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Job Demand and Cardiovascular Disease Risk Factor in White-collar Workers

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Abstract: This study was conducted to determine whether job demand played a role as a risk factor of cardiovascular diseases by comparing changes of blood pressure, heart rate and rate pressure product (RPP) showing myocardial oxygen consumption (MVO_2) according to levels of job demand. This cross-sectional study divided 177 male white-collar workers without a cardiovascular or metabolic disease according to their job demand and analyzed their body composition and results of graded exercise testing. There was no significant difference in height, body weight, body mass index (BMI), waist to hip ratio (WHR) and body fat percentage according to job demand. Maximal oxygen consumption (VO_2max) and anaerobic threshold (AT) also did not show a significant difference. However, systolic blood pressures at the seventh and eighth stages over AT during exercise were significantly different and RPP was found to have a significant difference overall according to the job demand ($p<0.05$). These results meant that job demand affected systolic pressure in physical activities or at exercise intensity over AT and reduced energy efficiency of myocardium during physical activities. The results suggest that high job demand may be a risk factor of cardiovascular diseases.

Key words: Job demand, Graded exercise testing, Myocardial oxygen consumption, Rate pressure product, Blood pressure, Heart rate

Introduction

Among factors affecting cardiovascular diseases, especially stress is a key one inducing or deteriorating the diseases and it can be divided into acute and chronic stress. Acute stress related cardiovascular disease that triggers myocardial ischemia, promotes arrhythmogenesis, stimulates platelet function, and increases blood viscosity through hemoconcentration[1]. Chronic stress promotes arteriosclerosis by inducing excessive sympathetic activation and damage of cells on intima, decreases heart rate variability (HRV) chronically[2, 3] and increases prevalences of arteriosclerosis, ischemic heart diseases, sudden cardiac death, myocardial infarction and arrhythmia[4, 5]. Moreover, it grows insulin resistance and prevalences of cardiovascular diseases by triggering unhealthy lifestyles[6].

Investigation on health condition of workers performed every five years by the ministry of health, labour and welfare in Japan[7] reported that the ratio of workers answering that they had ‘strong anxiety, worry and stress’ associated with their job, tended to increase from 50.6% in 1982 to 57.3% in 1992 and 61.5% in 2002. Job stress can be defined as the harmful physical and emotional responses that occur when the requirement of the job do not match the capabilities, resources, or needs of the worker[8]. Work stress is mediated through indirect effects on health behaviors and direct effects on neuroendocrine stress pathways[9]. According to Kivimaki *et al.*[10] their prospective cohort study with 812 workers from 1973 to

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2001 found that high job strain (high job demand and low job control) showed 2.2 times higher cardiovascular mortality risk compared with their colleagues with low job strain. Also, high job strain was associated with increased serum total cholesterol at the 5 yr follow up. Effort-reward imbalance predicted increased body mass index at the 10 yr follow up. In particular, for hypertension, one of major risk factors of cardiovascular diseases[11], a follow-up study for 7.5 yr revealed that male workers with job stress had high systolic blood pressure[12] and most cross-sectional studies measuring ambulatory BP showed that there was a significant correlation between blood pressure and job stress[13–18]. Many researches investigating ambulatory BP measured blood pressure at working or conducting daily activities. However, this study examined whether job demand works as a risk factor of cardiovascular diseases by gauging blood pressure, heart rate and rate pressure product (RPP) meaning myocardial oxygen consumption (MVO_2) at each stage of exercise with making all subjects conduct a same exercise gradually increased. So, this study was conducted to determine whether job demand played a role as a risk factor of cardiovascular diseases by comparing changes of blood pressure, heart rate and RPP showing MVO_2 according to levels of job demand.

Methods

Subjects

Subjects of this study were 177 male white-collar workers, who underwent general health check-ups at national fitness center in Seoul between July and December 2007. We investigated history of heart disease, hypertension, metabolic disease, medication and exercise habit and smoking habit before measurement. Regular exercise group was regarded as over the 3 d per week more than 3 months. Smoking was categorized as either a current smoker or not a current smoker. Resting EKG and blood pressure was measured before the graded exercise testing. They did not have cardiovascular or metabolic diseases and their blood pressures at rest were less than 140/90 mm Hg at the measuring day. Also, they were never permitted about smoking and alcohol intake before the testing day.

