Effects of Repeated Cold Exposures on Thermal Responses of Man

Yutaka TOCHIHARA¹, Tadakatsu OHNATA², Shinya YAMAZAKI³ and Keiichi YOSHDIA³

1) Department of Physiological Hygiene, The Institute of Public Health, Shirokanedai, Minato-ku, Tokyo 108, Japan
2) Department of Hygiene, School of Medicine, Showa University, Hatanodai, Shinagawaku, Tokyo 142, Japan
3) Faculty of Home Economics, Jissen Women’s University, Hino 191, Japan

Recently, the number of workplaces in artificially cold environments, e.g. cold storages, has increased, and air temperatures (Ta) in these environments have become lower. As the set temperatures of these environments were lower, the shorter the working time in cold environments had become. Work in such severe cold environments and large temperature difference between the inside and the outside of the cold room have produced some medical problems (Tochihara, Y. et al., 1979). The effects of cold exposure on physiological responses and performances have been frequently studied (e.g. Tanaka et al., 1981). However, investigations on effects of repeated cold exposures are limited in number. This paper describes some experiments with effects of repeated cold exposures on thermal responses of men wearing cold-protective clothing.

METHODS

Four healthy male students volunteered for this study. Their mean age, height and weight were 22.0 years, 165.9 cm and 63.9 kg, respectively. The subjects wore underwear, a working uniform, socks, cold-protective trousers, a cold-protective jacket with a hood, a pair of gloves and a pair of cold-protective mittens. Total clothing weight was 3.1 kg. In addition, they wore cold-protective boots (2.1 kg). Cold chamber was kept at Ta of −5°C, −20°C or −35°C. The air velocity was 0.4 m/sec. The subjects kept rest in a thermoneutral (22–25°C) room for 20 minutes (warm period), thereafter, they stayed in the cold chamber for 30 minutes. This pattern was repeated three times, therefore total cold exposure time was 90 minutes for one experiment. In each cold environment, the subject rested in a sitting position for 30 minutes (rest experiment), or rested for 10 minutes and then loaded with work, stepping up and down a bench of 15 cm high at a rate of 15 times/min, for 15 minutes (work experiment). Rectal temperature (Tre) and skin temperatures at five points (chest, upper arm, thigh, leg and finger) were measured with thermistor thermometers. Mean skin temperature (Tsk) was calculated according to the formula of Ramanathan (1964). Oxygen uptake (Vo2) was measured by Douglas bag method during cold exposure. Heart rate (HR) was obtained from ECG using chest leads during collection of expired air. Experiments were carried out during August.

RESULTS AND DISCUSSION

Figure 1 showed the time response curves of Tre, Tsk and skin temperature of finger (Tf). Rectal temperatures remained almost unchanged during the first cold exposures in all experiments. However, with the exception of the work experiment at −5°C Ta, Tre decreased gradually by repeated cold exposures. The decrease of Tre during warm period was greater than that during cold exposure period in both experiments. Therefore, it is important to reduce the after-drop of Tre during repeated cold exposures (Tochihara et al., 1982). Skin temperatures decreased gradually by repeated cold exposures, and these phenomena were remarkable at lower Ta. After cold exposure, Tsk and Tf did not increase to pre-cold exposure values during 20
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Fig. 1 Changes in rectal temperature, mean skin temperature and skin temperature of finger during repeated cold exposures. Values are means of the subjects.

Fig. 2 Changes in pain, thermal sensation and onset of frank shivering during repeated cold exposures. Values of pain and thermal sensation are means of the subjects.

In the work experiments, and the onset of frank shivering was delayed due to work at -35°C Ta (Fig. 2).

Oxygen uptakes and HR during cold exposures were presented in Fig. 3. Analysis of variance concerning \( \dot{V}O_2 \) in the rest experiments showed that the factors of Ta and the repeats of cold exposure had significant influences, suggesting \( \dot{V}O_2 \) increase by lowering Ta and repeated cold exposures. On the other hand, in the work experiments the factor of the repeats of cold exposure had no significant influence on \( \dot{V}O_2 \). Analysis of variance concerning HR in the rest experiments showed that the factors of Ta and repeats of cold exposures had significant influences. The onset of shivering appeared along with an increase of HR and \( \dot{V}O_2 \). The correlation coefficient between HR and \( \dot{V}O_2 \) was significant \( (r=0.501, P<0.01) \) in the rest experiments. On the other hand, HR in the work experiments decreased by colder exposures and repeated cold exposures. There was no significant relationship between HR and \( \dot{V}O_2 \) in the work experiments.
Fig. 3 Mean and SE of oxygen uptake and heart rate during cold exposures.

It was concluded that the effects of repeated cold exposures on thermal responses were strongly influenced by Ta and physical activity levels. Therefore, it is important to take into account not only Ta but also types of work (sedentary work such as driving a fork-lift truck or heavy work such as loading manually) to evaluate cold stress.

REFERENCES

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