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The Relationship between Cold Exposure and Hypertension

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Abstract: The Relationship between Cold Exposure and Hypertension: Joon-Youn KIM, *et al.* Department of Preventive Medicine, Medical College, Dong-A University, Korea—This study was performed to determine whether there was any relationship between cold exposure and hypertension, and to evaluate risk factors affecting hypertension in cold-exposed workers. In 11 refrigeration industries, 68 male workers working in cold areas more than once per day were selected as the cold-exposed group, and 68 workers not exposed to cold were selected as the control group. The questionnaire survey, clinical and laboratory tests were performed. Systolic and diastolic blood pressures were significantly higher in the cold-exposed group, and body core temperature was significantly lower in the cold-exposed group ($p<0.05$). In logistic regression analysis, age, cold exposure severity and milk intake were significant variables affecting hypertension in cold-exposed workers, whose odd ratios were 5.204 (95% CI 1.440–18.812), 2.674 (95% CI 1.080–6.618), and 0.364 (95% CI 0.141–0.942), respectively. Cold exposure was a risk factor for hypertension, and risk factors affecting hypertension in cold exposed workers were age, cold exposure severity, and milk intake. Therefore, cold exposed workers should minimize cold exposure time as much as possible, and ingest foods containing calcium such as milk. In particular, old workers working in cold areas should check their blood pressure and electrocardiogram periodically.
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Key words: Cold exposure, Hypertension, Refrigeration

In 1999, 30.3% of all deaths were due to cardiovascular disease including hypertension, ischemic heart disease and cerebrovascular disease[1]. Hypertension does not induce early symptoms, but complications in the cerebrovascular system, heart and kidneys may develop if early stage hypertensive patients are not treated properly[2].

The death rate due to cardiovascular disease including hypertension is known to be higher in winter than in summer. Kristal-Boneh *et al.*[3] reported that blood pressure was higher in winter than in summer, so that hypertensive patients would be more likely to die in winter. Donaldson *et al.*[4] reported that cold exposure would induce a reduction in hemoglobin, red blood cell counts, serum albumin and the erythrocyte sedimentation rate, and an increase in systolic and diastolic blood pressure.

Known risk factors of hypertension include hereditary factors, old age, obesity, salt ingestion, increase in blood cholesterol, smoking, alcohol drinking, coffee drinking, stress, and so on. In the case-control study carried out by Kam *et al.*[5], risk factors for hypertension were alcohol drinking, salt ingestion, obesity and milk drinking.

Men working in the refrigeration industry are exposed to cold at –50 – –20°C ambient temperature, and they are sensitive to diseases due to cold exposure[6]. Health hazards due to cold exposure include reduction in body core temperature and skin temperature, reduced physical and psychological function, hypertension and angina, exacerbated back pain, impaired peripheral circulation[6, 7].

This study was carried out to determine the risk factors in cold exposed workers in the refrigeration industry, and suggest preventing methods for hypertension in cold-exposed workers.

Subjects and Methods

1. Study subjects

In 11 refrigeration industries, 68 male workers working in cold areas (–20 – –50°C) more than once a day were selected as the cold-exposed group, and 68 workers not exposed to cold were selected as the control group. They were daytime labor workers working 8 hours a day. They worked in low temperature areas or normal temperature areas. The ambient temperature of the control group was

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Table 1. General Characteristics of study subjects

Variables		Cold exposed group (n=68)	Control group (n=68)	p-value
Age (yr, mean ± SD)		36.8 ± 8.8	38.6 ± 9.0	0.128
Education (yr)	< 9	18	9	0.213
	9–12	34	39	
	> 12	36	20	
Marital status	Single	15	13	0.617
	Married	53	55	
Alcohol drinking (times/wk)	< 1	20	14	0.127
	1–2	18	30	
	> 3	30	24	
Smoking (pack-years, mean ± SD)		11.2 ± 9.3	11.2 ± 11.0	0.925
Exercise (times/wk)	<1	26	27	0.836
	1–2	27	23	
	> 3	15	18	
Salt intake	Not salty	21	17	0.890
	Moderate	29	30	
	Salty	18	21	
Milk intake	No	26	25	0.795
	Sometimes	27	32	
	Frequently	15	11	
Family history of hypertension	Yes	15	10	0.275
	No	53	58	
Past history of hypertension	Yes	7	5	0.545
	No	61	63	

about 15–20°C, and the ambient temperature of the cold-exposed group was about 15–20°C (normal temperature area) or about –20 – –50°C (low temperature area). An age-matching method was used to select the control group.

