and of the peripheral vasoconstriction which reduce heat dissipation for this response, the effect of the loose restraint on core temperature was investigated in thermally acclimated rats.

MATERIALS and METHODS

Adult male Wistar rats were used for the experiment. Rats of 1.2 months old were divided randomly into three groups and were reared for 4 to 5 months at the room temperature 10℃ (cold−acclimated rats; C−rats, N=7), 30℃ (heat−acclimated rats; H−rats,

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N=6), and 22−24℃ (control rats; N−rats, N=6), respectively. Two or three rats were housed in a cage under 12−12 light-dark cycles (light on 8.00−20.00 h) with food and water available *ad libitum*. These three groups of rats were used for Experiment A at 5.8 months old and for Experiment B at 6.4 months old.

For loose restraint, each conscious rat was placed in a loosely fitting wiremesh cage suspended in the air of the climatic chamber, of which temperature was kept constant. Rats were allowed to move forth and back and groom their heads with forelimbs but prevented from the turning in the cage. Rats extended their tails outside of the cage. Rectal temperature (Tre), tail skin temperature (Ttail) and air temperature (Ta) were detected by means of thermistor probes.

In Experiment A, room temperature was kept at 10℃ for C−rats, 30℃ for H−rats and 25℃ for N−rats. In Experiment B, Ta was kept at 25℃ for C−, N− and H−rats. For measurement of Tre, the probe was inserted into the rectum more than 5cm beyond the anus and was taped to the tail in Experiment A, while it was fixed by rubber bands pulling the probe in the cranial direction in Experiment B.

For measurement of Ttail, another probe was attached on ventral tail surface and was covered by one layer of adhesive tape. In order to express magnitude of vasodilation in the tail, the difference (dTtail) between Ttail and Ta (dTtail=Ttail−Ta) was calculated. All parameters were simultaneously recorded on a UV oscillograph (Type 3L, SANEI, Japan). All values were presented as means ± S. E. M.. Statistical significances in parameters were determined by Mann−Whitney U test.

RESULTS

(1) Experiment A

Rats were reared for 4.6 months in each room temperature. Age was 5.8 months old. Mean body weights of C−rats, H−rats and N−rats were 554 ± 16g, 543 ± 18g and 608 ± 18g, respectively. Mean body weights in C−rats and H−rats were significantly smaller than the value in N−rats. Each rat was restrained at the temperatures (10,30 and 25 ℃) to which rat was acclimated. Mean initial Tre was 37.3 ± 0.1℃, 37.3 ± 0.0℃ and 37.2 ± 0.1℃ in C−, H− and N−rats as control, respectively. There were not statistically significance among these values. During the restraint, Tre was elavated and maintained at a high temperature level during more than 60 min. Maximal values were observed between the 10th min and 30th min from the beginning of the restraint. At the 20th min after beginning of the restraint, mean Tre in C−rats, H−rats, and N−rats were 39.0 ± 0.2℃, 38.1 ± 0.1℃ and 38.5 ± 0.1℃, respectively. Values in C− and H−rats were significantly ($p < 0.05$) different compared to control. As shown in Fig. 1, mean Tre in C−rats during the restraint was significantly higher than that in other two groups during more than 90 min. Increases in Tre during the first 20 min in C−, H− and N−rats were 1.7 ± 0.2℃, 0.9 ± 0.1℃ and 1.3 ± 0.1℃, respectively. Value in H−rats was significantly ($p < 0.05$) smaller than that in N−rats. At the beginning of the restraint, mean dTtail, difference between Ttail and Ta, in C−rat was greater than that in other two groups. From the 10th to 90th min during the restraint, dTtail in the three groups were nearly always small and this indicates the vasoconstriction in the tail.

