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# Studies on Heat Adaptation

## —Measurement of the sweating reaction of a tropical inhabitant—

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**Abstract**: The sweating response evoked by a local heat load was studied in an inhabitant of tropics in a climatic chamber. The change of skin temperature according to sweating was monitored by thermography. Time lag of the onset of sweating in the subject was about 10 minutes after initiation of a heat load. In such a condition, a Japanese volunteer sweated instantly without any heat load. The central and peripheral mechanism of heat acclimatization was discussed from the aspects of temperature regulation.

*Key words*: Sweating response, Heat acclimatization, Local heat load, Thermograph.

1) It is well known that tropical natives have some tolerance to heat. Such characteristics seem to be not only hereditary but also acquired one. Furthermore, it is said that their physical status, basal metabolism and some other physiological characteristics are influenced by the climate in which they were born and raised (Adolph, 1946; Dill *et al.*, 1938; Kuno 1934, 1956). Indeed, inhabitants of tropics show slender body shape, and their subcutaneous fat layer is thinner than people who are not acclimatized to heat (Hori *et al.*, 1976, 1977).

In order to clarify the mechanism of acclimatization, it is important to understand the tolerance in heat-acclimatized man. Sweating is the main way of heat dissipation for man in a hot environment (Libert *et al.*, 1983). Therefore, we paid an attention to the

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sweating responses in a man who lived in a tropics. Usually, sweating responses were detected by modified Minor's method (Kuno. 1934) or by touching fingers, but in the case of coloured people, these procedures are somehow difficult to detect the sweating. However, these difficulties can be overcomed by detecting the decrease of skin temperature shortly after the onset of sweating. Therefore, appoaches were made with thermography, a method for measuring the infrared radiation from surface of the skin (Dauncey *et al.*, 1983), to observe the sweating responses.

2) A healthy male subject, a native Indonesian, participated in the experiments performed in November, 1983 at the Institute for Tropical Medicine, Nagasaki University. He came to Japan at the beginning of September, and stayed three months in Nagasaki before the experiment. All the experiments were performed in a climatic chamber of which air temperature and humidity were automatically regulated (Kosaka *et al.*, 1980). The physical characteristics of the subject are shown in Table 1.

Table 1. Physical characteristics of the subject

| Age (yr) | Ht. (cm) | Wt. (kg) | BSA ($m^2$) |
|---|---|---|---|
| 37 | 167 | 62 | 1.7 |

BSA=Body Surface Area

Basal metabolic rate was calculated from oxygen consumption measured with Benedict Roth's respirometer. The subject rested in the supine position on a bed for 30 minutes in the climatic chamber of which air temperature and humidity were kept constant at 25°C and 60%, respectively.

The serum electrolytes were measured by an auto-ion analyser (Sera 300, Horiba Co.). Effects of a local heat load were examined in the climatic chamber kept at 30°C, 60%. In the climatic chamber, the subject were only shorts and sat on a chair. The following physiological data were recorded throughout the experiment:

a) The oral temperature by a thermistor probe inserted at sublingual portion as an index of core temperature.

b) The average skin temperature in the area of the upper chest by thermography (JTG-IBL, Nihon-Denshi Co.).

After staying at reat in a climatic chamber for 30 minutes, the subject was exposed to a local heat load by immersing the legs, just below the knees, into a stirring water bath kept at 43−44°C for 30 minutes. The onset of sweating is detected by means of modified Minor's method on his back.

3) The measured basal metabolism of the subject was 34.26 $Kcal/m^2/hr$ in this experiment. The values of concentration of serum electrolytes were Na : 141.0 mEq/L, K : 5.1mEq/L. Cl: 106mEq/L. Change in temperature of oral cavity was shown in the upper part of Fig. 1. Initial oral temperature (To) was about 36.7°C, and four minutes

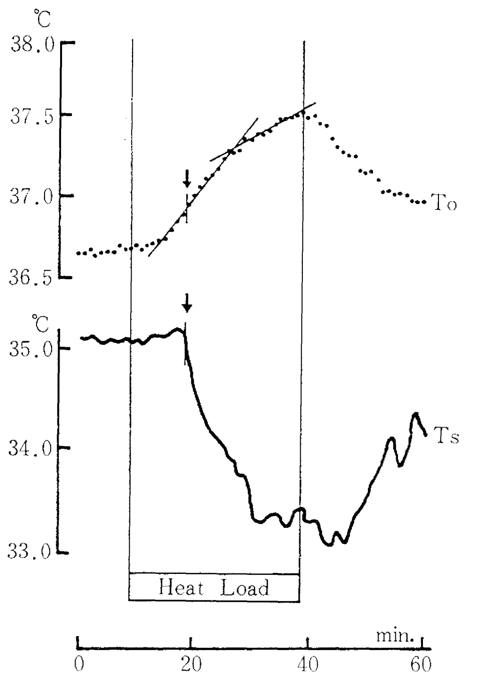


Fig. 1 Effects of a local heat load on oral temperature (upper trace) and skin temperature (lower trace) by immersing lower legs into a hot water. Arrows: Onset of sweating detected by modified Minor's method.

