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The blood pressure responses to an acute and long-term whole-body cryotherapy (−110°C) in men and women

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Abstract

The blood pressure responses to an acute and long-term (three months) whole-body cryotherapy (WBC) were measured in men and women. Acute cold exposure (−10°C, −60°C, −110°C) increased both systolic and diastolic blood pressures temporarily. Neither significant gender differences nor adaptation in blood pressures were found during WBC. The variation of individual responses to the acute and long-term WBC was wide.
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1. Introduction

Acute exposure to a cold environment, either air or water, causes a stress reaction. One of the first physiological effects of cold-induced cooling in man is skin vasoconstriction and a concomitant increase in peripheral resistance, and blood pressure. Facial cooling increases blood pressure and results in bradycardia in resting subjects (LeBlanc et al., 1975b). An elevated blood pressure exerts a greater load on the heart and thus increases the cardiac oxygen demand (Hanna et al., 1975; Kitamura et al., 1972). Increased blood pressure in the cold constitutes an increased risk for patients with cardiac diseases and may be a risk factor for certain diseases in healthy individuals who are regularly exposed to cold (Lloyd, 1991).

Whole-body cryotherapy (WBC) is one mode of cold therapy, during which patients are exposed to very cold air (−110°C) in minimal clothing. It was developed in Japan and is widely used in Germany and in some other European countries. WBC is used to alleviate inflammation and pain in, for example, arthritis (Fricke, 1989; Samborski et al., 1992a; Wichmann and Fricke, 1997), and osteoarthritis (Metzger et al., 2000) and is used for pain relief in fibromyalgia (Samborski et al., 1992b). The duration of WBC usually varies from 1 to 3 min.

Little data are available about the effects of WBC on blood pressure, and no long-term effects have been reported. WBC has been found to influence blood pressure little (Fricke, 1989; Taghawinejad et al., 1989a, b) in spite of such a cold ambient temperature as −110°C.

The present study is a part of a project undertaken to ensure the safety of WBC for patients and personnel. This study was designed to evaluate

1. changes in blood pressure induced by an acute cold exposure (−10°C, −60°C, −110°C) and
2. if repeated WBC (−110°C) causes adaptation in blood pressure response?

Some reports exist that men are more sensitive to cold stress having earlier and faster cardiovascular

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and metabolic adjustments than women (Gerra et al., 1992; Walsh and Graham, 1986; Stevens et al., 1987; Graham et al., 1989). Therefore, an additional aim was to find out

3. if changes in blood pressure differ between men and women when exposed to -110°C?

2. Methods

2.1. Subjects

After the approval of the Ethical Committee of the Hospital District, two groups with a different protocol, signed informed consents and volunteered to participate in this study. All subjects were sedentary, healthy, normotensive and with no medication. Ten females (group 1) were participating in the study, which compared WBC and winter swimming. Their mean age (mean ± SD) was 38 ± 3 years, height 167 ± 7 cm, weight 68 ± 14 kg, BMI 24 ± 3 kg/cm^2, resting systolic pressure 126 ± 12 mmHg and resting diastolic pressure 79 ± 10 mmHg. Twelve females and ten males formed group 2. Group 2 participated only in this study. Their mean age (mean ± SD) was 40 ± 12 years, height 171 ± 7 cm, weight 69 ± 11 kg, BMI 24 ± 3 kg/cm^2, resting systolic pressure 128 ± 12 mmHg and resting diastolic pressure 76 ± 10 mmHg.

2.2. Thermal exposures

WBC is a specially built, temperature-controlled unit (Zimmer Elektromedizin), which consists of three chambers. At the first visit each subject was exposed to the first pre-chamber (-10°C), at the second visit to the second pre-chamber (-60°C) and at the third visit to the therapy-chamber (-110°C). After that subjects were exposed only to the therapy-chamber three times a week during three months. The exposure time was 2 min. Subjects passed through the pre-chambers before coming into the therapy-chamber. The actual temperature of the therapy-chamber was -110 to 113°C. Air in the therapy-chamber was dry and clear. The subjects were wearing a bathing suit, surgical mask, cap, gloves, socks and shoes during the exposure. While in the therapy-chamber, the subjects were advised to move slightly their fingers and legs and to avoid breathholding. Subjects had not practised regularly winter swimming and they were not allowed to practise it during the experimental period. Subjects were advised to maintain the same physical activity level during this period as before that.