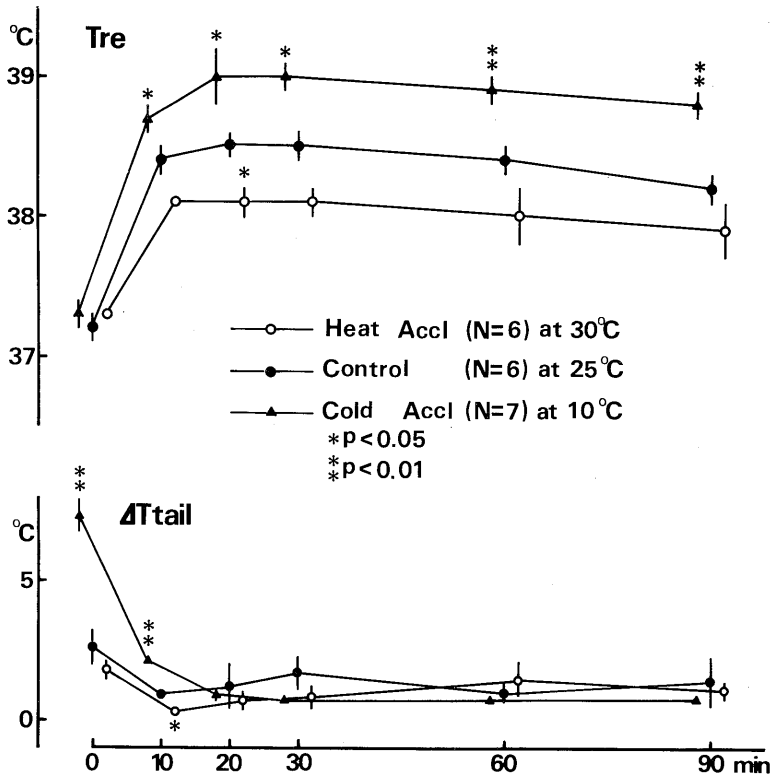

Fig. 1. Mean rectal temperature (Tre) and the difference (dTtail) between tail skin (Ttail) and air (Ta) temperatures during loose restraint in cold−(C−rats; solid triangles, N=7), heat−(H−rats; open circles, N=6) acclimated rats and control rats (N−rats; solid circles, N=6). Asterisks indicate statistical significance (*; $p < 0.05$, **; $p < 0.01$) compared to values in control. Each rat of the three groups was restrained at the temperature to which they were acclimated. Restraint started at time 0.

(2) Experiment B

Rats were used at 6.4 months old, mean body weights in C−rats, H−rats and N−rats were 576 ± 14g, 578 ± 17g and 621 ± 13g, respectively. Each rat of the three groups was restrained at the standard temperature of 25℃. As shown in Fig. 2, mean initial Tre was 36.9 ± 0.2℃, 37.2 ± 0.1℃ and 36.9 ± 0.1℃ in C−, H− and N−rats, respectively. There were not statistically significances between these values. At the 20th min, elevated Tre was 38.0 ± 0.2℃, 37.7 ± 0.1℃ and 38.0 ± 0.1℃ in the same order, respectively. There were not statistically significances among each value. Increases in Tre during the first 20 min in C−, H− and N−rats were 1.1 ± 0.2℃, 0.5 ± 0.1℃ and 1.1 ± 0.1℃, respectively. Value in H−rats was significantly ($p < 0.01$) smaller than that in N−rats. Index for the tail vasodilation, dTtail were in the order C−rats > N−rats > H−rats. From the beginning to the 30th min a sustained tail vasodilation in C−rats was observed. At the 60th min from the beginning of the restraint, dTtail in C−, H−and N−rats was 4.9 ± 1.1℃, 0.1±0.1℃ and 1.4 ± 0.7℃, respectively. Values in H−and C−rats were significantly ($p<0.05$) different compared to that in N−rats. Results in Experiments A and B are summarized in the Table 1.

