

## The Response of Blood Pressure to Humid Heat

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The experimental study was conducted to throw light on the response of blood pressure of men to humid heat and to determine the permissible limits of environmental heat. The physiological disequilibrium seemed to be imminent sooner or later in the exposure to the humid heat of 95° F effective temperature (33-34°C wet bulb temperature) or more. Therefore, the permissible upper limits of environmental heat seemed to be around 95°F effective temperature.

Numerous investigators have described experiments made on men exposed to severe humid heat, but little work has been done to study the response of blood pressure to various levels of environmental heat. This problem seems to be very important for the purpose of determining the permissible limits of environmental heat in which men can still work effectively. In 1945 and 1946 EICHNA et al<sup>5)</sup> and AIZAWA<sup>1)</sup> recognized that men, exposed to such humid heat as 33°C wet bulb or more, might be subjected to heat stroke. Therefore, the authors conducted the experimental study on the response of blood pressure of men lying down in humid heat to the various levels of wet bulb temperature.

### METHODS

The subjects were 6 students in good physical condition, aged from 18 to 22 years. The experiments were conducted from August to early September 1963. For our resting experiments the subjects were asked to lie down on deck-chair. After 30 minutes' rest in the ordinary room temperature, the subjects were exposed to humid heat in the specially constructed climatic room for 60 to 180 minutes.

The levels of environmental heat were classified into the three groups of 30°-31°C, 33°-34°C and 36°-37°C wet bulb temperature.

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The details of the environmental heat for each exposure were shown in Figures 1–7 in which the experimental data were described.

The measuring items were as follows:

1) The blood pressure was measured by Riva-Rocci sphygmomanometer every 5 minutes. Systolic blood pressure was recorded at the first phase of the Korotkoff sounds. When the diastolic blood pressure, as recorded at the fifth phase of the Korotkoff sounds, fell to zero, it was recorded at the fourth phase.

2) The oral temperature and pulse rate were measured every 15 minutes.

3) The skin temperature was measured on the three spots of the frontal area, occiput and thigh. Then, the mean skin temperature was calculated by the formula of  $\frac{1}{2} \{(\text{temp. of occiput}) + (\text{temp. of thigh})\}$ , introduced by Kurata and Funazu<sup>9)</sup>.

4) The electrocardiogram was recorded by the standard limb leads before and in the midst of the exposure.

5) The rate of sweating (represented by the loss of body weight) was measured by weighing the men unclothed before and after the exposure.

6) The general clinical appearance and psychic changes were recorded during the exposure.

## RESULTS

1) 30°–31°C wet bulb temperature (Fig. 1~2)

When the climatic room was kept at 33°C dry bulb (88°F effective temp.), the physiological reactions remained almost unchanged, and the mean loss of body weight was only 144 gm. per hr.

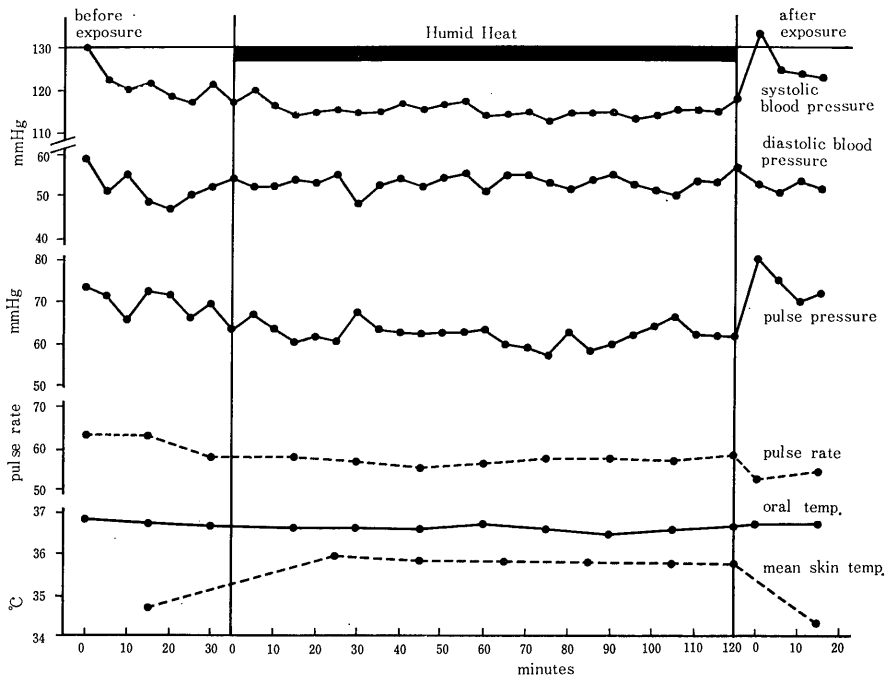
In the case of 43°C dry bulb (93°F effective temp.), the systolic blood pressure remained almost unchanged. But the diastolic blood pressure began to fall slightly after 60 minutes' exposure, and then soon maintained a steady state through the exposure. Therefore, a slight increase in pulse pressure appeared in the latter half of the exposure. The oral temperature, mean skin temperature and pulse rate maintained a steady state, excepting the initial slight rise or increase. The loss of body weight was only 267 gm. per hr.

