Physiological Responses of Men and Women during Prolonged 40% $\dot{V}O_2$ max Exercise at Different Ambient Temperatures

Yutaka TOCHIHARA

Department of Hygiene, School of Medicine, Showa University

Abstract Eight male and female physically active students performed bicycle ergometer exercises for 100 min in cool (9.5°C), neutral (22.0°C) and hot (34.5°C) environments. Relative humidity was 55-65% and air velocity was 20 cm/sec. Work load for each subject was based on 40% $\dot{V}O_2$ max as determined in neutral environment. Heart rate (HR), systolic blood pressure (SBP), rectal temperature (Tre), pulmonary ventilation ($\dot{V}_E$), oxygen uptake ($\dot{V}O_2$) and sweat rate (SR) were measured during exercise.

There were no sex differences in the magnitudes of HR and Tre increases in cool and neutral environments. However in hot environment, the final exercise HR and Tre for the males were significantly higher than those for the females. While SBP of male subjects tended to decrease after 80 min exercise in hot environment, this trend was not observed for female subjects. Significant increases in $\dot{V}_E$ during exercise in hot environment were only shown in male subjects, and the increases in $\dot{V}O_2$ through the exercise time were more severe for the male than for the female subjects. The male had significantly more SR per degree increase in Tre than did the female subjects, indicating that evaporative cooling in the males was not as effective as in the females in the humid heat environment.

INTRODUCTION

Studies on physiological responses to exercise at different ambient temperatures have been done extensively (e.g., ROWELL, 1974). However, most investigations having been performed on male subjects, the investigations on female subjects are limited in number. When both male and female subjects performed exercises in hot environments, higher heart rates and higher rectal temperatures have been reported for females than for males (BROUHA *et al.*, 1960; HERTIG *et al.*, 1963; WYNDAHM *et al.*, 1965; HORI *et al.*, 1978). It was gen-

erally concluded that women had inferior performance capacity in a hot environment when compared with men. However because men are frequently more physically fit than women, it is not clear whether thermoregulatory response differences previously reported occurred because of innate sexual difference or because of difference in physical fitness between both sexes. Indeed, WEINMAN *et al.* (1967) found that during exercise in a hot environment, when compared with sedentary men, active women had superior performance rate and lesser indices of heat stress. Therefore, it is necessary to equate work load on a relative basis for all subjects when compar-

ing men and women.

The purpose of this study is to investigate sex differences related to changes in physiological reactions during moderate prolonged exercise of equal relative intensity at different ambient temperatures.

METHODS

The subjects were 8 male and 8 female students. They were all physically active badminton players. None of them was heat acclimatized at the time of the experiment. Each subject performed the exercise in the following environments: (1) 9.5°C, 55% rh (cool environment), (2) 22.0°C, 60% rh (neutral environment), (3) 34.5°C, 65% rh (hot environment) with an air velocity of 20 cm/sec in each environment. The order of the 3 environmental exposures was randomized and separated by several days. Prior to the experiment, maximal oxygen uptake ($\dot{V}O_2 \text{ max}$) was determined in a neutral environment from multistage bicycle ergometer testing modified from GIMENEZ *et al.* (1981). After resting on a chair in a climate chamber for 20 min, the subjects performed a 100 min bicycle ergometer exercise at a work load which corresponded to about 40% $\dot{V}O_2 \text{ max}$ for each subject. The rate of pedaling was kept constant at 50 rpm.

The physical characteristics of male and female subjects are presented in Table 1. Body fat content (%Fat) was determined by body densitometry (underwater weighing) in a separate day. Residual lung volume was obtained with the neon dilution method during underwater weighing. Relative work load (% $\dot{V}O_2 \text{ max}$)

Table 1. Physical characteristics of subjects.