2. Methods

1) Questionnaire survey

All subjects replied to the questions about general characteristics including education, marital status, alcohol and smoking history, exercise, salt intake, milk intake, familial and past history of hypertension, and the cold-exposed group replied to the questions about occupational histories including cold exposure time and duration, exposure frequency, and protective clothing.

2) Blood pressure and laboratory tests

Blood pressure and laboratory tests were checked in each industry whose ambient temperature was about 15–20°C. Blood pressure was measured in two occasional periods, and an average of two measurements was obtained. Laboratory tests included electrocardiogram, blood cholesterol and liver function tests. Blood pressure and laboratory tests of cold-exposed workers were checked before working in cold areas.

3) Body core temperature measurement

Tympanic membrane temperatures accurately reflect body core temperature, since the tympanic membrane shares its blood supply with the temperature control center in the brain, the hypothalamus. We therefore measured the tympanic membrane temperature with an IRT 3020 Barun Thermoscan Thermometer. The tympanic membrane temperature was checked in each industry whose ambient temperature was about 15–20°C. The tympanic membrane temperature of cold-exposed workers was checked before working in cold areas. It was measured twice and the higher measurement was selected.

3. Statistical analysis

Variables were compared with McNemar's test and the paired t-test, and a logistic regression analysis was done to determine the risk factors for hypertension in the cold-exposed group. SAS windows version 6.12 was used for statistical analysis.

Results

1. General characteristics of study subjects

68 men were selected for the cold-exposed group, and 68 men for the control group (Table 1). The cold-exposed group were older than the control group, but not significantly (p>0.05). Alcohol drinking and smoking

were similar in the two groups, and salt and milk intake were also similar. Familial and past histories of hypertension were not significantly higher in the cold exposed group (p>0.05).

2. Work-related characteristics of the cold-exposed group

Cold exposure duration in the cold-exposed group was 5.6 ± 5.6 yr. Daily cold exposure time was 3.1 ± 1.8 h, which implied that the workers were working more than one third of their daily working time in the cold (Table 2). Daily cold exposure frequency was 15.7 ± 13.9 times. Working time in the cold area was enquired about, and was under 10 min, 10–30 min, and over 30 min. Work under 10 min occurred 9.6 ± 13.8 times per day, whereas work over 30 min took place 1.0 ± 1.7 times per day. 41 workers in the cold-exposed group replied that they always used protective clothing, but 2 workers replied that they did not use protective clothing.

3. Clinical findings in study subjects

Body mass index (BMI) was similar for the two groups (Table 3). Systolic and diastolic blood pressure was significantly higher in the cold-exposed group (p<0.05). 19 and 9 workers were hypertensive patients in the cold-exposed and control groups, respectively so that prevalence of hypertension was significantly higher in the cold-exposed group (p<0.05). The body core temperature was significantly lower in the cold-exposed group (p<0.05).

Total cholesterol, triglyceride, HDL, LDL, hemoglobin, AST, ALT and γ-GTP were not significantly different in the two groups (Table 4).

4. Relationship of body core temperature in the cold-exposed group

The cold-exposed group was divided into 3 groups according to body core temperature, below 36.0°C, 36.0–36.6°C, and over 36.6°C, respectively (Table 5). Systolic and diastolic blood pressure was high in workers with a body core temperature below 36.0°C and low in workers with a body core temperature over 36.6°C (Figs. 1, 2). Therefore, systolic and diastolic blood pressure had an

Table 2. Work-related characteristics in the cold-exposed group

(Mean ± SD)

Variables		Cold exposed group (n=68)
Cold exposure duration (yr)		5.6 ± 5.6
Daily cold exposure time (h)		3.1 ± 1.8
Cold exposure frequency per day (times)		15.7 ± 13.9
Cold exposure frequency (times)	–10 min	9.6 ± 13.8
	10–20 min	5.0 ± 7.3
	30– min	1.0 ± 1.7
Protective clothing	Always	41
	Sometimes	25
	Rare	2

Table 3. Clinical findings in study subjects

(Mean ± SD)

Variables		Cold exposed group (n=68)	Control group (n=68)	p-value
Body mass index (kg/m^2)		23.4 ± 3.1	23.5 ± 2.5	0.9519
Systolic blood pressure* (mmHg)		130.0 ±13.3	118.3 ±12.1	0.0001
Diastolic blood pressure* (mmHg)		82.7 ± 8.5	77.4 ± 8.7	0.0002
Hypertension*	Yes	19	9	0.025
	No	49	59	
Body core temperature (°C) *		36.1 ± 0.7	36.4 ± 0.5	0.0032
Heart rate (times/min)		74.1 ± 7.5	73.5 ± 8.3	0.6131
Cardiac hypertrophy in EKG				
	Yes	10	9	0.782
	No	58	59	