2) 33°–34°C wet bulb temperature (Fig. 3~4)

In the case of 35°C dry bulb (93°F effective temp.), the blood pressure remained almost unchanged. The mean loss of body weight was 312 gm. per hr.

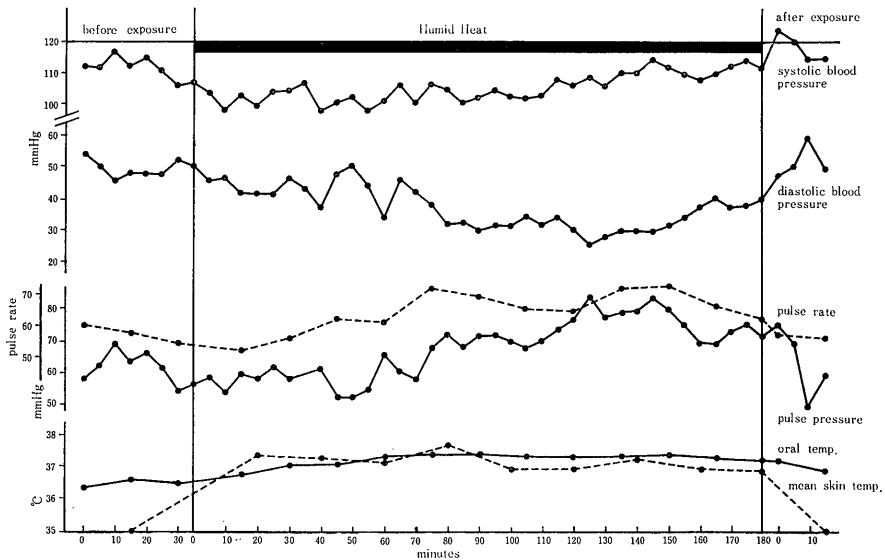
The response of blood pressure to heat seemed to be fairly different from the above results, when the climatic room was heated to 43°C dry bulb (95°F effective temp.) The systolic blood pressure remained