	Men (n=8)	Women (n=8)
Age (years)	20.6±0.9	21.3±0.5
Height** (cm)	168.4±5.0	160.2±4.4
Weight(Wt)* (kg)	64.7±3.4	56.8±5.4
BSA** (m ²)	1.69±0.06	1.55±0.09
BSA/Wt* (cm ² /kg)	261.8±6.5	273.1±10.3
%Fat* (%)	15.1±4.7	20.6±5.0
$\dot{V}O_2 \text{ max}$ ** (l/min)	3.66±0.30	2.76±0.23
% $\dot{V}O_2 \text{ max}$ (%)	41.4±2.0	40.8±1.3
Load** (W)	101.9±8.8	74.4±8.6

Values are means±SD. BSA: body surface area (FUJIMOTO *et al.*, 1968).

*P<0.05, **P<0.01: Significant sex differences.

was calculated from the oxygen uptake at the 10th min exercise in neutral environment and $\dot{V}O_2 \text{ max}$. There was no sex difference of % $\dot{V}O_2 \text{ max}$.

Heart rate (HR), systolic blood pressure (SBP), cardiac output (CO), rectal temperature (Tre), skin temperatures, pulmonary ventilation ($\dot{V}_E$), and oxygen uptake ($\dot{V}O_2$) were determined at the 10th min, 20th min, 40th min, 60th min, 80th min, and 100th min of the exercise. Expired air was collected through a gas mask and tubing into a spirometer for 3 min. The mixed air samples were analyzed for O₂ and CO₂ concentration using a polarographic and infrared analyzer (Fukuda Sangyo BM-79), respectively.

Net efficiency (NE) of work was calculated as follows:

$$NE(\%) = (0.0143 \text{ W}) / (M - Mo) \times 100$$

where: W = work rate in watt

0.0143 = factor to convert W to kcal

M = metabolism during exercise
in kcal

Mo = metabolism at rest (preexercise value) in kcal

HR was obtained from the electrocardiogram using chest leads. SBP in the left arm was taken by brachial auscultation. CO was determined by CO₂ rebreathing method: the mixed venous CO₂ pressure was estimated by the method as described by KLAUSEN (1965), and the arterial CO₂ pressure was assumed to be the same as in the end-tidal air. Stroke volume (SV) was calculated from the values of CO and HR. Tre was recorded with a thermister probe inserted 12 cm beyond the anal sphincter. Skin temperatures were also measured with thermisters, installed 7 different areas: forehead, abdomen, forearm, hand, thigh, leg, and foot. Mean skin temperature ($\bar{T}_{sk}$) was calculated according to the formula of HARDY and DuBOIS (TEICHNER, 1957). Sweat rate (SR) was determined by nude body weight measurements with a platform scale to within ± 5 gm at the beginning and the end of exposure. Water losses were not replaced until all procedures were completed.

The subjects wore shorts, sleeveless shirts, socks, and shoes. Experiments were carried out during spring and early summer.

RESULTS

All of the subjects completed 100 min of exercise in 3 environments. Figure 1 shows the mean HR and Tre curves during exercise for men and women in 3 environments. In hot environment, HR increased significantly ($P < 0.01$) with exercise time for men and women. Over time, HR for men increased to higher levels than those for women. The final exercise

HR for men were significantly ($P < 0.05$) higher than those for women. There were no sex differences of HR during exercise in cool and neutral environments. In all environments, Tre increased significantly ($P < 0.01$) through the exercise time for men and women. In cool and neutral environments, Tre attained a steady state after 60 min of exercise. However in hot environment, a steady state was not achieved during exercise and a progressive increase in Tre took place. Differences of Tre between both sexes were significant ($P < 0.05$) after 60 min of exercise in neutral environment and after 40 min of exercise in hot environment. However, when expressed as the magnitude of Tre increase from preexercise values, the sex differences were not significant throughout exercise in neutral environment. The magnitude of $\bar{T}_{sk}$ change during exercise was very small in each environment. Sex differences in $\bar{T}_{sk}$ did not occur during the exercise period in any time of the 3 environments. The means of $\bar{T}_{sk}$ for both sexes during exercise in cool, neutral, and hot environments were 29.0°C, 32.5°C, and 36.0°C, respectively.