Methods

Subjects participating in the graded exercise testing after health examination and physical fitness test were explained the purpose and procedures of this study and they were divided according to references of Korean occupational stress scale by investigating job demand with a short-form questionnaire, the scale of 7 categories including 24 questions which reliability and validity were verified through a standardized study[19]. Investigational Review Board approval for the study was obtained from the Catholic University of Korea, Songeui Campus (CUSC IRB No.07-20). Written informed consent was obtained from the subject. The graded exercise testing used a modified Balke protocol increasing gradient by 2.5% every one minute at 85 m/min. Aerobic capacity was measured by Jaeger (Oxycon delta, Germany) and exercise induced BP and HR was measured by Q-stress (Quinton, USA) and Tango (Suntech, USA). In each stage of the test, blood pressure and heart rate of subjects were measured and RPP was calculated by multiplying systolic blood pressure by heart rate. As respiratory gas was collected continuously during exercise, maximal oxygen consumption (VO_2max) and anaerobic threshold (AT) were set. The laboratory temperature and humidity were below 22°C and 60%. Waist circumference was measured to the nearest 0.5 cm above the iliac crests and below the lowest rib margin at minimal respiration in a standing position. Body weight, height and body fat % were measured in light clothing without shoes using Inbody 4.o (Biospace, Korea). Body mass index (BMI) was calculated by weight (kg)/height (m^2).

Statistical analysis

Means and standard deviations of all measured data were calculated and subjects were divided based on reference suggested by Chang *et al.*[19] into the high and low groups according to job demand levels. For age, height, body weight and cardiovascular endurance, independent-T test was conducted. In addition, analysis of variance for repeated measure was performed for blood pressure, heart rate and RPP during exercise according to job demand with setting age, exercise habit, smoking habit and BMI as covariates. Exercise stages were at rest and 1 to 8 stages submaximal intensity and 10 stages as the maximal intensity and *t*-test was performed according to the stages. A statistically significant level was considered to be 0.05 for data analysis.

Results

Ranges and means of ages, height, body weight, BMI, WHR and body fat percentage of all subjects were shown in Table 1. Differences in observed variables according to job demand were presented in Table 2. Age, height, body weight, BMI, body fat percentage, WHR and physical composition did not have a significant difference according to job demand and VO_2max and AT meaning cardiovascular endurance were also not different between the two groups. Table 3 presented results of analysis on heart rates at each stage according to job demand. Although heart rates at rest, during exercise and at maximal exercise were significantly different with growing stages (p<0.01), there was no significant difference between the groups according to job demand. Table 4 showed results of analysis on systolic blood pressures at each stage according to job demand. The systolic blood pressures at rest, during exercise and at maximal exercise were significantly different according to increasing stages (p<0.01) but the difference between the groups according to job demand was not statistically significant. An average difference of systolic blood pressure between the groups at each stage was significant at stage 7 and 8 (p<0.05). Results of analysis on diastolic pressure of each exercise stage according to job demand were presented in Table 5. Diastolic blood pressure at rest, during exercise and at maximal exercise had a significant difference with growing stages only in the low job demand group (p<0.01) and the difference between the groups according to job demand was not statistically significant. Results of analysis of RPP at each exercise stage according to job demand were presented in Table 6. RPPs at rest, during exercise and at maximal exercise were sig-

Table 1. Physical characteristics of the subjects

	Unit	Mean	Minimum	Maximum	SD
Age	yr	43.2	25	61	7.9
Height	cm	171.4	157.8	186.0	5.8
Weight	kg	69.9	53.3	92.6	8.3
BMI	kg/m^2	23.8	17.6	31.2	2.4
%Body fat	%	21.9	10.9	32.5	4.3
WHR	W/H	0.90	0.75	1.04	0.05

Table 2. Differences of physical characteristics according to job demand

	Low job demand (n=72)		High job demand (n=105)		p-value*
	Mean	SD	Mean	SD	
Age	44.3	7.6	42.5	8.1	0.125
Height (cm)	170.8	6.1	171.7	5.5	0.296
Weight (kg)	68.4	6.6	70.8	9.1	0.057
BMI (kg/m^2)	23.5	1.9	24.0	2.7	0.158
%Body fat (%)	21.5	4.0	22.2	4.5	0.300
WHR	0.90	0.04	0.90	0.05	0.680
VO_2max (ml/kg/min)	41.7	6.8	41.3	5.2	0.682
AT (ml/kg/min)	28.9	5.6	28.5	4.4	0.629

*: t-test.