Fig. 1. Influence of Humid Heat (W.B. 30–31°C) on Subjects



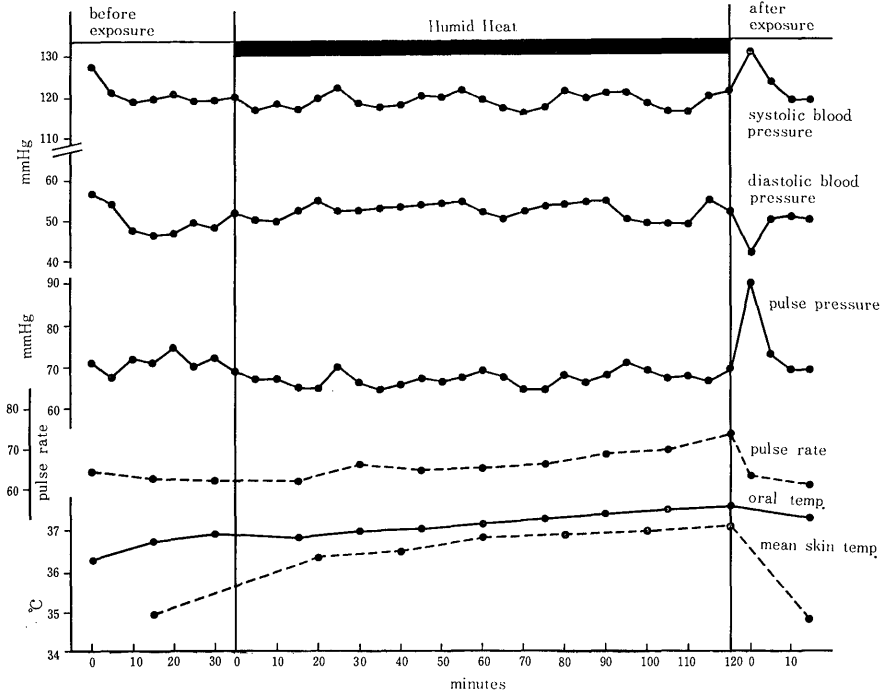
Note : (1) before exposure (D.B. 27.2°C, W.B. 25.1°C, E.T. 78.5°F)  
 Humid Heat (D.B. 32.9°C, W.B. 30.7°C, E.T. 88.0°F)  
 after exposure (D.B. 28.4°C, W.B. 25.8°C, E.T. 80.0°F)  
 (2) Mean Loss of Body Weight.....288g. (144 g. per hr.)

Fig. 2. Influence of Humid Heat (W.B. 30–31°C) on Subject



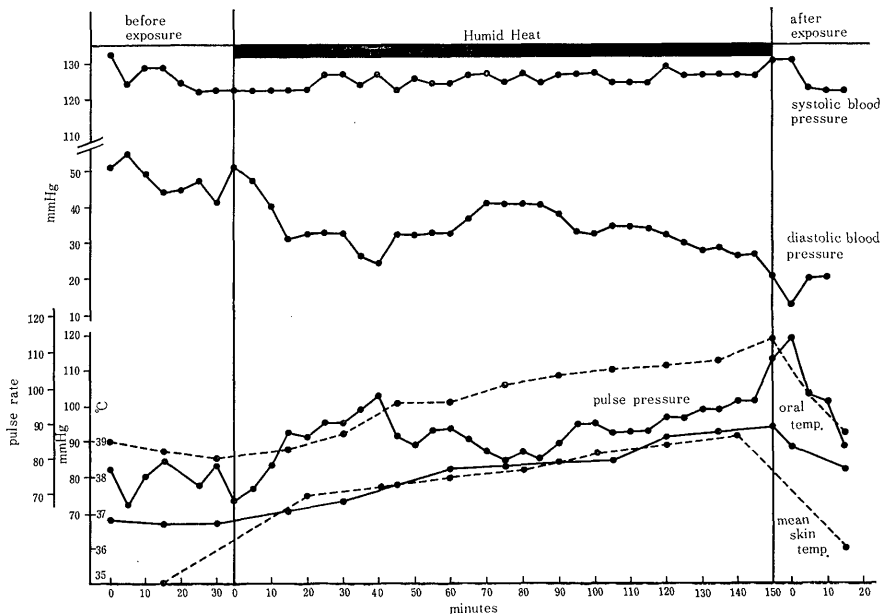
Note : (1) before exposure (D.B. 28.0°C, W.B. 20.0°C, E.T. 74.0°F)  
 Humid Heat (D.B. 42.4°C, W.B. 31.1°C, E.T. 93.0°F)  
 after exposure (D.B. 28.4°C, W.B. 25.8°C, E.T. 80.0°F)  
 (2) Loss of Body Weight.....800g. (267g. per hr.)