after the start of the local heat load, oral temperature began to rise at the of 0.042 °C/min. Sweating was detected with modified Minor's method. The latency of the onset of sweating was 9 minutes 45 seconds. A few minutes sfter onset of sweating the increasing rate in oral temperature changed to 0.021°C/min. Immediately after end of the local heat load, oral temperature recoverd to initial value. Changes in the average skin temperature (Ts) of the upper chest calculated from recording of thermography is shown in lower trace of Fig. 1. The initial skin temperature of the given area of this Indonesian subject was 35.2°C. However, 10 minutes after the start of the heat load, decrease of skin temperature was elicited which coincides with the onset of sweating that is indicated by an arrow in this figure. On the other hand, a Japanese volunteer sweated instantly without any additional heat load in the same environmental condition.

Three thermograms of the upper frontal view of the Indonesian subject were shown in Fiure 2. They demonstrate the changes in skin temperatures recorded one minute before the heat load (I), two minutes after (II), and 15 minutes after (III) onset of sweating. These data clearly demonstrate that skin temperature started to decrease after onset of the sweating.

4) In this experiments, sweating response of the tropical inhibitant was studied by using the local heat load in a climatic chamber. Time lag of the onset of sweating in this subject was 9.8 minutes after the start of a heat load. According to Hori *et al.* (1976), under the similar condition of which air temperature and humidity were kept constant at 30°C, 70%, inhibitants of Naha, Okinawa, where locates in the southern part of Japan and in subtropical region, showed that onset of sweating triggered by heat load of legs in water bath at 42°C was 8.9 minutes, whereas that of the inhabitants of mainland of Japan was 3.5 minutes. The mean air temperature a year in Djkjkarta Indonesia is 26.9°C, that in Naha, Okinawa is 22.4°C and that in Nagasaki, Japan 16.6°C. Time lag of onset of sweating in this Indonesian subject is longer than that in Japanese

mentioned above. There are some possible explanations for this phenomenon as follows: a) shift of threshold body temperature of onset of sweating. b) set of body temperature to lower level. c) decline of rising curve of body temperature during heat load. The factors which determine the set-point of body temperature are lower basal metabolism concerning to heat production and the physical constitution relating to heat dissipation of this subject. (Hammel *et al.* 1963)

It is clear that the reduction of the basal metabolic rate in a hot environment has advantages for the inhabtants of tropics. The results on basic metabolic rate, body surface area and body weight of this Indonesian subject compared with Japanese standard values are reasonable, namely, BMR: −6%, BSA: 1.7m² and BW: 62 Kg, respectively. The clo value of the clothes, which necessary to get a thermal comfort, chosen by this subject was 2.3 clo. The value of the special clothes for skiing was reported as 1.9−2.1 clo (Ogawa *et al.*, 1983). Therefore, it suggests that capacity of heat insulation of this subject against cold is small. From these facts, it can be assumed that this subject from tropics was constistutionally well acclimatized to a hot environment. Since, the skin temperature is determined by the heat flow to the skin surface from within the body and by the net losses or gains from the surface itself by conduction, convection and radiation (Barners, 1963, 1967). Thermography is a valuable means to detect the sweating reaction by measuring the average skin temperature of a certain area expected without disturbance of any attachments. And further, this instrument is suitable for promotion of such studies on temperature regulation as well as heat adaptation.

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暑熱順化に関する研究ー熱帯地住民の発汗能に関する研究ー

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熱帯地住民は暑さに強い事がよく知られている．彼等は，軀幹に比べ四肢が長く，体重当たりの体表面積が大きく，体構成では，皮下脂肪が少なく，能動汗腺総数の増加が見られる等，放熱に有利な特徴を備えている．これらの差異を知る事は，暑熱環境への順化のメカニズムを考える上で重要であると思われる．そこで我々は，熱放散反応のなかから，特に発汗現象に注目し，熱帯地住民を被験者として，一定条件（気温30°C 相対湿度60％）下で局所温度負荷をかけ発汗を誘発した．それに伴う深部体温と皮膚温の変化は，それぞれ舌下に入れたサーミスター温度計と，前胸部をサーモグラフィでモニターした．その結果，両膝下部を43～44°C の温湯に30分つけるという局所負荷で，被験者の負荷開始時点から発汗までの潜時は10分であった．比較の為に同一条件で行った日本人による実験では，被験者は，負荷以前に発汗してしまい，潜時は測定出来なかった．この事から，被験者となった熱帯地住民は，日本人被験者に比べ，発汗までの潜時が非常に長い事がわかった．この理由としては，暑熱環境に順化した人の方が非順化人よりも，発汗に関する深部体温の閾値が高いかあるいは刺激前の深部温度が低い為に，同じ強さの温度負荷に対しても，発汗までの潜時が長いという可能性が考えられる．今後データの集積をはかり，更に詳細について検討していく所存である．