Table 2 presents SBP, CO, and SV for each period of exercise as the means for all subjects of both sexes. There was a significant ($P < 0.05$) increase of SBP with exercise time for men in cool environment. In hot environment, SBP increased significantly ($P < 0.05$) with exercise time for men and women at the 40th or the 60th min of exercise time. SBP of male subjects tended to decrease after 80 min

Figure 1. Changes in heart rates and rectal temperatures during exercise under 3 environments. Values are means of male and female subjects. *($P<0.05$), **($P<0.01$); statistical differences from 10th min exercise values. †($P<0.05$), ††($P<0.01$); statistical sex differences.

exercise in hot environment. However these trends were not observed for female subjects. Therefore in hot environment, SBP for male subjects were significantly ($P<0.05$) higher at the 10th, the 40th, and the 60th min of exercise than those for female subjects, although there were no sex differences in SBP at the 80th and the 100th min of exercise. There was no significant changes in CO with exercise time for both sexes in each environment. CO of male subjects decreased significantly ($P<0.05$) after the 80 min of exercise compared with the 20th min values, whereas CO of female subjects was relatively constant throughout the 100 min of exercise. SV reduced significantly ($P<0.05$) with exercise time after 40 min of exer-

cise for both sexes in hot environment. The magnitude of SV decrease for men was greater than that for women.

Table 3 presents $\dot{V}_e$, $\dot{V}_{O_2}$, and NE for each time of the exercise as the means for all subjects of both sexes. There were distinct sex differences related to changes in $\dot{V}_e$ in hot environment. $\dot{V}_e$ of male subjects increased significantly ($P<0.05$) with exercise time after 40 min of exercise. $\dot{V}_e$ at the 100th min of exercise was greater by 20% than that at the 10th min of exercise in hot environment. In neutral environment, $\dot{V}_e$ of female subjects significantly ($P<0.01$) decreased with exercise time after 40 min exercise. However the magnitude of $\dot{V}_e$ decrease was very small. Changes in respiratory

Table 2. Systolic blood pressure, cardiac output, and stroke volume during exercise under 3 environments. Values are means of male (M) and female (F) subjects. Same marks are used as in Figure 1.

	Ta	sex	10 min	20 min	40 min	60 min	80 min	100 min
Systolic blood pressure (mmHg)	34.5° C	M	149.8	152.8	157.3*	157.3	149.8	146.3
		F	†† 134.3	† 136.3	† 139.9*	† 141.8*		
	22.0° C	M	148.8	152.0	152.8	150.5	149.8	150.3
		F			† 137.3	† 134.0	† 133.8	† 136.5
	9.5° C	M	148.0	151.8	152.8*	155.6*	153.9*	154.3
		F	† 131.0	†† 129.8	†† 129.8	†† 132.0	†† 132.8	†† 133.3
Cardiac output (l/min.m ²)	34.5° C	M	7.99	8.55	8.20	8.12	7.50	7.29
		F	† 6.89	†† 6.97	† 7.01	† 6.77		
	22.0° C	M	7.96	8.23	8.23	8.20	8.47	8.21
		F	†† 6.87	† 7.00	† 7.14	†† 6.60	†† 6.70	†† 6.70
	9.5° C	M	8.53	8.69	8.96	8.87	8.75	8.74
		F	†† 6.82	†† 6.64	†† 6.85	†† 6.78	†† 6.91	†† 6.99
Stroke volume (ml/min.m ²)	34.5° C	M	69.0	68.4	60.2**	55.7**	48.5**	45.2**
		F	† 59.1	† 57.7				
	22.0° C	M	74.7	76.1	75.0	75.3	76.4	73.1
		F	†† 62.3	†† 62.4	† 62.8	† 57.7	†† 58.2	†† 57.2
	9.5° C	M	84.6	84.3	85.2	83.5	83.1	82.4
		F	†† 66.4	†† 63.5	†† 66.5	†† 64.5	†† 65.7	†† 65.9

frequency with exercise time were the same as changes in $\dot{V}_e$. The increases of $\dot{V}_e$ in hot environment were caused mainly by the increase of respiratory frequency. Only in hot environment, there was a significant ($P < 0.05$) increase of $\dot{V}_{O_2}$ with exercise time for both sexes. However the increase of $\dot{V}_{O_2}$ during exercise was more severe for male than for female subjects.

