Influence of Age on Cardiorespiratory Responses of Firefighters During Exercise in the Heat

Key words: Age differences—Exercise in the heat—Firefighter—Sweat rate—Cardiorespiratory responses

Severe work load in heat represents an occupational hazard for firefighters because it brings about intense cardiorespiratory responses.^{1,2)} Since the average age of firefighters in Japan is expected to increase in the future,³⁾ it is becoming an urgent problem to assess the influence of aging on the cardiorespiratory responses of firefighters when they work in heat. This study was undertaken to investigate the age differences in cardiorespiratory responses during exercise in the heat when firefighters wore protective clothing and equipment.

Forty professional firefighters of the Tokyo Fire Defense Board, all in good health, volunteered to participate in the experiments. The subjects were all men and divided into four age groups, 10 being aged 20–28 years (group 1), 11 aged 30–38 years (group 2), 12 aged 40–46 years (group 3) and seven aged 50–56 years (group 4). The physical characteristics of the subjects are summarized in Table 1. There were two experiments for each subject. In the first, a temperature-controlled room was maintained at $50 \pm 1^\circ\text{C}$ dry-bulb temperature with a relative humidity of $70 \pm 5\%$. In the second, at least one week after the first experiment, the temperature was $25 \pm 1^\circ\text{C}$ dry-bulb temperature with a relative humidity of $40 \pm 5\%$. In each experiment, the air movement was 50 ± 10 cm/min. The subject wore protective clothing with an air respirator and entered the temperature-controlled room. After five minutes rest in a sitting position, the recovery process was also measured for 10 minutes at room temperature subject performed bicycle ergometer exercises at 300 kpm/min for five minutes. The recovery process was also measured for 10 minutes at room temperature immediately after cessation of the ergometer exercise. The heart rate was recorded continuously with electrocardiographic monitors. Systolic and diastolic blood pressure were obtained on a sphygmomanometer by the auscultation method. Expired gas analysis for percent concentration of O_2 and CO_2 was performed continuously with a Fukuda Respilyzer. Pulmonary ventilation and respiratory frequency were calculated from the continuous readings of a Fukuda Respirometer. The data were analyzed by analysis of variance and Student's *t*-test.

The resting values for the heart rate and blood pressure are given in Table 1. As for the diastolic blood pressure, there was a tendency for it to increase with age. Fig. 1 shows the peak values of all parameters during exercise at 25°C and 50°C . At the end of exercise, the heart rate achieved nearly a steady level at 25°C , but not at 50°C due to the heat. There were no statistical

Table 1. Physical characteristics, resting heart rate and resting blood pressure of each age group. Mean $\pm$ S.D. are shown

	Age group yr	Height cm	Weight kg	BSA m ²	Heart rate beats/min	Blood pressure	
						Systolic mmHg	Diastolic mmHg
Group 1 (n=10)	22.8 ± 2.4	168.4 ± 4.7	62.0 ± 3.5	1.66 ± 0.06	63.3 ± 5.5	131.7 ± 5.6	83.4 ± 9.4
Group 2 (n=11)	32.3 ± 2.3	167.8 ± 3.8	68.6 ± 9.4	1.73 ± 0.11	66.1 ± 2.3	131.9 ± 8.7	87.4 ± 10.3
Group 3 (n=12)	42.8 ± 2.8	166.6 ± 4.5	67.8 ± 10.0	1.71 ± 0.13	67.1 ± 4.5	134.1 ± 11.2	90.0 ± 5.8
Group 4 (n=7)	52.7 ± 2.0	162.9 ± 6.1	61.9 ± 6.3	1.62 ± 0.09	69.6 ± 5.9	135.5 ± 3.3	91.2 ± 5.1

differences in the peak heart rate between any of the age groups at either 25°C or 50°C. The percent increase changes of heart rate during exercise and the percent decrease changes of heart rate during the recovery phase were calculated at both 25°C and 50°C, but no significant differences were observed between any of the groups. The peak systolic blood pressure at 25°C in groups 2, 3 and 4 were significantly higher than that of group 1, but there were no significant differences between any of the groups at 50°C. On the other hand, the peak diastolic blood pressure showed significant age-related differences at 50°C, but not at 25°C. The rate-pressure product revealed significant age-related differences at 25°C, but not at 50°C.

The oxygen consumption, pulmonary ventilation and respiratory frequency tended to increase at 50°C as compared to 25°C. As with the pulmonary ventilation, group 4 revealed significantly greater values than groups 1 and 2 at 25°C, but not at 50°C. The older groups tended to have greater respiratory frequency, but the differences were not significant at either 25°C or 50°C. There were no significant differences in oxygen consumption between any of the groups at either 25°C or 50°C.

Age differences in cardiovascular responses were noted in systolic and diastolic blood pressure. The peak systolic blood pressure increased with age at 25°C, which was consistent with the reports of previous workers,^{4,5)} On the contrary, the peak systolic blood pressure did not reveal age differences at 50°C. This was because the younger groups showed greater increases in systolic blood pressure when exposed to heat. The rate-pressure product, which reflects the oxygen demand of the heart muscle,⁶⁾ showed the same tendency as the systolic blood pressure. The diastolic blood pressure at rest and the peak diastolic blood pressure at 50°C increased significantly with advancing age. This was thought to be due to elevated peripheral resistance in the older men.⁷⁾ It is safe to say that the tendency for diastolic blood pressure to increase with age, observed at 25°C, was augmented at 50°C. The peak heart rate showed no age differences at either 25°C or 50°C. Considering these results as a whole, it seems that age

Significant difference between two groups.

* : $p < 0.05$

** : $p < 0.01$

Fig. 1. Peak values of cardiorespiratory parameters at 25°C (unshaded columns) and 50°C (shaded columns). Mean $\pm$ S.D. are shown

differences in peripheral vascular responses were clearer than those in cardiac responses with heat and exercise.

The oxygen consumption and respiratory frequency did not reveal age differences at either 25°C or 50°C. It is known that the maximal oxygen consumption declines with advancing age.⁸⁾ This implies that the relative work load, expressed by percent ratio of oxygen consumption of the subject to his maximal oxygen consumption ($\% \text{Vo}_2\text{max}$), was greater in the older groups in this experiment.

Age differences in cardiorespiratory responses to exercise were not observed except for the peak diastolic blood pressure at 50°C. This means that the older firefighters could not work the same as the younger ones in real firefighting activities. Our results also exhibited that the heart rate and systolic blood pressure achieved nearly 170 beats/min and 200 mm Hg, respectively, at 50°C for five minutes. These intense cardiovascular responses, provoked by heat and exercise, may be stressful to older firefighters who have cardiovascular diseases. Especially important are ischemic heart diseases, which are considered to be an occupational hazard of firefighters because of their severe physical exercise⁹⁾ as well as inhalation of carbon monoxide.^{10,11)}

As we reported previously, physiological responses upon exposure heat and exercise are augmented by antifire coats, probably due to the reduction of radiant heat transfer and effective evaporation.¹²⁾

In addition, in real firefighting activities, a firefighter must carry several pieces of equipment, such as an air respirator, a ladder, ropes and hoses. Thus, a near-maximal to maximal work load could easily be attained during firefighting.^{2,9)}

Since the percentage of the older firefighters will increase in the future in Japan, better training programs to promote physical fitness with regard to age and early detection of ischemic heart diseases are necessary.

ACKNOWLEDGEMENT

The authors would like to express their appreciation to the members of the medical department of the Fire Science Laboratory of the Tokyo Fire Defence Board for their extensive technical assistance.

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(Received July 4, 1985 and in revised form September 3, 1985)