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CHANGE IN SKIN TEMPERATURE OF FINGER EXPOSED TO HEAT—HUNTING TEMPERATURE REACTION TO HEAT—(Preliminary Report)

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There are a number of papers on measurement of the skin temperature of the finger exposed to cold, and a very interesting phenomenon called cold-induced vasodilation (or hunting temperature reaction to cold) is known. In a previous paper[3] on analysis of change in the temperature of the skin exposed to cold with the lapse of time, the author[3] disclosed that Newton's law of cooling would generally be applicable to the falling process of skin temperature if a certain temperature (τ) was taken into consideration. There are a relatively large number of studies on variations in the blood flow with heating of the whole body or the forearm, but there are few or no papers on the measurement of skin temperature of finger by heating the finger. Based on such a thinking that the skin temperature (θ) of the finger exposed to heat would initially be elevated, but fall thereafter, namely, a phenomenon similar to cold-induced vasodilation (or hunting temperature reaction) might present itself, the finger was immersed in warm water which was hotter than body temperature, and as expected, a phenomenon which could be called "heat-induced vasodilation" (or hunting temperature reaction to heat) presented itself. And it was disclosed that the process to manifestation of this phenomenon followed a law similar to Newton's law of cooling (a law which may be called the "law of heating") if a certain temperature (τ') was taken into consideration.

A. OUTLINE OF METHODS

Healthy female students (aged 18~20) were kept at rest in a chair-sitting position for not less than thirty minutes two hours after lunch, and their fingers were immersed in a thermostat (warm water), to measure the skin temperature of finger (θ) along with time (t). A copper-constantan thermocouple was fixed with an adhesive tape (Nichiban) to the dorsal side of the Art. interphalangea proximalis manus of the right middle finger. After petrolatum was spread over it, the finger was immersed into warm water up to the Art. interphalangea distalis manus, and its potential difference was recorded on the 150 mm strip chart 6 point recorder (Okura Electric Co.) at 30 second intervals, and converted to temperature. (Room temperature: 20~22°C).

B. RESULTS AND DISCUSSION

An experimental result at a water temperature of 43.7°C is presented in **Fig. 1.** The θ rises rapidly after immersion of the finger in the warm water, reaches the maximum temperature of 42.63°C in three minutes thirty seconds, then falls and fluctuates up and down thereafter, namely, a phenomenon similar to the so-called hunting reaction presents itself. The result of experiment at a water temperature of 47.8°C is shown in **Fig. 2.** The θ rapidly rises after immersion of the finger in the warm water, reaches the maximum temperature of 45.00°C, and then fluctuates up and down, presenting the so-called hunting phenomenon. In the recovery stage, the θ rapidly falls close to the temperature before immersion (of the finger in the warm water) in fifteen minutes. **Fig. 3** shows variations in the θ of the right middle finger in the warm water at the temperature of 45.3°C, that in the θ over the dorsal metacarpal vein of the back of the right hand and that in the θ of the left middle finger. The back of the right hand and the left finger remained in the air (at room temperature of 21.6°C). The θ of the right finger rapidly rises after immersion in the warm water, reaches the maximum temperature of 44.85°C in three minutes, and shows an apparent hunting phenomenon thereafter. The θ of the back of the right hand rises at the same time as the right finger was immersed in the warm water, reaches the maximum temperature of 38.42°C in three

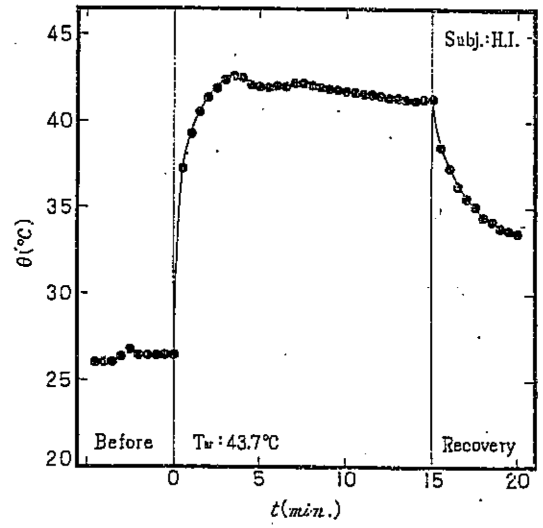

Fig. 1. Hunting phenomenon at water temperature of 43.7°C.