Figure 2 shows the relations between the magnitude of $\dot{V}_e$ change and the magnitude of $\dot{V}_{O_2}$ change from the 10th min exercise values in hot environment for both

sexes. The correlation coefficient for male subjects was high ($r = 0.65$, $P < 0.001$), although there was no appreciable correlation for female subjects. Similarly, the correlation coefficient between the magnitude of $\dot{V}_{O_2}$ change and the magnitude of $\dot{V}_e$ change from the 10th min exercise values for male subjects was significant ($r = 0.532$, $P < 0.001$), but that for female subjects was not significant. Mean NE of both sexes at 10th min exercise were 23.6–25.5%; there was no sex difference of NE in each environment. NE of female subjects did not change significantly with

Table 3. Oxygen uptake, pulmonary ventilation, and net efficiency during exercise under 3 environments. Values are means of male (M) and female (F) subjects. Same marks are used as in Figure 1.

	Ta	sex	10 min	20 min	40 min	60 min	80 min	100 min
Oxygen uptake (ml/min. kg)	34.5°C	M	22.64	22.94	23.48*	23.75**	23.87**	24.29**
			††	††	††	††	††	††
		F	18.95	19.21	19.61*	19.41	19.39	19.78
	22.0°C	M	23.38	23.72	23.51	23.86	24.12	24.44
			††	††	††	††	††	††
Pulmonary ventilation (l/min. m ²)	9.5°C	F	19.87	19.89	20.05	19.69	19.95	19.72
		M	24.01	23.93	24.23	23.98	24.17	24.28
			††	††	††	††	††	††
		F	19.91	19.97	20.01	20.02	19.71	20.31
Net efficiency (%)	34.5°C	M	23.30	24.05	24.75*	26.42**	26.03**	28.24**
			††	††	††	††	††	††
		F	17.82	17.63	17.19	17.49	17.30	17.48
	22.0°C	M	23.97	24.16	23.31	23.51	23.77	23.94
			††	††	††	††	††	††
exercise time in any environments, while		F	17.78	17.94	17.25	17.01**	16.62**	16.80**
	9.5°C	M	22.87	23.49	23.48	23.13	23.03	22.91
			††	††	††	††	††	††
		F	17.96	18.44	17.90	17.92	17.23	17.78
NE of male subjects deceased significantly	34.5°C	M	25.07	24.68	24.13*	23.81**	23.88*	23.38**
							†	†
		F	25.48	25.18	24.70	25.03	25.12	24.51
	22.0°C	M	24.36	23.69	24.08	23.80	23.47*	23.18**
								†
for female subjects in these environments		F	24.35	24.37	24.40	24.96*	24.67	25.08
	9.5°C	M	23.59	23.73	23.56	23.92	23.75	23.75
		F	24.12	24.17	24.41	24.50	25.05	24.27

exercise time in any environments, while NE of male subjects deceased significantly ($P < 0.05$) with exercise time after the 40 min of exercise in hot enviroment and after 80 min exercise in neutral environment. At the end of the exercise, NE of male subjects was significantly ($P < 0.05$) lower than that of female subjects in neutral and hot environments.

Mean ($\pm$ SD) of SR (per body surface area per hour) for male subjects in cool, neutral, and hot environments were 135 (± 31)g/m².hr, 275(± 33) g/m².hr, and 550 (± 124)g/m².hr, respectively. And those

for female subjects in these environments were 52 (± 26)g/m².hr, 201(± 45)g/m².hr, and 390 (± 55)g/m².hr, respectively. The differences between both sexes and among environments were all significant ($P < 0.01$). SR of male subjects were greater than those of female subjects in 3 environments.

DISCUSSION

The effects of the menstrual cycle on responses to thermal stress have generally been found to be negligible (WELLS and HORVATH, 1974; BURSE, 1979). This study

Figure 2. Relations between the magnitude of pulmonary ventilation change and the magnitude of rectal temperature change from 10th min exercise values in hot environment for both sexes.

did not take menstrual cycle into account. However, no subject was menstruating during the period of these experiments.

