Ann. Physiol. Anthrop.
8(3) : 151-154,1989.

Effect of Precooling on Heat Tolerance of Resting Men in a Hot Environment : Comparison with Seasonal Effect on It

Koichi IWANAGA[1], Kazuhiko YAMASAKI[2], Akira YASUKOUCHI[3],
Shigeki WATANUKI[4], Haruhiko SATO and Masahiko SATO

Department of Ergonomics, Kyushu University of Design Sciences
Shiobaru, Minami-ku, Fukuoka 815, Japan

1) Saga Research Institute, Otsuka Pharmaceutical Co., Ltd., Higashisefuri, Kanzaki-gun, Saga 842-01, Japan

2) Department of Ergonomics, The 1st Research and Development Institute, Japan Defence Agency, Nakameguro, Meguro-ku, Tokyo 153, Japan

3) Department of Industrial Physiology, National Institute of Industrial Health, Nagao, Tama-ku, Kawasaki 214, Japan

4) Faculty of Science of Living, Osaka City University, Sugimoto-cho, Sumiyoshi-ku, Osaka 558, Japan

Four healthy Japanese males volunteered as subjects. They were exposed to hot environment of 50°C with 50% relative humidity for 61 minutes immediately after the precooling where they rested in a 10°C for 30 minutes. Their physiological data were compared with that of a previous report (Iwanaga et al., 1983), in which we studied the physiological responses of the same subjects at rest in a 50°C without precooling in summer and winter. After precooling (PC), all the four subjects completed heat exposure for 61 minutes. But without precooling in summer (NC), two of the subjects stopped heat exposure before 61 minutes because of hyperthermia. Rectal temperature (T_R) was lower in PC than in NC before and during heat exposure. During heat exposure, T_R in PC had risen at the 30th minute, but T_R in NC at 20th minute. Whereas there was no difference in heart rate (HR) during heat exposure between summer and winter, in PC HR remained lower than in NC because rising time of HR was prolonged during heat exposure.

Key words : Heat tolerance, Precooling, Rectal temperature

It has been reported that precooling is an effective means of increasing tolerance to heat stress due to work or exposure to a hot environment. Veghte and Webb (1961) reported that the lower the body temperature is decreased at the beginning of exposure to a hot environment by precooling, the longer tolerance time is prolonged. Schmidt and Bruch (1981) also reported that precooling causes the sweating threshold to drop, resulting in sweating occurring at a lower body temperature and indicating a lower heart rate during work.

In a previous report (Iwanaga et al., 1983), we compared the physiological responses of males at rest in a 50°C environment in winter and summer. Even though they were exposed to a neutral-temperature environment for 30 minutes, their rectal temperature at the beginning of exposure to the hot environment was lower in winter than in summer, indicating that tolerance time was extended by a shift in the change in rectal temperature during 50°C exposure to a lower temperature. However, there do not appear to be any studies that have been carried out to determine whether these seasonal changes are the same as the effect of precooling. Therefore, we performed the same high-temperature exposure as in the previous study conducted in summer with precooling and attempted a comparison of seasonal changes.

METHODS

The subjects were four healthy males who had participated as subjects in the study covered by the previous report. The study was performed during summer following the summer when the study of the previous report was performed. The physical characteristics of the four subjects are shown in Table 1. None of them experienced any significant changes from the previous year in their dwelling place and living environment or physical characteristics.

The study was carried out as described in the previous report, so please refer there for details. Below is just a summary of the method used in this study. The subjects wore cotton shirts and short pants and remained at rest in the supine position for 30 minutes in a climatic chamber with a controlled environment of 28°C, 50% relative humidity and 0.5-0.7m/sec air flow rate. They were then immediately transferred to another climatic chamber with a controlled environment of 10°C, 50% and 0.5-0.7m/sec, and where they also rested in the supine position for 30 minutes for precooling. After completion of precooling, they rested in the supine position for 61 minutes in a climatic chamber with a controlled environment of 50°C, 50% and 0.5-0.7m/sec. High-temperature exposure was performed for 61 minutes, but if the subject's rectal temperature exceeded 39.10°C, expired air was sampled for 2 to 3 minutes, an electrocardiogram was performed and exposure was stopped. In the previous study, the subjects were exposed to a neutral-temperature environment, after which they were immediately exposed to a hot environment without precooling. The data from the study were used as a control for comparison. Rectal temperature was measured immediately before completion of neutral-temperature exposure, at the 10th and 20th minute and immediately before completion of precooling, and every 10 minutes during high-temperature exposure. Skin temperature of the chest, upper arm, thigh and lower leg was measured at 10th and 20th minute and immediately before completion of precooling, and every 10 minutes during high-temperature exposure. Oxygen uptake and heart rate were measured immediately before completion of neutral-temperature exposure, at the 10th and 30th minute and immediately before completion of high-temperature exposure.

Sweating volume was obtained from the change in body weight from before the beginning of the study, and the sweating rate was measured on the chest by a filter paper method (Ohara, 1968) every 10 minutes during high-temperature exposure.

