A New Approach for Analysing the Patterns of Thermoregulatory Responses in Heat Acclimated Rabbits

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Abstract: Rabbits were reared in a hot environment (30°C, 60% R.H.) for more than 6 months as a model of the heat acclimated animals. And, to clarify the mechanisms of physiological modifications which appeared during and/or after heat acclimation, various thermoregulatory responses to change in ambient temperature have been investigated in those rabbits. After 6 months of continuous heat exposure, change in rectal temperature in response to general heating (40°C) and cooling (10°C) of heat acclimated rabbits was smaller than that of control rabbits (control rabbits were reared in thermoneutral environment; 25°C, 60%). Furthermore, remarkable differences were observed in threshold temperature for starting vasodilation or vasoconstriction of the ear skin. These patterns were analysed to define the thermoregulatory responses to heat acclimation.

Key words: Heat acclimated rabbits, Rectal temperature, Cutaneous vasodilation and vasoconstriciton, Thermoregulatory pattern analysis, Habituation

INTRODUCTION

Homeothermic animals are able to regulate their body temperature within a certain range under changing external and internal conditions, and they develop adaptive modifications of already exisiting regulatory processes (Ashby, 1966). For many years attempts were made to determine these physiological mechanisms which appeared during and/or after thermal acclimation (Hensel, 1973, 1981). These modifications consist of not olny

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*Participant in JICA-sponsored Research Training for Tropical Medicine, 1984−1985 the functional changes in regulatory system or capacities of effectors, but also the morphological changes such as changes in body size, shape or fatty layer. To analyse this problem, various thermoregulatory responses such as cutaneous vasodilation or vaso-constriction, changes in respiratory frequency and rectal temperature to thermal stimulation have been investigated in heat acclimated rabbits (Fujiwara *et al.*, 1985). So far, these responses were sequentially followed up in the time course of thermal stimulation. However, relationships between the thermal stimuli and the thermoregulatory effects are somewhat difficult to detect directly. Therefore, in the present experiments, a new approach was induced for analysing the patterns of thermoregulatory responses to change in ambient temperature of heat acclimated rabbits, and these underlying mechanisms were discussed.

MATERIALS AND METHODS

Two groups of male albino rabbits weighing from 2.5 kg to 2.8kg were used. For first two weeks, both groups of animals were reared in a thermoneutral environment (25°C, 60%), being checked their general conditions. They were fed by 150g of commercial rabbits chow/day, and taken water *ad libitum*. Body weight, food and water intake, respiratory frequency and rectal temperature were measured at 10 o'clock in every morning. After this period, one group of rabbits was started to expose in a hot environment (30°C, 60%) as heat acctimated rabbits, and the other remained under the thermoneutral conditions as control.

The present experiments were carried out in an environmental control chamber without anesthesia. Both heat acclimated and control rabbits were lightly restrained just around the cervical region, and submitted to the following experimental program of general thermal stimulation. Namely, change rate of ambient temperature (Ta) was set to be 0.5°C/min, and was automatically programmed from 10°C to 40°C as follows; for the first half an hour, the environmental control chamber was kept at 25°C. Then, the ambient temperature was raised to 40°C within 30 minutes. The temperature of 40°C was maintained for another half an hour. Next, the temperature was lowered to 10°C in the same rate of temperature change. It took about one hour to reach 10°C. The temperature was again raised to 25°C and kept in the same condition for 30 minutes. In each experimental procedure, 240 minutes were required to thermal stimulation.

Temperatures of the rectum (Tre), ear skin (Tea), and ambient (Ta) were continuously measured with the thermistor probes. Blood pressure (BP) was measured from the femoral artery, and heart rate (HR) was calculated from its pulse. Respiratory frequency (RF) was detected from the electrical resistance changes of a strain gauge attached around the abdomen (For details, see Ohwatari *et al.*, 1983).

RESULTS

Figure 1 represents the simultanous recordings of the various thermoregulatory responses to general heating and cooling in a control rabbit. At the bottom of this figure, experimental program of thermal stimulation was shown. Change in Tre induced by the general heating and cooling was about 1.6°C. The ear skin temperature changed markedly, and was responsible to the change in Ta. Increase of respiratory frequency (RF) started at 40°C of Ta, and diminished toward the initial level according to the general cooling (10°C). However, the change pattern of RF to the displacement of Ta was not always consistent in each experiment. Furthermore, blood pressure (BP) and heart rate (HR) were fairly constant by general thermal stimulation. Therefore, in the present experiment, comparison was made between the changes of Tre and Tea to general heating and cooling.