Fig. 3. Influence of Humid Heat (W.B. 33-34°C) on Subjects



Note : (1) before exposure (D.B. 30.2°C, W.B. 23.6°C, E.T. 77.0°F)  
 Humid Heat (D.B. 35.5°C, W.B. 33.6°C, E.T. 93.0°F)  
 after exposure (D.B. 30.9°C, W.B. 24.3°C, E.T. 80.0°F)  
 (2) Mean Loss of Body Weight.....625g. (312g. per hr.)

Fig. 4. Influence of Humid Heat (W.B. 33-34°C) on Subject



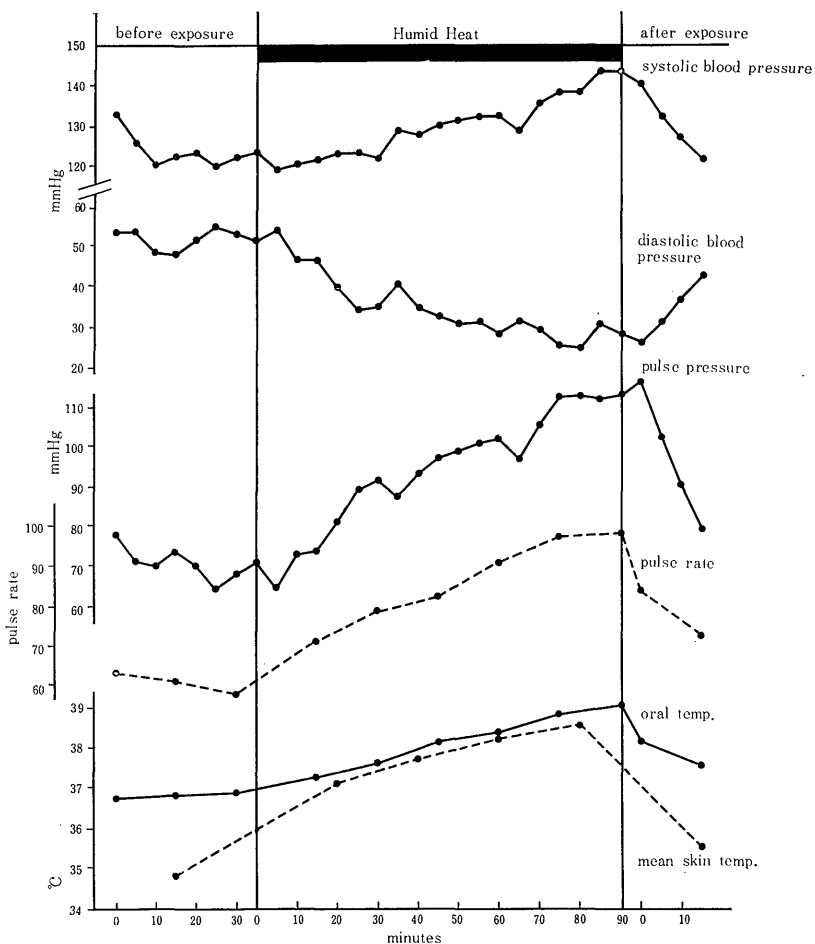
Note : (1) before exposure (D.B. 28.8°C, W.B. 25.0°C, E.T. 79.5°F)  
 Humid Heat (D.B. 43.2°C, W.B. 33.6°C, E.T. 95.5°F)  
 after exposure (D.B. 29.2°C, W.B. 26.2°C, E.T. 81.0°F)  
 (2) Loss of Body Weight.....1500g. (600g. per hr.)

almost unchanged. But the diastolic blood pressure, remained at a steady state after an initial rapid fall, began to fall gradually after 150 minutes' exposure. Therefore, the pulse pressure increased at the end of exposure, according to the change of diastolic blood pressure. Besides, the oral temperature, mean skin temperature and pulse rate steadily rose or increased. After 150 minutes' exposure, the subject flushed with heat and became irritable and complained of weakness, faintness and of being very hot. The loss of body weight amounted to 600 gm. per hr.