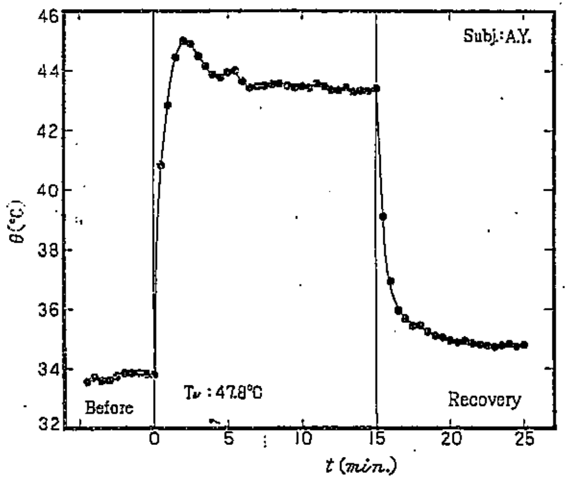

Fig. 2. Hunting phenomenon at water temperature of 47.8°C.

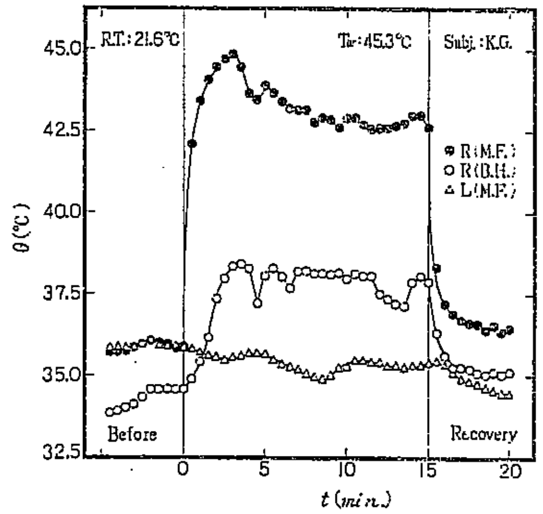

Fig. 3. Variations in the skin temperature of the right finger immersed in warm water at 45.3°C, R (M. F.), in that of the back of the right hand in the air, R (B. H.), and in that of the left finger in the air, L (M. F.).

minutes thirty seconds, and presents relatively similar variation to that in the θ of the right finger thereafter. The θ of the left finger falls little by little when the right finger was immersed in the warm water, and shows similar fluctuation to that in the θ of the right finger in the stage beyond two minutes thirty seconds after immersion of the right finger in the warm water.

Described in the foregoing are the experimental findings in a small number of subjects, but it is obvious that when the finger is immersed in warm water, the skin temperature (θ) of the finger rapidly rises, but falls in several minutes, followed by manifestation of the hunting phenomenon. This phenomenon may be compared to the cold-induced vasodilation observed in the skin temperature of the finger exposed to cold, and called the heat-induced vasodilation. It presented itself when the finger was immersed in water warmer than ca. 40°C, and the higher the water temperature, the more marked it was. When the forearm is immersed in water at 37~42.5°C, the blood flow in the forearm gradually increases initially, reaches the maximum about one hour after the beginning of warming, and then decreases1)2). This phenomenon is called the "die away", but AHMAD1) reported that it was not seen in the fingers. The heat-induced vasodilation observed in the present experiments may, of course, be attributed to variations in local blood circulation, but because it appeared about three minutes after immersion of the finger in warm water, it differed in the appearing time from the so-called "die away" which is seen in the forearm. Because in the experiments by AHMAD1), the blood flow was measured at five minute intervals, the absence of the "die away" in the finger might have been attributed to the effect that it was overlooked because of measurement of blood flow at such long intervals.