RESULTS AND DISCUSSION

Fig. 1 shows the rectal temperature (T_R), the relative change of rectal temperature (ΔT_R) using the temperature obtained before beginning high-temperature exposure as a reference, mean skin temperature ($\bar{T}s$, by Ramanathan, 1964), oxygen uptake ($\dot{V}O_2$), heart rate (HR) and chest sweat rate (SR) obtained with (PC, solid line) and without (NC, dashed line) precooling. In NC, two of the four subjects stopped high-temperature exposure before 61 minutes had elapsed, but in PC, all four subjects completed high-temperature exposure for 61 minutes.

In the 30 minutes of precooling, the T_R of three of the four subjects fell, and the T_R at the beginning of high-temperature exposure was somewhat lower in PC than in NC. However, the T_R on PC was already lower than in NC before beginning precooling (upon completion of neutral-temperature exposure), and so this difference could not be said to be due to precooling. Furthermore, the T_R during high-temperature exposure was lower in PC than in NC in all four subjects. The cause of the difference observed in T_R upon completion of neutral-temperature exposure is not clear, but since the study was performed in PC during the same period of the year following the year it was performed in NC, the difference was thought to be due to some change in climatic conditions or the subject's manner of living over this period. This difference in T_R before beginning high

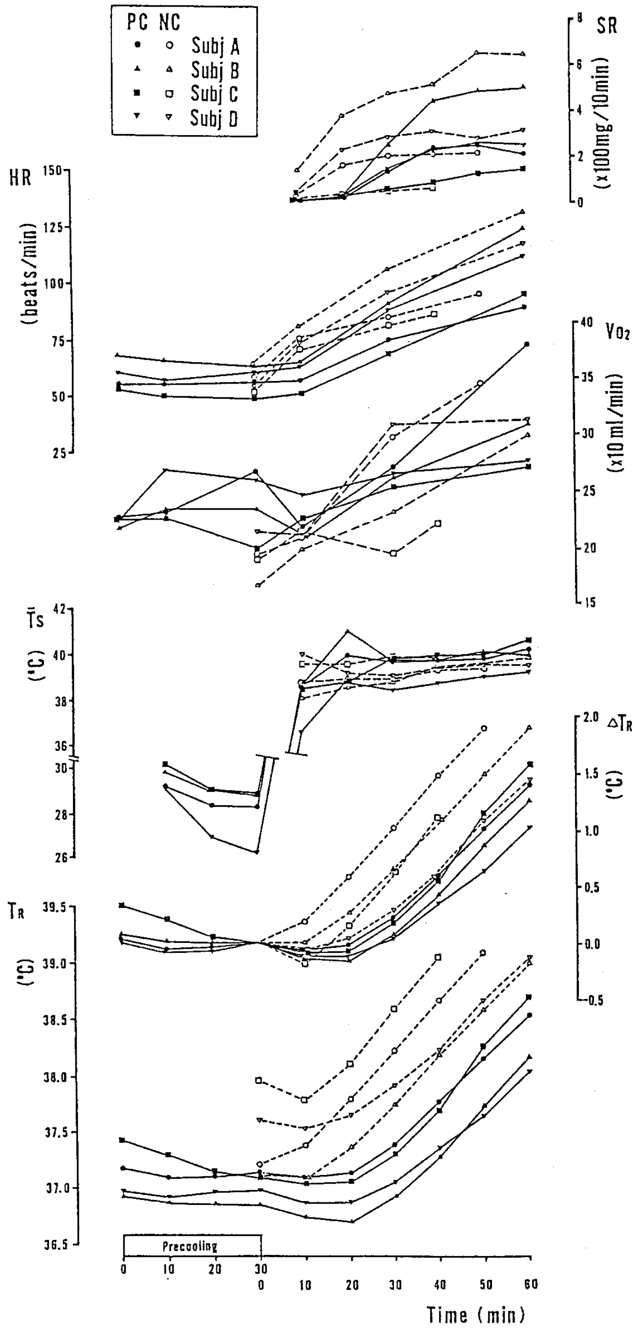

Fig. 1 Changes in rectal temperature (TR, ΔTR), mean skin temperature ($\bar{T}$S), oxygen uptake ($\dot{V}O_2$), heart rate (HR) and chest sweat rate (SR). ΔTR shows a relative change in TR using a reference of TR at the beginning of heat exposure.Solid and dashed lines shows with (PC) and without (NC) precooling respectively.