3) 36°–37°C wet bulb temperature (Fig. 5~7)

The climatic room was regulated at 39°–40°C dry bulb (100°F effective temp.). In 30 minutes' exposure after entering the climatic

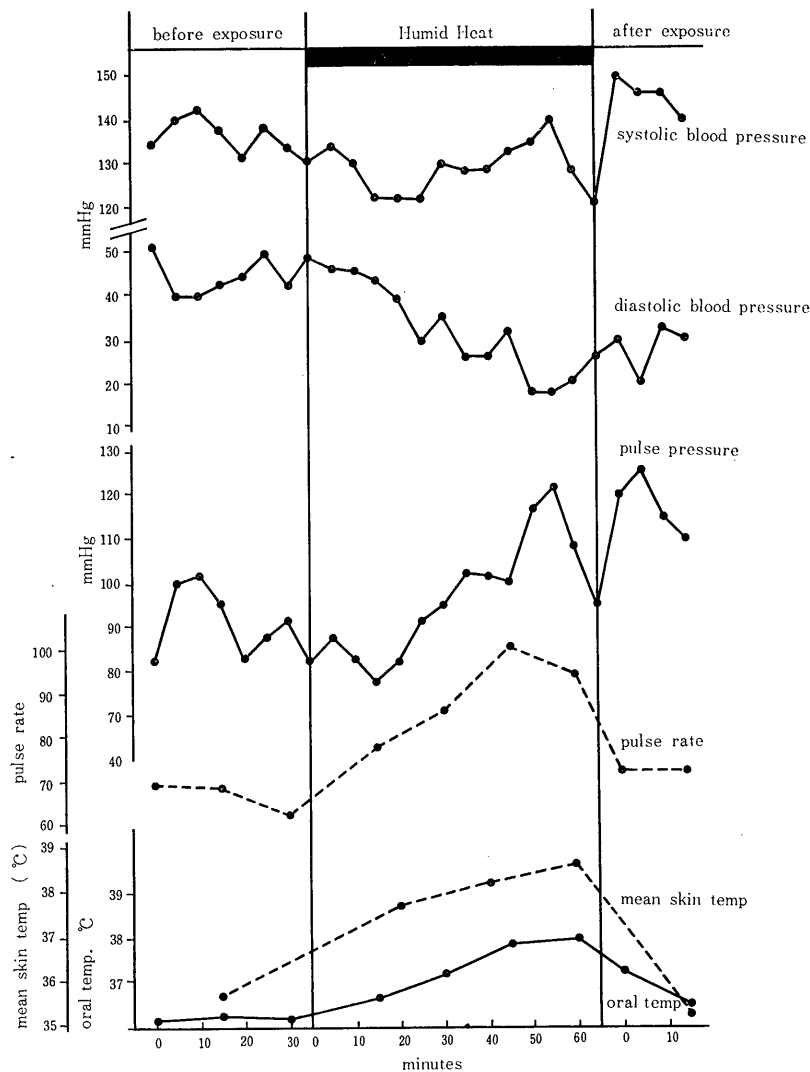
Fig. 5. Influence of Humid Heat (W.B. 36–37°C) on Subjects



Note : (1) before exposure (D.B. 28.9°C, W.B. 24.5°C, E.T. 78.5°F)  
 Humid Heat (D.B. 39.9°C, W.B. 36.7°C, E.T. 100.0°F)  
 after exposure (D.B. 29.2°C, W.B. 25.8°C, E.T. 80.5°F)  
 (2) Mean Loss of Body Weight.....1422g. (948g. per hr.)

room, the systolic blood pressure gradually began to rise, and the marked rise appeared after 60 minutes' exposure. The diastolic blood pressure fell considerably and, as recorded at the fifth phase of the Korotkoff sounds, frequently fell to zero. With continued exposure the pulse pressure developed into a marked increase. The oral temperature, mean skin temperature and pulse rate steadily rose or increased. As exposure continued, the subjects complained of being extremely hot, and the general clinical appearance and psychic changes developed. The mean loss of body weight amounted to 948 gm. per hr.