2.3. Blood pressure measurements

Blood pressure measurements were done during the first week in connection with the visit at -10°C, -60°C and -110°C and after that with the visit at -110°C once a month during three months. Blood pressure was measured just before the cold exposure and immediately after the exposure in the sitting position and the forearm supported in the horizontal position at heart level. Blood pressure was measured by a clinically validated automatic blood pressure monitor Omron 711 Automatic IS (Omron Matsusaka Co. Ltd., Japan). The mean arterial pressure (MAP) was calculated as: $\text{MAP} = \text{diastolic BP} + 1/3 \times \text{pulse pressure}$. Heart rate was measured by Polar S 810 telemetric system (Polar Electro, Kempele, Finland) during the blood pressure measurements. Mean heart rate before and after the cold exposure was calculated as the mean over 1 min. Heart beats were analysed using Polar Precision Performance SW 3,0 analysis software (Polar Electro, Kempele, Finland).

Group 1 was requested not to eat, drink or smoke for 4 h before the measurements. They rested in the supine position for 10 min, after which they sat 5 min before the measurements. Group 2 was requested not to eat heavy food, and not to drink coffee, tea, cola drinks for 2 h and smoking was forbidden for 4 h before the measurements. This group sat 5 min or until blood pressure readings were consistent before measurements.

2.4. Statistics

There were no statistically significant differences in blood pressure between the two groups. Therefore, the results of the two groups were combined and analysed as a single population, but the results for men and the women were analysed separately.

The mean changes of blood pressures and heart rates (95% confidence interval) were calculated from the reference values (values before the exposure) to blood pressures and heart rates measured immediately after the exposure.

3. Results

During the trials resting blood pressures did not change. After each exposure (-10°C, -60°C, -110°C) both systolic and diastolic blood pressures were on average significantly higher compared to pre-exposure values (Table 1). Systolic blood pressure increased significantly more in connection with the -110°C than with -10°C ($p<0.01$) and -60°C ($p<0.001$) cold exposures, but the increase was similar in connection with the -10°C and -60°C cold exposures. Diastolic blood pressure increased similarly in all cold exposures. Interindividual variation was wide in both systolic and especially diastolic blood pressure responses, and the variation tended to be largest in the coldest exposure (Fig. 1). There were no differences in response of MAP

Table 1
Blood pressures at rest before the cold exposures and the change from pre-exposure values

Temperature (°C)	Systolic (mmHg)		Diastolic (mmHg)	
	Before mean (SD)	Change mean (95% CI)	Before mean (SD)	Change mean (95% CI)
−10	130 (11)	14.4 (10.4–18.4)	81 (8)	4.8 (1.7–7.9)
−60	129 (12)	15.0 (11.1–19.0)	81 (7)	2.9 (0.5–5.3)
−110	128 (12)	23.6 (19.6–27.6)	81 (9)	4.8 (1.7–7.9)

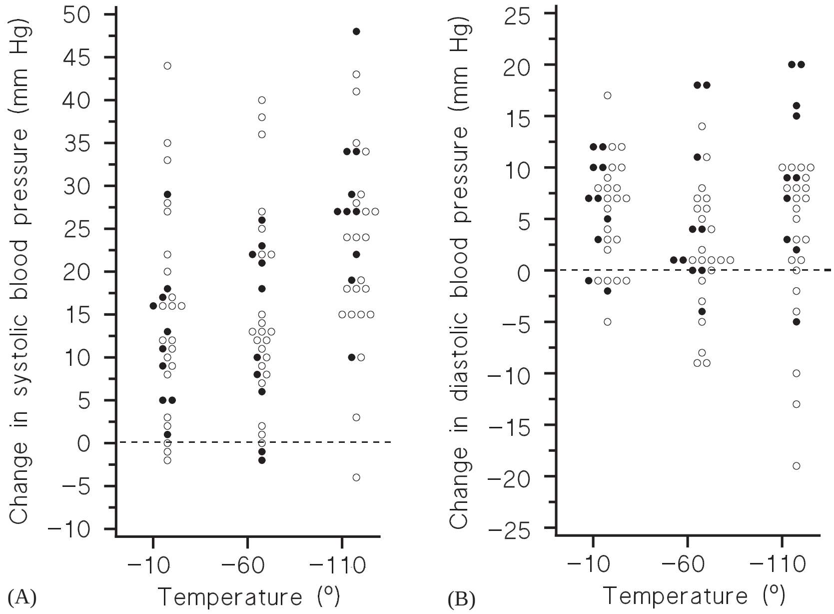

Fig. 1. Individual changes in systolic (A) and diastolic (B) blood pressures in men (solid) and women (open) during (post-pre) −10°C, −60°C and −110°C exposure.