* : p-value < 0.05

Table 4. Laboratory findings in study subjects (n=61)

Variables	Cold exposed group (n=68)	Control group (n=68)
Total cholesterol (mg/d*l*)	184.7 ± 34.3	184.0 ± 29.5
Triglyceride (mg/d*l*)	146.0 ± 75.5	161.3 ±116.7
HDL (mg/d*l*)	56.9 ± 19.2	51.0 ± 16.7
LDL (mg/d*l*)	100.2 ± 37.6	100.1 ± 28.8
Hemoglobin (g/d*l*)	14.8 ± 1.0	14.6 ± 1.0
ASL (IU/*l*)	26.5 ± 12.8	23.8 ± 7.7
ALT (IU/*l*)	28.5 ± 19.5	27.2 ± 13.8
γ-GTP (IU/*l*)	40.5 ± 49.2	29.8 ± 19.7

Tables 5. Blood pressure according to body core temperatures in the cold-exposed group (n=68)

(Mean ± SD)

Variables		Body core temperatures (°C)			p-value
		< 36.0	36.0–36.6	≥36.7	
Systolic BP (mmHg)		131.9 ±13.3	130.3 ±13.7	127.5 ±12.9	0.5617
Diastolic BP (mmHg)		84.3 ± 8.5	83.4 ± 8.9	80.1 ± 8.0	0.2484
Hypertension	Yes	9	7	3	0.127
	No	16	16	17	

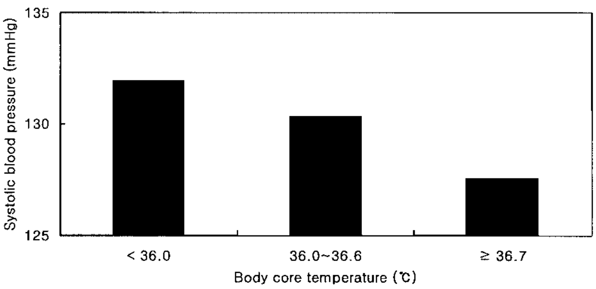

Fig. 1. Relationship between body core temperature and systolic blood pressure in the cold-exposed group

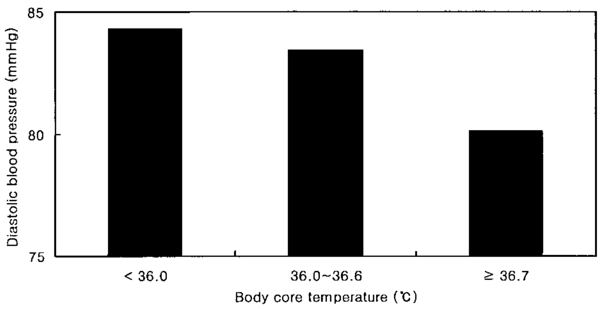

Fig. 2. Relationship between body core temperature and diastolic blood pressure in the cold-exposed group

inverse relationship with body core temperature, but it was not significant (p>0.05). The lower the body core temperature was, the higher the prevalence of hypertensive patients, but that also was not especially significant (p>0.05).

5. Risk factors for hypertension in the cold-exposed group

To determine the risk factors for hypertension in the cold-exposed workers, logistic regression analysis was done. Hypertension was selected as a dependent variable, and independent variables were selected in terms of cold exposure severity, protective clothing, age, smoking, alcohol drinking, exercise, salt intake, milk intake, body mass index and past history of hypertension. Among 68 cold-exposed workers, 7 workers who had a past history of hypertension were excluded from the logistic regression analysis. Workers were classified into 3 grades according to cold-exposure duration and daily cold exposure time. Workers whose cold exposure duration was below 2 yr and whose daily cold exposure time was below 2 h were given a grade 1 classification. Workers whose cold exposure duration was over 5 yr or whose daily cold exposure time was over 5 h were given a grade 3 classification. Workers not classified in grades 1 or 3 were given a grade 2 classification.

In univariate logistic regression analysis, age, cold exposure severity and milk intake were significant variables, whose odds ratios were 4.078 (95% CI 1.315–

Table 6. Result of univariate logistic regression analysis (n=61)

Variables	Odds ratio (95% CI)	p-value
Age (≥ 40 yr) *	4.078 (1.315–12.653)	0.0150
Cold exposure severity*	2.713 (1.201– 6.127)	0.0164
Protective clothing	0.645 (0.221– 1.884)	0.4228
Alcohol drinking (1–2 times/wk)	1.818 (0.519– 6.373)	0.3502
Smoking	0.606 (0.130– 2.831)	0.5243
Exercise (1–2 times/wk)	2.100 (0.653– 6.749)	0.2129
Salt intake	0.956 (0.305– 2.996)	0.9383
Milk intake*	0.438 (0.199– 0.965)	0.0406
BMI (24 kg/m^2)	1.786 (0.602– 5.298)	0.2960
Family history of hypertension	1.393 (0.405– 4.789)	0.5990