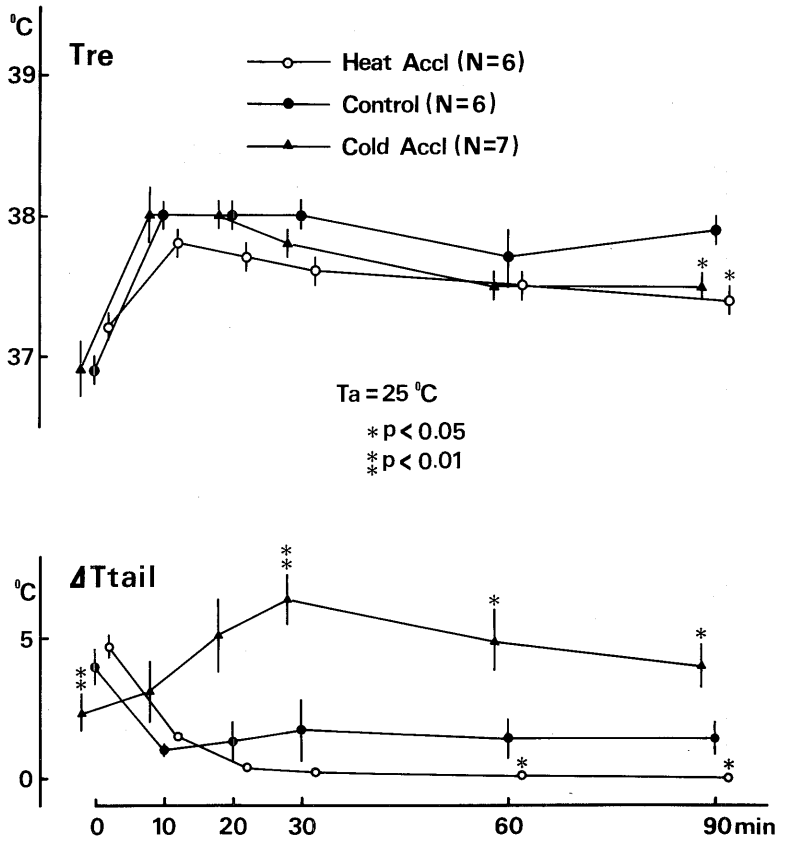

Fig. 2. Mean rectal temperature (Tre) and the difference (dTtail) between tail skin (Ttail) and air (Ta) temperatures during loose restraint in cold−(C−rats; solid triangles, N=7), heat−(H−rats; open circles, N=6) acclimated rats and control rats (N−rats; solid circles, N=6). Asterisks indicate statistical significance (*; $p < 0.05$, **; $p < 0.01$) compared to values in control. Each rat of the three groups was restrained at the standard temperature, 25℃. Restraint started at time 0.

Table 1. Mean rectal temperature (Tre) at the beginning and at the 20th min after beginning of the restraint, and mean increase in Tre (dTre) during the first 20 min of the restraint and the differences (dTtail) between the tail skin (Ttail) and air (Ta) temperatures during the loose restraint at the 20 min and the 60 min. Each rat was restrained at the acclimated temperatures (10, 25, 30℃) in A and at the standard temperature of 25℃ in B. N; Number of animals, symbols for statistical significances are as follows, *; $p<0.05$, **; $p<0.01$ compared to values in control.

		A. At the acclimation temperatures (10, 25, 30℃)	B. At the standard temperature (25℃)	N
Tre (at Time 0 min)	C	37.3±0.1	36.9±0.2	7
	H	37.3±0.0	37.2±0.1	6
	N	37.2±0.1	36.9±0.1	6
Tre (at Time 20 min)	C	39.0±0.2*	38.0±0.2	7
	H	38.1±0.1*	37.7±0.1	6
	N	38.5±0.1	38.0±0.1	6
dTre (in the first 20 min)	C	1.7±0.2	1.1±0.2	7
	H	0.9±0.1*	0.5±0.1**	6
	N	1.3±0.1	1.1±0.1	6
dTtail (at Time 20 min)	C	0.9±0.1	5.1±1.3	7
	H	0.7±0.3	0.4±0.1	6
	N	1.2±0.8	1.3±0.7	6
dTtail (at Time 60 min)	C	0.8±0.1	4.9±1.1*	7
	H	1.5±0.6	0.1±0.1*	6
	N	1.0±0.3	1.4±0.7	6