SALTIN and HERMANSEN (1966) and DAVIES (1979) found that the level of Tre during physical work is determined by the % $\dot{V}O_2$ max and not by the rate of metabolism in neutral environment. Since the same facts were observed in HR, it is the relative work load and not the abso-

lute work load that determines HR during exercise (ÅSTRAND and RODAHL, 1970; ROWELL, 1974). WYNDHAM *et al.* (1970) also extended these observations to hot environment. Namely, over a range of % of $\dot{V}O_2$ max from 32 to 60% at 32.2°C Twb (wet bulb temperature), there is a close relationship between the 4th hour Tre and % $\dot{V}O_2$ max. Also, DRINKWATER *et al.* (1976) reported that there were no differences between athletes and nonathletes in Tre and HR during two 50 min exercises (30% $\dot{V}O_2$ max) at 28 and 35°C Ta. In this study, there were no sex differences in the magnitude of Tre and HR increase in cool and neutral environments. However in hot environment, the magnitude of Tre and HR increases for men was larger than that for women during the latter periods of exercise (Figure 1). HERTIG *et al.* (1963), WYNDHAM *et al.* (1965) and HORI *et al.* (1978) reported higher Tre and HR for women than for men during exercise of the same absolute work load in hot environments. When both sexes perform exercises of the same absolute work load, women are usually exercising at a greater relative intensity than are men. This accounts for the previously reported greater HR and Tre on the part of women.

Decreases of SV were found after 40 min exercise for both sexes in hot environment (Table 2). The reduction of SV during exercise in hot environment would be caused by the reduced central blood volume as the result of pooling of the cutaneous venules (ROWELL, 1974). During exercise in hot environment, increases of HR compensated for this decrease in SV,

and CO were relatively constant during prolonged exercise for women. However, for men, the increase in HR at the end of the exercise might not be sufficient for the maintenance of SBP and CO in hot environment.

According to HARDY and DuBOIS(1940), women showed a marked drop in resting metabolism as an acute reaction to heat exposure, while men showed no such drop. HORI *et al.* (1978) reported that the increase of $\dot{V}O_2$ during exercise for men was larger than that for women in a hot environment. In this study, there were distinct sex differences related to changes in $\dot{V}_E$, $\dot{V}O_2$, and NE during prolonged exercise in hot environment (Table 3). Significant increases in $\dot{V}_E$ during exercise in hot environment were only shown in male subjects, and the increases in $\dot{V}O_2$ during exercise were more severe for male than for female subjects. Since NE is inversely proportional to energy requirements, a reduced NE for male at the latter period of exercise in hot environment reflects an increased energy requirement. This relatively moderate increase in metabolism in hot environment is obviously favorable for body temperature regulation in women and probably accounts for the smaller rise in Tre. It is well known that the increase of $\dot{V}_E$ in a hot environment for animals (panting) is very effective in allowing for more heat loss. However for human beings, as an increase of $\dot{V}_E$ was accompanied by an increase of $\dot{V}O_2$, an increase of $\dot{V}_E$ was not so effective for heat loss.

The final exercise Tre of male and fe-

male subjects are plotted against the SR for the 3 environments in Figure 3 and regression lines have been fitted to the plots. In both sexes, there were high linear relationships between final Tre and SR. However, by analysis of covariance comparing regression lines obtained for men and women, the slope of the line was significantly ($P < 0.01$) different between both sexes. Namely, the male had significantly more SR per degree increase in Tre than did the female subjects, indicating that evaporative cooling in the males was not as effective as in the females in hot environment. These facts would support the suggestion of WYNDHAM *et al.* (1965) that the male, in humid hot conditions, is a prolific and wasteful sweater whereas the female adjusts her SR better to required heat loss. This wasteful

Figure 3. Relations between sweat rate and final exercise rectal temperature for male and female subjects.

sweat for men might produce greater increase of metabolism. Recently, WELLS (1980) reported that no differences between both sexes occurred in HR or $\dot{V}E$ during 50% $\dot{V}O_2$ max exercise in dry heat environment (39°C Ta, rh 10%). Because the skin is almost dry, higher sweat production of the male is available for temperature regulation in a dry hot environment. However, PAOLONE *et al* (1978) reported that the male subjects had higher HR and greater SR during 40 min 50% $\dot{V}O_2$ max exercise in humid heat environments (32 and 40°C Ta, rh 55%). It appears that women have a physiological advantage when tested under humid heat, and men have an advantage under dry heat. Sex differences in physiological advantages during exercise in hot environment seem to be related to the humidity of the environment (SHAPIRO *et al.*, 1980).