Fig. 6. One Case in which Heat Stroke occurred

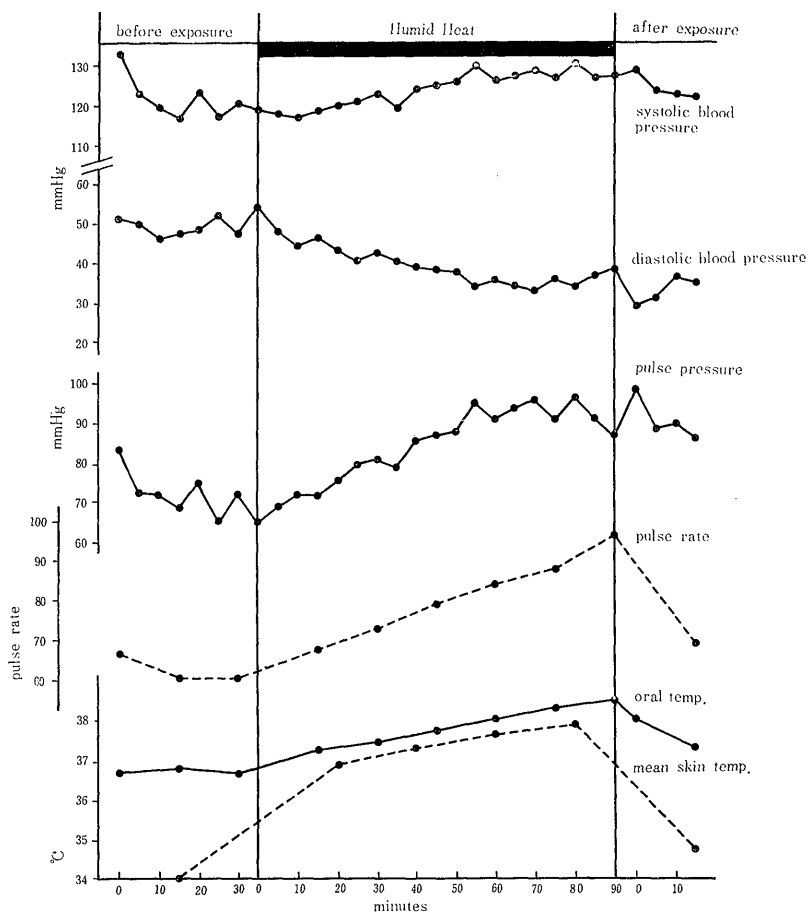


- Note : (1) before exposure (D.B. 29.2°C, W.B. 23.8°C, E.T. 78.5°F)  
 Humid Heat (D.B. 38.6°C, W.B. 36.9°C, E.T. 100.0°F)  
 (2) Loss of Body Weight.....1350g. (1228g. per hr.)

One case in which the experiment was interrupted by the onset of heat stroke, was illustrated in Figure 6. The changes in blood pressure more rapidly developed, and the rising systolic blood pressure rapidly turned to a fall after 55 minutes' exposure. At the same time the falling diastolic blood pressure began to rise slightly, and the increasing pulse pressure began to decrease. The subject complained of being extremely hot, and the disturbances of the nervous system developed, including faintness and restlessness. And then, the exposure to humid heat was interrupted. The loss of body weight amounted to 1228 gm. per hr.

The case in which the occiput of the subjects was cooled by ice-bag, was illustrated in Figure 7. Some investigators<sup>(1)(2)(3)</sup> have reported that such procedure would be effective for the prevention of heat stroke.

Fig. 7. The Case in which the head back of Subjects was cooled by ice-bag



Note : (1) before exposure (D.B. 28.6°C, W.B. 26.3°C, E.T. 81.0°F)  
 Humid Heat (D.B. 39.7°C, W.B. 37.0°C, E.T. 100.0°F)  
 after exposure (D.B. 28.9°C, W.B. 25.9°C, E.T. 80.0°F)  
 (2) Mean Loss of Body Weight.....1100g. (733g. per hr.)

Therefore, the authors intended to observe the response of blood pressure to humid heat under such procedure.

The subjective symptoms were markedly improved and the subjects complained of few pains during 90 minutes' exposure. Excepting the delayed appearance of the changes of blood pressure, no influence on the response of blood pressure to such severe humid heat could, however, be noticed on such procedure.