In a previous paper3), the author disclosed that the falling process of the skin temperature of the finger immersed in cold water, that of the skin temperature of the forearm exposed to cold air, and that of the local skin temperature by local cold malagma followed Newton's law of cooling, if a certain temperature (τ) was taken into consideration, and that even in the rising process of the θ in the recovery stage, the rising process of the skin temperature followed a similar law to Newton's law of cooling (law of heating) if a certain temperature (τ') was taken into consideration. In the results of the present experiments (**Figs.** 1 and 3), the certain temperature τ' (the temperature at which the rising velocity of the finger skin temperature with warm water was in equilibrium with the temperature falling velocity with the finger (blood flow), assuming that in the reaction process, either vasoconstriction or vasodilatation or other special physiologic reactions did not occur, namely, the temperature at which the θ became stable) was obtained3), and the relation between $\log(\tau'-\theta)\equiv\log\theta'$ and t was examined. It was found that there was a linear relation between the parameters as presented in **Figs. 4 and 5.** These figures also show the relation between $\log(\theta_M-\theta)$ and t by use of the maximum determined temperature (θ_M), where the $\log(\tau'-\theta)\sim t$ curve is linear up to three minutes thirty seconds (Fig. 4) or up to three minutes (Fig. 5), while the $\log(\theta_M-\theta)\sim t$ curve is linear only up to two minutes thirty seconds (Fig. 4) or up two minutes (Fig. 5), but is deviated from linearity in the stage beyond it. The gradients of these curves (heating velocity constant, k_1) obtained from the $\log(\tau'-\theta)\sim t$ curve are smaller than those obtained from the $\log(\theta_M-\theta)$

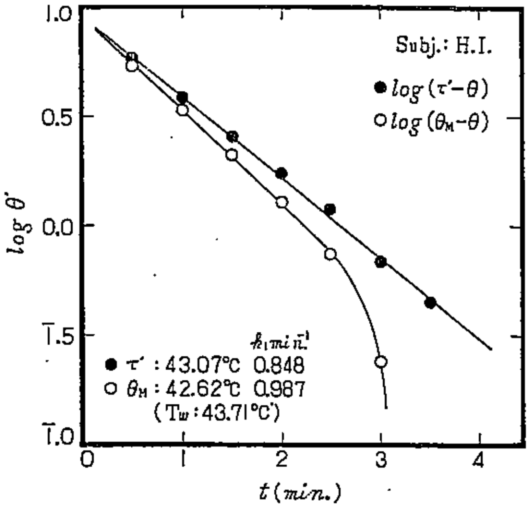

Fig. 4. Analysis of the initial stage of heating curve shown in Fig. 1 (comparison between τ' and θ_M).

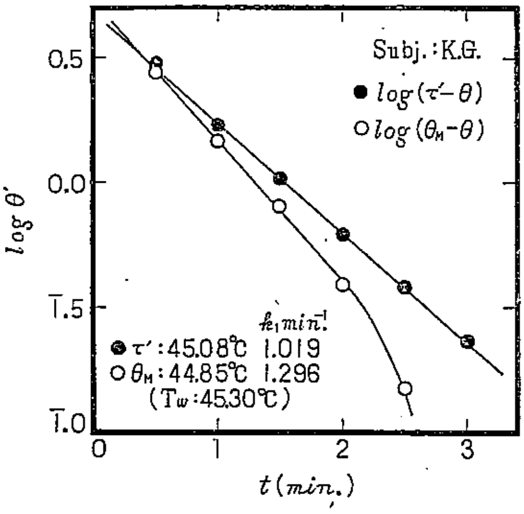

Fig. 5. Analysis of the initial stage of heating curve shown in Fig. 3 (comparison between τ' and θ_M).