to the different cold exposures. MAP (SD) before and after −10°C were 98 (8) and 106 mmHg (8), before and after −60°C 97 (7) and 104 mmHg (9) and before and after −110°C 96 (8) and 107 mmHg (9), respectively. Mean heart rates (SD) before and after −10°C were 71 (9) and 67 beats min^{-1} (10), before and after −60°C were 74 (9) and 69 beats min^{-1} (10) and before and after −110°C were 74 (10) and 69 beats min^{-1} (10), respectively.

The average response in systolic, diastolic and MAP was similar to the repeated −110°C cold exposures during the three months. However, the individual blood pressure responses to the repeated WBC differed from the average results. 44% of the subjects had decreasing trend in systolic blood pressure response, 44% had a variable reaction or there was no change and 12% had rising trend during the three months. The subjects with the most remarkable increases in systolic blood pressure after first time at −110°C reacted similarly or their trend was decreasing. In diastolic blood pressure 50% of the subjects had a variable reaction or there was no change, 28% had decreasing trend and 22% had rising trend. The average blood pressure responses to the acute and long-term WBC were not significantly different between men and women (Figs. 1 and 2). However, a wider variability was observed in men's response to WBC (Fig. 2) compared to women indicating that at individual level some men had a more intense blood pressure reaction.

4. Discussion

In the present study, systolic blood pressure increased more at −110°C cold exposure than at lower temperatures (−10°C, −60°C). The increase in systolic blood pressure in connection with −110°C cold exposure was large in our study, and more than in previous studies. Fricke (1989), Taghawinejad et al. (1989a) and Taghawinejad et al. (1989b) have reported systolic blood

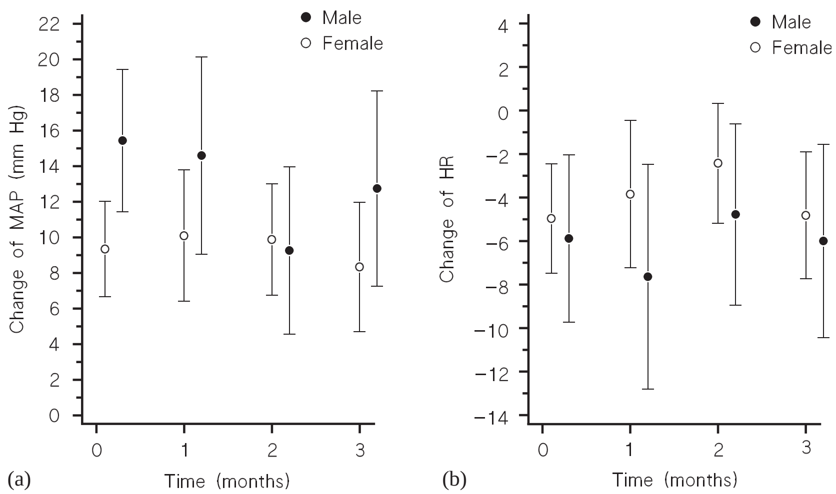

Fig. 2. The average changes of MAP (a) and heart rate (b) in men and women during the first visit, and after repeated WBC (−110°C) at 1, 2, and 3 months. The values are means (CI).

pressure to be increased by 9–10 mmHg immediately after WBC compared to the values before the WBC. In their studies, the exposure time was from 30 s to 3 min (Fricke, 1989; Taghawinejad et al., 1989a) and from 30 to 90 s (Taghawinejad et al., 1989b). The increase in diastolic blood pressure was about the same (5 mmHg) in our study as that achieved by Taghawinejad et al. (1989a). Fricke (1989) found diastolic blood pressure to be increased by 10 mmHg after WBC compared to the values before WBC, but Taghawinejad et al. (1989b) reported no change in diastolic blood pressure measured after WBC. In the literature, there is no data about blood pressures after the pre-chambers (−10°C, −60°C).