Therefore, the physiological disequilibrium seemed to take place sooner or later in the exposure to such severe heat as  $36^{\circ}$ – $37^{\circ}\text{C}$  wet bulb, even though the occiput of the subject is cooled by ice-bag.

## DISCUSSION

Numerous investigators<sup>8)14)11)10)12)4)</sup> have reported the response of blood pressure of men exposed to severe heat. They are solid for the fall of diastolic blood pressure, but they do not always have a perfect congruity with one another for the response of systolic blood pressure to severe heat.

HIGASA<sup>8)</sup> reported that the response of blood pressure to severe heat could be divided into the four types which would be effective for the evaluation of individual resistance to heat. But this result seems to be open to discussion, because his experiments were conducted under a pretty wide range of wet bulb temperature (from around  $35^{\circ}$  to  $40^{\circ}\text{C}$  wet bulb).

The responses of blood pressure to humid heat in our experiments are schematically illustrated in Figure 8.

In our experiments, the diastolic blood pressure of subjects exposed to humid heat of  $36^{\circ}$ – $37^{\circ}\text{C}$  wet bulb ( $100^{\circ}\text{F}$  effective temp.), began to fall soon after entering the climatic room. The fall in diastolic blood pressure, as other investigators explained, should be mainly caused by the decreased peripheral resistance, due to the dilatation of dermal vessels.

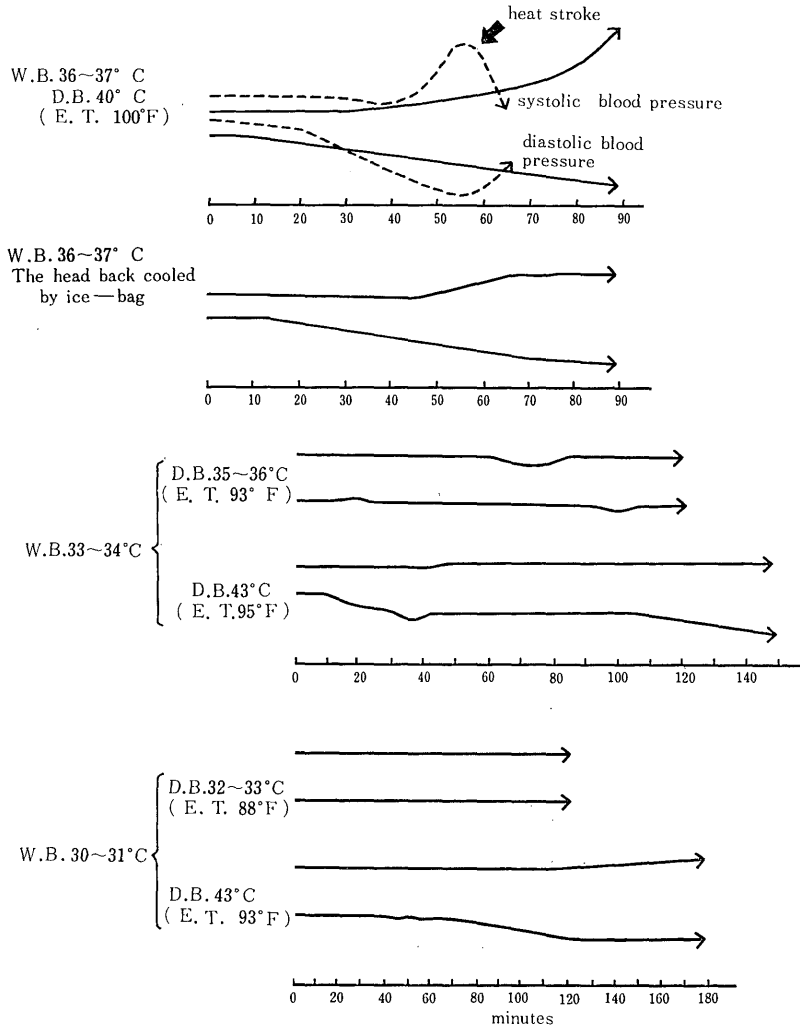
The rise in systolic blood pressure seemed to be caused by the gradual increase in cardiac output, surmounting the effects of the factors reducing blood pressure. But there was some individual variations in the response of systolic blood pressure to such humid heat. In one case among 6 subjects, the systolic blood pressure remained almost unchanged through the exposure.