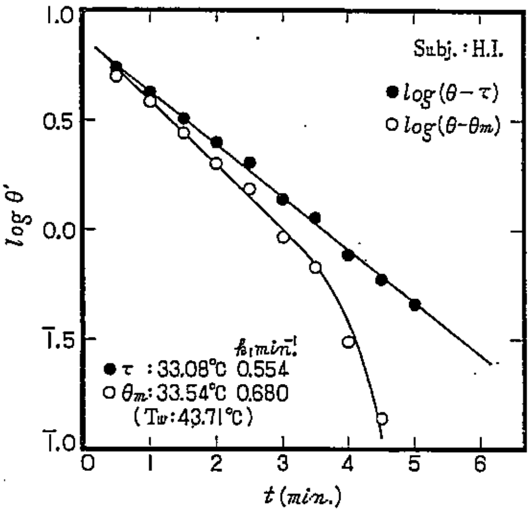

Fig. 6. Analysis of the recovery stage shown in Fig. 1 (comparison between τ and θ_m).

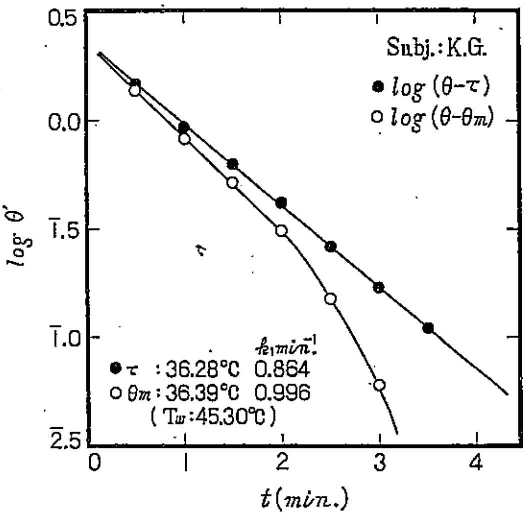

Fig. 7. Analysis of the recovery stage shown in Fig. 3 (comparison between τ and θ_m).

$\sim t$ curve. When the certain temperature in the recovery stage, τ, was obtained to examine the relation between $\log(\theta-\tau)\equiv\log\theta'$ and t, such linear relations were obtained as are shown in **Figs. 6** and **7**, and it is obvious that Newton's law of cooling is applicable to the falling process of the θ in the recovery stage. These figures also show the relation between $\log(\theta-\theta_m)\equiv\log\theta'$ and t, by use of the minimum determined temperature θ_m. It is clear that the $\log(\theta-\tau)\sim t$ curve is linear up to five minutes (Fig. 6) or up to three minutes thirty seconds (Fig. 7), while the $\log(\theta-\theta_m)\sim t$ curve is linear only up to three minutes thirty seconds (Fig. 6) or up to two minutes (Fig. 7). The gradients of these curves (cooling velocity constant, k_1) obtained by the former are smaller than those obtained by the latter. In short, it may be said that the law of heating or the law of cooling is applicable to the temperature of the skin exposed to given high temperature or to the skin temperature in the recovery stage if a certain equilibrium temperature is taken into consideration.

SUMMARY

The human finger was immersed in water at various high temperatures, and the skin temperature (θ) of the finger was measured along with time (t).

1) In water at not lower than about 40°C, the θ rapidly rose initially, reached the maximum in about three minutes, then fell, and fluctuated up and down thereafter, presenting a phenomenon which could be called the heat-induced vasodilatation(hunting temperature reaction to heat). The higher the water temperature, the more pronounced was this phenomenon.

2) There was a linear relation between $\log(\tau'-\theta)$ and t in the θ rising process up to manifestation of the heat-induced vasodilation, if a certain temperature (τ') was taken into consideration, and a law similar to Newton's law of cooling (law of heating) was substantiated.

3) In the θ falling process in the recovery stage when the finger was removed from warm water, there was a linear relation between $\log(\theta-\tau)$ and t, if a certain temperature (τ) was taken into consideration and Newton's law of cooling was substantiated.

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