Less loss of body fluids for women would be an advantage to the response of the circulatory system. As dehydration is promoted, venous return will be reduced and SV would decrease, thereby producing a reciprocal increase in HR (ROWELL 1974). Indeed, in this study, cardiovascular strains for men were greater than those for women during the end of the exercise in hot environment (Figure 1, Table 2).

The morphological differences in men and women are also thought to be important factors to be considered in making comparisons of temperature regulation between both sexes. In this study, body fat content (%Fat) and surface area-to-mass ratio (BSA/Wt) of women were higher than those of men (Table 1). In a hot

environment, the insulating fat layer apparently offers no additional hindrance to heat dissipation from the body core (BURSE, 1979). However, the size of BSA/Wt will have an influence on the thermal balance of the body. The higher BSA/Wt for women may be a morphological advantage in humid heat (SHAPIRO *et al.*, 1980). Since the air temperature (34.5°C) in this study was lower than $\bar{T}_{sk}$ (36°C), the higher BSA/Wt of women would allow for more heat loss via radiation and convection. Bergmann observed that with a single, polytypic, warm-blooded species, BSA/Wt of various subspecies usually increases with increasing habitat temperature (NEWMAN, 1975). From this Bergmann's rule, women who have generally higher BSA/Wt would be better adapted to hot humid environment.

ACKNOWLEDGEMENT

The author is indebted to Prof. K. YOSHIDA for his continuing guidance and review of this manuscript and Assoc. Prof. M. TANAKA for his continuing guidance of this study. The author is also deeply indebted to Mr. T. OHNAKA and Mr. S. YAMAZAKI for their technical assistance.

This study was supported in part by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science, and Culture.

REFERENCES

- ÅSTRAND, P.-O. and K. RODAHL, 1970: Text book of work physiology., McGraw-Hill Book Company, New York, : 165.
- BROUHA, L., P. E. SMITH, JR., DE LANNE, and M. E. MAXFIELD, 1960: Physiological reactions