In case of heat acclimated rabbits, these change patterns of thermoregulatory responses to general thermal stimulation were similar to those of a control rabbit shown in Figure 1.

In Figure 2, changes in rectal and ear skin temperatures of the same control rabbit shown in Figure 1 are continuously plotted against the time course to Ta displacement. The ambient temperature in the horizontal axis was shifted gradually from 25°C to 40°C, than lowered to 10°C, and backed to 25°C again in the same program of thermal stimulation shown at the bottom of Figure 1. Solid circles (●) and open circles (○) represent the starting and ending points of each trial, respectively. At the start of thermal stimulation (solid circles of which Ta shown at 25°C), Tea in Figure 2-A and Tre in Figure 2-B were 35.9°C and 38.6°C, respectively. 35.9°C of Tea indicated cutaneous vasodilation of

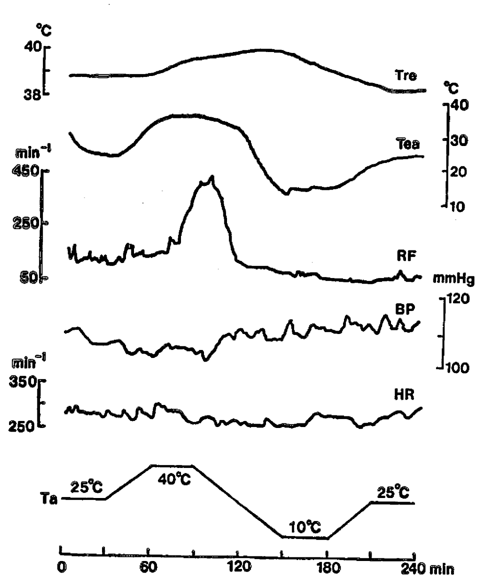

Fig. 1. Various thermoregulatory responses to general heating and cooling which programmed automatically from 10°C to 40°C in control rabbit.
Abbreviations: Tre; rectal temperature, Tea; ear skin temperature, Ta; ambient temperature
RF; respiratory frequency,
BP; blood pressure, HR; heart rate,

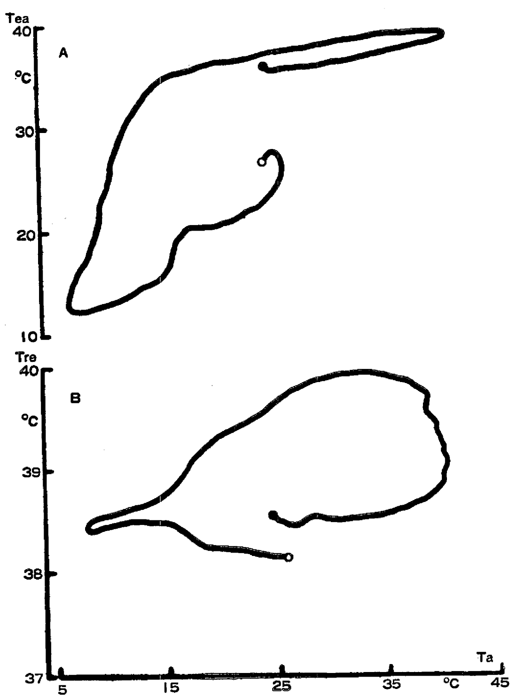

Fig. 2. Changes in rectal (A) and ear skin (B) temperatures of the same control rabbit shown in Fig. 1 to the time course of Ta displacement. Abbreviations are same as in Fig. 1.

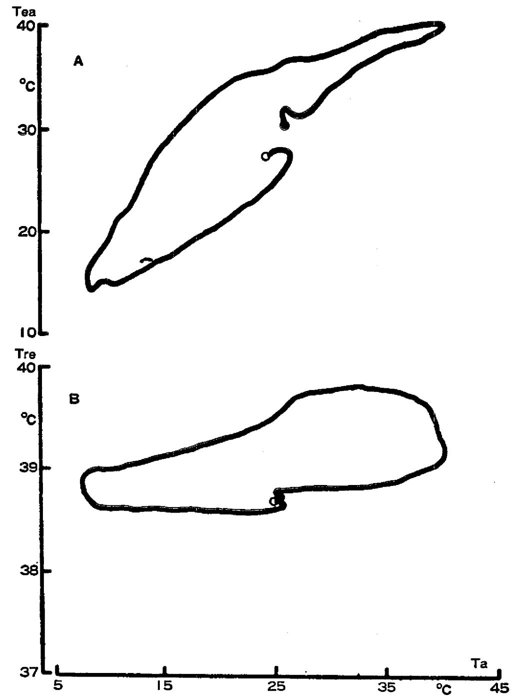

Fig. 3. Changes in rectal (A) and ear skin (B) temperature of a heat acclimated rabbit to the time course of Ta displacement. Abbreviations are same as in Fig. 1. and 2.