Acute cold exposure increased blood pressure significantly in our study, but the increase was only temporary. Sokolow et al. (1966) reported that short peaks in blood pressure cause much less harm than continuous states of raised blood pressure. In our Hospital (Rheumatism Foundation Hospital) in clinical use, WBC is not allowed for patients with cardiac disease and blood pressure has to be in stable and not over 160/100 mmHg. However, in Germany patients with cardiac diseases are allowed to use WBC 6 months after cardiac infarction. Compared to winter-swimming, blood pressure responses in the present study were lower. Zenner et al. (1980) reported systolic to increase by 43 mmHg and diastolic blood pressure by 14 mmHg after swimming in ice-cold water. Either, the changes of blood pressures in our study were not as much as they can be during submaximal exercise. Iellamo et al. (1997) compared different (isokinetic, isotonic and isometric) submaximal exercises (knee extension/flexion repetitions) on blood pressure in healthy subjects. In their study changes of systolic and diastolic pressures were 60 and 39 mmHg during isokinetic exercise, 70 and 50 mmHg during isotonic exercise and 37 and 23 mmHg during isometric exercise. However, it is important to notice, that we measured blood pressure after WBC, not during WBC. Most probably blood pressures were higher during the exposure, but the pressures could not be measured by the auscultatory technique.

No adaptive changes in blood pressures were found in the present study. Hirvonen et al. (2002) reported that mean resting systolic blood pressure of winter swimmers fell from 134 to 128 mmHg ($p<0.05$) during one winter swimming season (average 5–6 times a week) and a slight but non-significant drop was also seen in the controls not doing winter swimming. The mean diastolic pressure did not change in either of the groups during the winter. The researchers did not mention the method of blood pressure measurement. We do not know, if a longer experimental period or more frequent cold exposures per week would have caused adaptation in blood pressure in the present study, too. However, a seasonal influence on blood pressure has been observed (Rose, 1961; Brennan et al., 1982). Brennan et al. (1982) have reported that systolic blood pressure was higher in winter than in summer for mild hypertensives. Our experimental periods were in autumn and in spring.

In the present study the men reacted to WBC slightly stronger than the women, but the difference was not significant. Pettit et al. (1999) reported mean arterial pressure to be significantly higher in the men throughout cold exposure (2 h, 5°C), but it was significantly higher at baseline, and the relative changes did not differ significantly between the genders. Gerra et al. (1992) found that systolic and diastolic blood pressure increased in males, but not in females after 30 min cold exposure at 4°C. The physiological mechanisms associated with the previously reported gender related differences in cardiovascular function are not well understood. The sympathetic nervous system is known as a major cardiovascular regulating system. The information on catecholamine responses during rest in cold air is contradictory, especially on epinephrine response (Wilkerson et al., 1974; Weiss et al., 1988; O'Malley et al., 1984).

Individual differences in blood pressure responses to cold exposures were large. This finding is in concordance with the previous reports, in which considerable individual differences in cardiovascular response to cooling have been found (Buskirk et al., 1963; Davis, 1961; Hardy et al., 1970; Mannino and Washburn, 1987). Although many studies have demonstrated that cardiovascular response to overall body cooling is significantly related to percent of body fat, metabolic rate and fitness level (Daniels and Baker, 1961; LeBlanc, 1975a), there have also been wide individual differences observed in response to cold between individuals matched in age, level of fitness, previous exposure to cold and percent of body fat (Buskirk et al., 1963; Davis, 1961; Hardy et al., 1970). Zenner et al. (1980) reported some remarkable decreases in systolic pressure (changes of systolic pressures were 40 mmHg in one subject and 36 mmHg in another) and impressive increases in systolic and diastolic pressure (changes of systolic/diastolic pressures were 50/50 mmHg in one subject and 49/10 mmHg in another) in winter swimmers. Because of striking individual differences in response to cold, Hines (1940) has divided subjects into hyporeactors and hyperreactors. Although there were large individual differences in blood pressure in the present study, no untoward clinical signs were noted in any subjects.

In conclusion, acute cold exposure increased the average levels of blood pressures, but the variation of individual responses was wide. The magnitude of the increase is supposed, however, to be safe for the healthy persons. No adaptive responses were found during 3 months of WBC, but individual responses differed from the average results. The changes in blood pressures due to WBC were not significantly different between men and women.

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