(C: C−rats, H: H−rats, N: N−rats) *($P<0.05$), **($P<0.01$)

DISCUSSION

In this experiment, elevation of Tre during restraint stress was compared in the three groups heat−, cold−acclimated and control rats. When rats were restrained at the temperature at which they had been reared and acclimated, Tre increased in the three groups. These increases in Tre were in the order C−rats > N−rats > H−rats, while tail vasoconstriction was observed nearly always in the three groups. On the other hand, when rats were restrained at the standard temperature of 25℃, elavated Tre of the three groups were similar, while tail skin temperatures were in the order C−rats > N−rats > H−rats.

It has been reported that core temperature of the rat was elevated (Briese and DE Quijada, 1970) and that plasma level of adrenaline and noradrenaline were significantly increased (Kvetnansky, *et al.*, 1978; Depocas and Behrens, 1977) when rats were confronted with psychological stress or the novel environment, such as, handling, loose restraint, noise, air jet and transfer of cage with rats to another room and so on. In these stress response in rats, the maximal changes in plasma level of hormones were around 15 min from the beginning of the stress in cases of catecholamines, corticosterone and growth

hormone (Kvetnansky *et al.*, 1978; Seggie and Brown, 1975). In this study, maximal rectal temperatures were observed at the 10th min to 30th min from the beginning of the restraint. But because the noradrenaline concentration around the sympathetic nerve terminals of BAT is higher than plasma level of it (Seydoux and Girardier, 1977) and thermogenesis in BAT was observed during the stress, which disappeared after sectioning sympathetic nerves to BAT, it is suggested that the stress induced thermogenesis may be produced by an increased tone of sympathetic nerves to BAT rather than increased circulatory catecholamines (Shibata and Nagasaka, 1982; Girardier and Seydoux, 1986).

Numerous reports show that in rodents, BAT is anatomically and functionally developed by cold−acclimation due to prolonged cold exposure (Smith and Roberts, 1964; Foster and Frydman, 1979), and it seems that heat-acclimation results in the reverse phenomenon (Chaffee Smith., 1963; Pospíšilová and Janský, 1976). In this study, the stress−induced elevations of core temperature in both cases of Experiments A and B were significantly small in H−rats. This suggests that in Experiment A, difference of the response in the three groups may be related to functional difference of BAT in the three groups due to thermal acclimation.

The vasoconstriction responses in the rat were observed during elevation in Tre after intracerebral administration of β−endorphin (Thornhill and Wilfong, 1982) and during the loose restraint in spontaneously hypertensive rats (SHR) (Tsuchiya *et al.*, 1989). It is well known that the rat tail is an important organ for heat dissipation. According to Rand *et al.*, (1965), though the rat tail has small surface area, it can dissipate a large ratio of the total heat loss. Critical Ta for the tail vasodilation was lower in C−rats than in both H−and in N−rats. In the Experiment B, during restraint at 25℃, tail vasodilation was occurred in C−rats but not in H−rats. Though heat production from BAT depends on Ta, elevation in Tre during the restraint in C−rats may be canceled out by heat dissipation through the tail surface in which vasodilation occurred in neutral Ta. These facts suggest that vasoconstriction in the tail is an contributing factor to stress−induced elevation of Tre as well as thermogenesis in BAT.

The elevation of core temperature due to psychological stimulation was called "emotional hyperthermia". Recently, Kluger *et al.*, (1987) pointed out that "stress hyperthermia induced by psychological stress" may be "a stress−induced fever", because this elevation of core temperature was inhibited by administrations of indomethasin or sodium salicylate, which indicated that this response is mediated by prostaglandins in the central nervous system (Singer *et al.*, 1986, Kluger, *et al.*, 1987). Detail mechanism for this phenomenon remains to clarify.

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