the ear skin. When Ta shifted from 25°C to 40°C, Tea gradually raised to 38.5°C with the slope of 0.1°C/min (Figure 2-A). The rectal temperature seems to raise instantly when Ta beyond 40°C (Figure 2-B). In the time course of general cooling, fall in Tea was slowly induced (0.1°C/min), and at 15°C of Ta, vasoconstriction of the ear skin suddenly began with rate of 4°C/min. Rapid fall in Tre was observed at 17.8°C in Ta, and afterwards, Tre reached at original level as shown in Figure 2-B.

Figure 3 shows the changes in rectal and ear skin temperature in heat acclimated rabbit to the same thermal stimulation as shown in Figures 1 and 2. At 25°C of Ta, Tea is 29.9°C, while Tre is 38.7°C. Vasodilation occured when Ta shiftd to 27 °C, and its slope (0.4°C/min) was steeper than that of control (0.1°C/min). Threshold temperature of Ta for starting vasoconstriction of ear skin was 24.8°C, and changing rate in Tea was slower than that of control.

DISCUSSION

It has been reported that mean Tre in those rabbits which were reared in a thermoneutral environment was 39.0±0.9°C (M.±S.D.), and that the value shifted temporarily to 39.3±0.2°C after heat exposure (Fujiwara *et al.*, 1985). These rabbits in a hot environment showed thermal panting, and decreased the food intake remarkably in comparison with the water intake. However, this dynamic alteration became smaller according to the time course of heat acclimation (Ingram, 1977). Then, about one month after heat exposure, difference of mean Tre between heat acclimated and control rabbits was almost negligible, and after that, mean Tre did not change in spite of the duration of thermal acclimation. Furthermore, as mentioned above, thermoregulatory responses which sequentially followed up in heat acclimated rabbits were similar to those in control rabbits. Therefore, to clarify the modifications of physiological mechanisms which appeared after heat acclimation, and additional approach must be introduced for analysing the patterns of thermoregulatory responses to the thermal stress. In the present experiment, by using new analysing procedure, several differences were shown between heat acclimated and control rabbits.

First, extents of changes both in Tea and Tre to Ta displacement were smaller in a heat acclimated rabbit (Figure 2) compared with those in a control rabbit (Figure 3).

Second, from the change patterns of thermoregulatory responses to general thermal stimulation, it is possible to lead out the threshold temperature of Ta for starting cutaneous vasomotor reactions. It was shown as the points at which Tea changes their slope markedly against Ta.

It is supported that after heat acclimation, shift of threshold temperature of Ta for starting the vasodiation and vasoconstriction appeared in order to prevent the change of core temperature. Thermal inputs from the peripheral region were transmitted to the central thermoregulatory system, and then, occured the modificational changes of effectors (Bligh, 1978).

One example of these modifications of physiological mechanism during long-term thermal stimulation, the phenomenon of "habituation" has been reported. In the human subjects, immersion of hand in water of 4°C causes an increase in arterial blood pressure and heart rate. However, Glaser (1966) observed that the vasomotor responses were decreased gradually after series of cold stimuli were repeatedly applied to the hand for 10 to 30 days. And mechanism of this habituation seems to be due to alterations of the central nervous system.

From the present results, therefore, it may be assumed that thermoregulatory properties under a hot environment is influenced by thermal inputs from the peripheral regions as well as central nervous system.

Further experiments are need to distinguish these alterations.

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暑熱順化ウサギの体温調節反応パターンの解析に関する試み

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暑熱（室温30°C，相対湿度60％）環境への暴露による生体の生理機能の変化とそのメカニズムを知るために，ウサギを6ケ月にわたって暑熱環境へ連続暴露して暑熱順化動物モデルとし，様々の体温調節反応を測定した．その結果，暑熱順化ウサギは，中性温（室温25°C，相対湿度60％）で飼育したウサギに比べ，10°C〜40°C の全身皮膚への温度負荷に対する深部温の変化幅が小さく，又，同一温度刺激に対する耳介皮膚血管の拡張及び収縮開始温度が異なる事がわかった．
以上の結果から，長期にわたり暑熱環境で飼育する事によって，高温環境下での体温調節機能が修飾される事が示唆された．

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