* : p-value < 0.05

Table 7. Result of multivariate logistic regression analysis (n=61)

Variables	Odds ratio (95% CI)	p-value
Age (≥ 40 yr) *	5.204 (1.440–18.812)	0.0119
Cold exposure severity*	2.674 (1.080– 6.618)	0.0335
Exercise (1–2 times/wk)	1.411 (0.606– 3.288)	0.4250
Milk intake*	0.364 (0.141– 0.942)	0.0372

* : p-value < 0.05

12.653), 2.713 (95% CI 1.201–6.127) and 0.438 (95% CI 0.199–0.965), respectively (Table 6).

Variables whose p-value was below 0.25 in univariate logistic regression analysis were selected for multivariate analysis. In multivariate logistic regression analysis, age, cold exposure severity and milk intake were significant variables, whose odds ratios were 5.204 (95% CI 1.440–18.812), 2.674 (95% CI 1.080–6.618) and 0.364 (95% CI 0.141–0.942), respectively (Table 7).

Discussion

This study was performed to investigate the relationship between cold exposure and hypertension, and to determine the risk factors affecting hypertension in cold exposure workers.

Many studies about hypertension have been performed[8–16] in laboratory animals, but studies about hypertension in cold-exposed workers are very rare.

Sun *et al.*[17] reported that the development of cold-induced hypertension was associated with blood volume expansion, and the high blood pressure was maintained by increased peripheral vascular resistance without blood volume expansion. Van Bergen *et al.*[13] reported that there was a sigmoid-type relationship between the hours per day a worker was exposed to cold and systolic blood pressure and the graded increase in systolic blood pressure that occurred with increasing daily duration exposure to cold.

The questionnaire included cold exposure time per day, working time in cold areas, frequency of work in cold areas, duration of cold-exposed work, and protective clothing. Cold exposure time per day, frequency of work in cold areas, and working time in cold areas varied according to the day or season.

All 68 workers answered that protective gloves, clothes, and boots were prepared. Among them, 27 workers answered that they sometimes used or did not use them, which implied that education about the importance of protective clothing is required.

Systolic and diastolic blood pressure was significantly higher in the cold-exposed group, and prevalence of hypertension was also higher in the cold- exposed group. These results were same as those of Park's study[18].

Shechtman *et al.*[19] suggested that 3 to 4 wk exposure of rats to a cold environment induced hypertension and caused ventricular hypertrophy, but in this study, the prevalence of left ventricular hypertrophy shown on the electrocardiogram for the 2 groups was no different.

A 32.2 to 35°C body temperature results in neurologic deficits, including loss of motor control, decreased response to stimuli and speech disturbance, A body temperature of 30°C results in dysfunction of temperature regulation, pulse rate and blood pressure. A 28°C body temperature causes arrhythmia, 27°C results in a coma, and 25 to 23°C induces death[20]. In this study, body core temperature was lower in cold-exposed workers, but body temperature for all workers was higher than 35°C, which could induce clinical signs. So differences in body core temperature for both groups was thought not to be clinically significant.

To determine the relationship between body core temperature and blood pressure, a chi-square analysis was done. There was an indirect relationship between body core temperature and blood pressure, but it was not significant. Further study related to this relationship may be required.

In logistic regression analysis, cold-exposure severity was a significant variable affecting hypertension in cold-exposed workers, which was similar to the results of van Bergen *et al.*[13].

Kristal-Boneh *et al.*[3] suggested that smokers had a greater seasonal variation in blood pressure and heart rate and showed a larger increase in the cardiovascular load in winter than nonsmokers. But in this study, smoking was not a significant variable affecting hypertension in logistic regression analysis.

It was reported that foods containing calcium had a preventive effect on hypertension[21–24]. In this study, milk intake was a significant variable affecting hypertension in logistic regression analysis because milk has high calcium content.

Regular exercise, salt intake and body mass index, which are known to have an effect on hypertension[25–27], were not significant variables in logistic regression analysis. It is not reasonable that those variables would not be related to hypertension in cold-exposed workers, because the subjects in this study were insignificant in terms of numbers.

According to the results of this study, cold exposure was thought to be a risk factor for hypertension, and the body core temperature was lower in cold-exposed workers. Age, cold exposure time and duration, and calcium containing foods might affect hypertension in cold-exposed workers. To determine the relationship between body core temperature, blood pressure and risk factors affecting hypertension in cold-exposed workers, further studies with a sufficient number of subjects would be required.

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