In the case in which heat stroke occurred, the rise in systolic blood pressure rapidly turned to a fall. It seemed to be signs of a circulatory failure.

In the case of  $33^{\circ}$ – $34^{\circ}\text{C}$  wet bulb with  $35^{\circ}\text{C}$  dry bulb ( $93^{\circ}\text{F}$  effective temp.), there was a balance between the heat stress and the physiological reactions through 120 minutes' exposure. But, with continued



Fig. 8. Schema of Response of Blood Pressure to Humid Heat



exposure to humid heat in which the climatic room was heated at 43°C dry bulb (95°F effective temp.), the onset of physiological disequilibrium seemed to be imminent.

In 1946 GERKING and ROBINSON<sup>7)</sup> suggested that men, whose rate of sweating being over 600–800 gm. per hr., should be subjected to heat stroke. The mean loss of body weight in our experiment also reached to this limit.

In the case of 30°–31°C dry bulb (88° or 93°F effective temp.), there was no physiological disequilibrium and the subjects seemed to adapt themselves to the humid heat.

In our all experiments, there was no special findings in ECG.

## SUMMARY

The authors conducted the experimental study on the response of blood pressure of 6 students in good physical condition, exposed to humid heat ranging from 30° to 37°C wet bulb temperature.

On the other hand, the subjective symptoms and other physiological reactions, such as oral temperature, mean skin temperature, pulse rate, ECG and loss of body weight, were observed.

The following results were obtained:

The response of blood pressure to humid heat were schematically shown in figure 8, and the permissible upper limits of environmental heat were considered to be around 33°–34°C wet bulb temperature.

Especially, the severe heat of 36°–37°C wet bulb (100°F effective temp.) was definitely harmful to health, and the subjects, exposed to humid heat of 33°–34°C wet bulb with 43°C dry bulb (95°F effective temp.), also seemed to be subjected to heat stroke sooner or later.

## ACKNOWLEDGMENT

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## REFERENCES

- 1) AIZAWA, R. : *Jap. J. Hyg.* 1 (1) : 5–6, 1946 (Japanese).
- 2) AIZAWA, R. : *Endem. Dis. Bull. Nagasaki Univ.* 2 (2) : 160–179, 1960 (Japanese).
- 3) ASMUSSEN, E. : *Amer. J. Physiol.*, 131 (1) : 54–59, 1940.
- 4) BURCH, G.E. & DIPASQUALE, N.P. : *Hot Climates, Man and His Heart*, 133–140, Charles C. Thomas, USA, 1962.
- 5) EICHNA, L.W. et al. : *J. Ind. Hyg. Toxicol.* 27 (3) : 59, 1945.
- 6) FUJIKI, S. : *Kokumin-Eisei* 19 (1,2) : 1–133, 1942 (Japanese).
- 7) GERKING, S.D. & ROBINSON, L.P. : *Amer. J. Physiol.* 147 (2) : 370–378, 1946
- 8) HIGASA, Y. : *Nippon Seirishi* 10 : 311–336, 1948 (Japanese).
- 9) KURATA, S. & FJNAZU, Y. : *Rōdō Kagaku* 30 (5) : 332–337, 1954 (Japanese).
- 10) LEE, S.T. : *Jap. J. Physiol.* 2(2) : 103–110, 1951.
- 11) MIURA, T. : *Rōdō Kagaku* 27 (2) : 53–60, 1951 (Japanese).
- 12) MIURA, T. & SAITO, H. : *Rōdō Kagaku* 28 (10) : 727–738, 1952 (Japanese).
- 13) SUZUKI, Y. : *Jap. J. Ind. Health* 4 (5) : 340, 1962 (Japanese).
- 14) TODA, K. : *Kosei-Kagaku* 4 (4) : 390–391, 1943 (Japanese).