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I

II

III

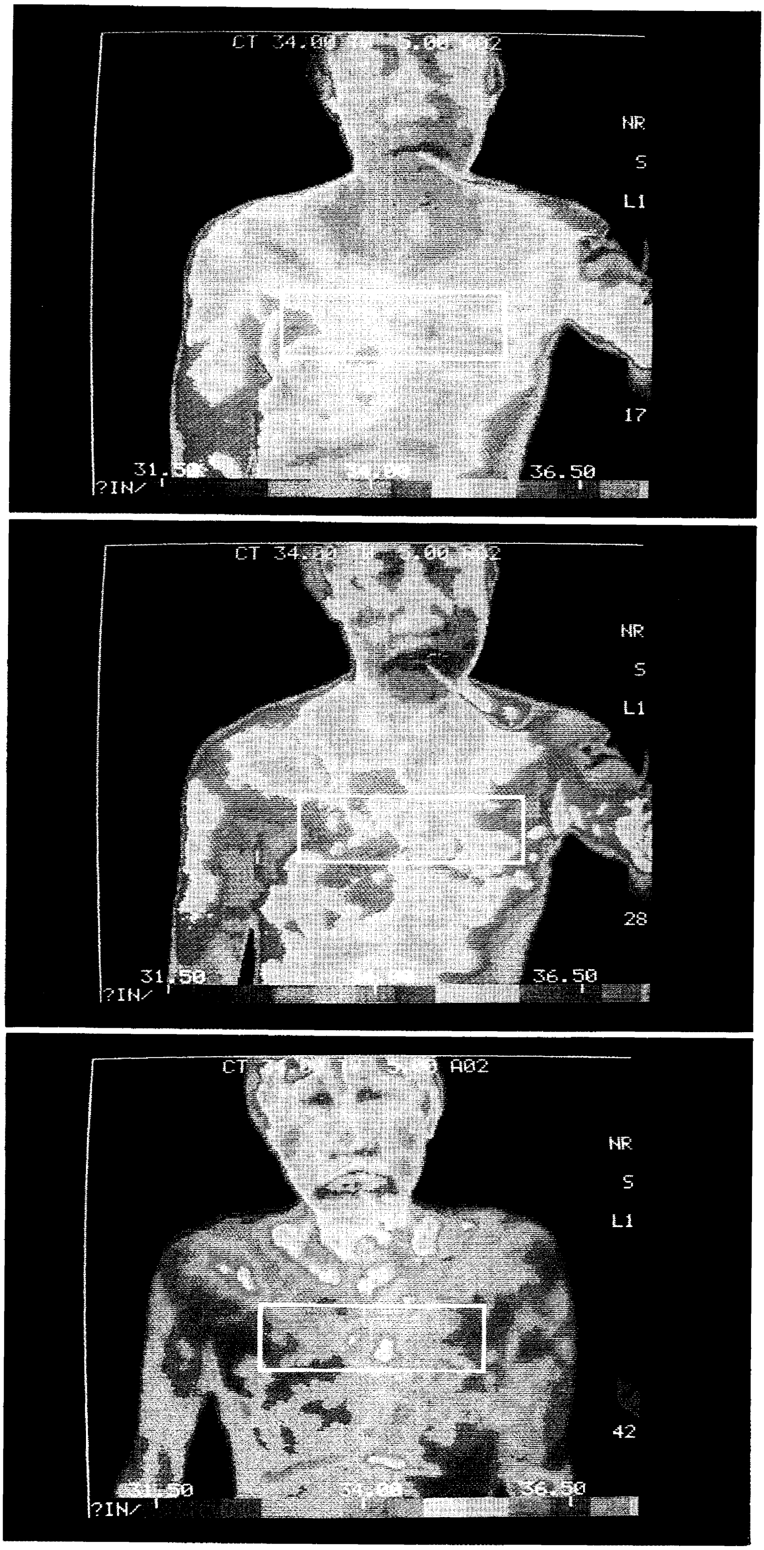


Fig. 2. Pattern changes of thermograms in frontal view of the subject. ( I ): 1 min. before the heat load, (II): 2 min. after the on set of sweating, (III): 15 min. after the on set of sweating Colour bands on bottom of each thermogram: a scale of temperature (0.5°C in one division).