-temperature exposure influenced the T_R during the subsequent high-temperature exposure as was discussed in the previous report. In other words, the T_R during neutral-temperature exposure in winter was significantly lower than that in summer, and that difference was maintained during high-temperature exposure, thus shifting the change in winter T_R to a lower temperature than in summer. Therefore, though T_R in PC was maintained lower than in NC during high-temperature exposure, it may be difficult to say whether it was due to the influence of precooling. However, if we look at the change in ΔT_R, ΔT_R in PC had not risen 20 minutes after beginning exposure and a rise was observed at the 30th minute in all subjects, while ΔT_R in NC had risen in all subjects at the 20th minute after beginning exposure. And, ΔT_R at a time during exposure was lower in PC than in NC for all subjects. These indicate that not only the difference in initial body temperature observed in the comparison of winter and summer but also precooling contributed to keeping the T_R lower during high-temperature exposure as a result of prolonging the onset of T_R increase due to high-temperature exposure. Veghte and Webb (1961) mentioned that the larger the decrease in T_R due to precooling, the longer the tolerance time in 71°C high-temperature exposure, and therefore precooling effectively improves heat tolerance when considered with respect to the length of exposure time to a high temperature.

The prolongation by precooling of the onset of T_R increase due to high-temperature exposure can be considered to be due to the differences in body heat distribution before high-temperature exposure. In other words, 30 minutes of precooling cools the peripheral parts, thus forming low-temperature shells. As a result, when the cutaneous blood flow increases due to high-temperature, the cooled peripheral blood is returned to the deep parts of the body (Schmidt and Bruch, 1981) where it suppresses the increase in T_R.

In addition to T_R, precooling also had a definite effect on HR and SR. HR increased in the 10th minute of high-temperature exposure in NC, but in PC it did not increase in the 10th minute and remained lower in all subjects during high-temperature exposure than in NC. SR showed the same

Table 1 Physical characteristics of subjects, and sweat volume (SV) obtained from the change in body weight due to experiment.

Subj	Wt, kg		Ht, cm		BSA, m^2		SV, kg	
	NC	PC	NC	PC	NC	PC	NC	PC
A	53.97	55.74	160.8	160.2	1.52	1.53	0.65*	0.57
B	74.26	74.82	172.9	173.6	1.83	1.84	1.13	0.82
C	53.45	55.24	175.5	176.3	1.60	1.63	0.85**	0.32
D	54.35	55.45	170.1	170.8	1.58	1.60	0.82	0.67

BSA : Body surface area according to Fujimoto et al., (1968).
* and ** show the SV for 51.5 and 41.5 minutes, respectively.

tendency, and a prolongation of the onset of sweating was observed. In subjects A and B, the level of SR was lower in PC than in NC, and the sweat volume based on body weight decrease was reduced in PC in all the subjects (Table 1). During high-temperature exposure in a resting state, no difference in HR was seen in a comparison between winter and summer (Iwanaga et al., 1983), and HR correlated with the increase in T_R (Iwanaga et al., 1985). In the comparison of winter and summer, the absolute value of T_R was significantly lower in the winter, but no seasonal difference was observed in the level of increase in T_R due to high-temperature exposure. Therefore, the change in HR during high-temperature exposure at rest was more dependent on the level of increase from the pre-exposure level than on the absolute value of T_R.

It has been reported that the onset of sweating was prolonged in winter more than in summer (Sato et al., 1987) and that the sweat volume was also reduced (Iwanaga et al., 1983). Therefore, the difference in SR and sweat volume observed between PC and NC in this study was basically the same as the difference between winter and summer. It has also been reported, however, that there are differences in the electrolyte concentrations of sweat in winter and summer (Ohara, 1966), but it is unclear as to whether precooling has an effect on the composition of sweat.

REFERENCES

Fujimoto, S., T. Watanabe, A. Sakamoto, K. Yukawa and K. Morimoto, 1968 : Studies on the physical surface area of Japanese. Part 18 Calculation formulas in three stages over all ages. Jpn. J. Hyg., 23 : 443-450.

Ohara, K., 1966 : Chloride concentration in sweat : its individual, regional and some other variations and interrelations between them. Jap. J. Physiol., 16 : 274-290.

Ohara, K., 1968 : Heat tolerance and sweating type. Nagoya Med. J., 14 : 133-144.

Ramanathan, N.L., 1964 : A new weighting system for mean surface temperature of the human body. J. Appl. Physiol., 19 : 531-533.

Sato, H., J. Ohashi, K. Matsuda and K. Iwanaga, 1987 : Seasonal variation in sweating threshold of men. Ann. Physiol. Anthrop., 6 : 33-36.

Schmidt, V. and K. Bruck, 1981 : Effect of a precooling maneuver on body temperature and exercise performance. J. Appl. Physiol. : Respirat. Environ. Exercise Physiol., 50 : 772-778.

Iwanaga, K., K. Yamasaki, A. Yasukouchi, H. Sato and M. Sato, 1983 : Seasonal difference in physiological responses to heat of resting men in hot environment at 50°C. Jap. J. Biometeor., 20 : 61-68 (in Japanese with English abstract).

Iwanaga, K., K. Yamasaki, A. Yasukouchi, H. Sato and M. Sato, 1985 : Physiological responses of resting men and women in hot environment at 50° C. Ann. Physiol. Anthrop., 4 : 27-34 (in Japanese with English abstract).

Veghte, J.H. and P. Webb, 1961 : Body cooling and response to heat. J. Appl. Physiol., 16 : 235-238.

(*Received January 4, 1989*)