- of men and women during muscular activity and recovery in various environments., *J. Appl. Physiol.*, 16(1): 133-140.
- BURSE, R. L., 1979: Sex differences in human thermoregulatory response to heat and cold stress. *Human Factors*, 26(6): 687-699.
- DAVIES, C. T. M., 1979: Thermoregulation during exercise in relation to sex and age. *Eur. J. Appl. Physiol.*, 42: 71-79.
- DRINKWATER, B. L., J. E. DENTON, I. C. KUPPRAT, T. S. TALAG, and S. M. HORVATH, 1976: Aerobic power as a factor in women's response to work in hot environments. *J. Appl. Physiol.*, 41(6): 815-821.
- FUJIMOTO, S., T. WATANABE, A. SAKAMOTO, K. YUKAWA, and K. MORIMOTO, 1968: Studies on the physical surface area of Japanese. Part 18 Calculation formula in three stages over all ages. *Jpn. J. Hyg.*, 23: 7-14.
- GIMENEZ, M., W. SALINAS, E. SERVERA, and C. KUNTZ, 1981: $\dot{V}O_2$ max during progressive and constant bicycle exercise in sedentary men and women., *Eur. J. Appl. Physiol.*, 46: 237-248.
- HARDY, J. D. and E. F. DuBois, 1940: Difference between men and women in their response to heat and cold. *Proc. Nat. Acad. Sci.*, 26: 389-398.
- HERTIG, B. A., H. S. BELDING, K. K. KRANING, D. L. BATTERTON, C. R. SMITH, and F. SARGENT II, 1963: Artificial acclimatization of women to heat. *J. Appl. Physiol.*, 18(2): 383-386.
- HORI, S., M. MAYUZUMI, N. TANAKA, and J. TSUJITA, 1978: Oxygen intake of men and women during exercise and recovery in a hot environment and a comfortable environment., *Environmental Stress*, Academic Press, New York: 39-52.
- KLAUSE, K., 1965: Comparison of CO_2 rebreathing and acetylene methods for cardiac output., *J. Appl. Physiol.*, 20(4): 763-766.
- NNEWMAN, R. W., 1975: Human adaptation to heat. In: *Physiological Anthropology* edited by DAMON, E., Oxford university press, New York, 80-92.
- PALONE, A. M., C. L. WELLS and G. T. KELLY, 1978: Sexual variations in thermoregulation during heat stress., *Aviat. Space Environ. Med.*, 49(5): 715-719.
- ROWELL, L. B., 1974: Human cardiovascular adjustment to exercise and thermal stress., *Physiol. Rev.*, 54: 75-159.
- SALTIN, B. and L. HERMANSEN, 1966: Esophageal, rectal, and muscle temperature during exercise., *J. Appl. Physiol.*, 21(6): 1757-1762.
- SHAPIRO, Y., K. B. PANDOLF, B. A. AVENLLIN, N. A. PIMENTAL, and R. F. GOLDMAN, 1980: Physiological responses of men and women to humid and dry heat., *J. Appl. Physiol.*, 49(1): 1-8.
- TEICHNER, W. H., 1958: Assessment of mean body surface temperature., *J. Appl. Physiol.*, 12: 169-176.
- WEINMAN, K. P., Z. SLABOCHOVA, E. M. BERNAUER, T. MORIMOTO and F. SARGENT II, 1967: Reactions of men and women to repeated exposure to humid heat., *J. Appl. Physiol.*, 22(3): 533-538.
- WELLS, C. L. and S. M. HORVATH, 1974: Responses to exercise in a hot environment as related to the menstrual cycle., *J. Appl. Physiol.* 36(3): 299-302.
- WELLS, C. L., 1980: Responses of physically active and acclimatized men and women to exercise in a desert environment., *Med. Sci. Sports Exercise*, 12(1): 9-13.
- WYNDHAM, C. H., J. F. MORRISON, and C. G. WILLIAMS, 1965: Heat reactions of male and female Caucasians, *J. Appl. Physiol.*, 20(3): 357-364.
- WYNDHAM, C. H., N. B. STRYDOM, A. J. V. RENSBORG, A. J. S. BENADE, and A. J. HEYNS, 1970: Relation between $\dot{V}O_2$ max and body temperature in hot humid air conditions., *J. Appl. Physiol.*, 29(1): 45-50.

(Received February 1, 1983)

長時間 40% $\dot{V}O_2$ max 運動時の生理反応に

及ぼす気温の影響とその性差について

栃原 裕

昭和大学医学部衛生学教室

身体的鍛練を行なっている男女各8名の大学生を被検者とした。気温は9.5°C（低温），22.0°C（常温），34.5°C（高温）の3条件で，相対湿度は55～65%で，気流は20 cm/secであった。各気温下20分間の安静の後，あらかじめ常温下で数回測定した各人の最大酸素摂取量の40%に相当する強度の自転車エルゴメータ運動を100分間行なわせた。実験中，心拍数，収縮期血圧，直腸温，肺換気量，酸素摂取量及び発汗率を測定した。

低温時と常温時の心拍数，直腸温増加度には性差は認められなかった。しかしながら，高温時には，運動終期の心拍数，直腸温増加度は，有意に男子の方が大であった。男子のみが高温下運動時に肺換気量の増加が認められ，しかも高温下運動中の酸素摂取量の増加は男子の方が著しかった。高温時には，男子の収縮期血圧は運動80分目以後低下傾向があったが，女子にはこの傾向は認められなかった。直腸温上昇度に対する発汗率は男子が，有意に大きく，高温高湿下運動時には，男子の発汗は女子ほどには効率的ではない様であった。

栃原 裕

昭和大学医学部衛生学教室

〒142 東京都品川区旗の台1-5-8

Yutaka TOCHIHARA

Department of Hygiene, School of Medicine,

Showa University

1-5-8, Hatanodai, Shinagawa-ku,

Tokyo 142