Table 3. Repeated measure of exercise heart rate

	Exercise stage										Time^	Covariate				Group^
	R	1	2	3	4	5	6	7	8	Peak		Ex	Sm	BMI	Age	
LJD	63.0	89.1	93.8	98.5	105.6	113.9	123.1	133.0	141.8	170.3	<0.001	0.006	0.017	0.381	0.161	0.194
HJD	63.7	91.0	95.4	100.8	107.5	115.6	124.8	134.5	145.2	173.8	<0.001					

LJD: low job demand, HJD: high job demand, R: resting HR, Peak: Peak HR during exercise, Ex: exercise, Sm: smoking, ^: ANOVA test for repeated measures.

Table 4. Repeated measure of systolic blood pressure

	Exercise stage										Time^	Covariate				Group^
	R	1	2	3	4	5	6	7*	8*	Peak		Ex	Sm	BMI	Age	
LJD	122.9	135.3	135.0	136.3	141.6	149.0	157.3	164.3	171.5	185.7	<0.001	0.628	0.758	0.000	0.846	0.175
HJD	123.9	137.0	138.1	140.7	146.7	153.0	162.8	170.5	178.8	192.1	0.001					

LJD: low job demand, HJD: high job demand, R: resting SBP, Peak: Peak SBP during exercise, Ex: exercise, Sm: smoking, *: p<0.05 t-test, ^: ANOVA test for repeated measures.

Table 5. Repeated measure of diastolic blood pressure

	Exercise stage										Time^	Covariate				Group^
	R	1	2	3	4	5	6*	7	8	Peak		Ex	Sm	BMI	Age	
LJD	83.0	78.5	78.5	76.8	75.8	76.0	75.6	76.8	77.8	83.3	0.003	0.970	0.105	0.001	0.012	0.375
HJD	83.1	80.0	78.6	78.4	78.0	78.2	79.5	80.6	79.7	84.5	0.178					

LJD: low job demand, HJD: high job demand, R: resting DBP, Peak: Peak DBP during exercise, Ex: exercise, Sm: smoking, *: $p<0.05$ *t*-test, ^: ANOVA test for repeated measures.

Table 6. Repeated measure of rate pressure product

	Exercise stage										Time^	Covariate				Group^
	R	1	2	3*	4*	5	6	7*	8*	Peak*		Ex	Sm	BMI	Age	
LJD	7,724	12,084	12,670	13,444	14,931	16,950	19,350	21,832	24,308	30,168	<0.001	0.233	0.294	0.000	0.568	0.044
HJD	7,908	12,537	13,250	14,266	15,872	17,778	20,432	23,044	26,040	32,097	<0.001					

LJD: low job demand, HJD: high job demand, R: resting RPP, Peak: Peak RPP during exercise, Ex: exercise, Sm: smoking, *: $p<0.05$ *t*-test, ^: ANOVA test for repeated measures.

nificantly different with increasing stages ($p<0.01$) and their difference was also significant between the two groups ($p<0.05$). Although average difference of the two groups at each stage was not significant at rest and stage 1 and 2, it became significant at stage 3 and 4, 7 and 8 and peak exercise through the procedure of the exercise ($p<0.05$).

Discussion

Cardiovascular diseases have high morbidity and mortality and have been treated as major health problems in researches on stress and diseases. Mental stress may be an important precipitant of myocardial ischemia[20, 21]. Especially, workers with high tension were reported to have more risk of the diseases and health behavior such as drinking, smoking, eating behavior in many studies[22–26].

Subjects of this study were male white-collar workers. According to Korean job stress factors for Koreans based on standardized job classification of a study on development and standardization of Korean occupational stress scale[27], specialists and white-collar workers were found to have more job demand (57.1 ± 12.8) compared to other job groups (50.3 ± 13.0). Job demand of subjects of this study (61.8 ± 13.4) was also observed to be higher than the reference of representative workers' group, and the result was considered to be attributed to job characteristics. Age, height and body weight were not different according to levels of job demand. Generally, obesity is induced by positive energy balance and chronic stress can work as a contributing factor of obesity. In a prospective cohort study conducted for 19 yr by Brunner *et al.*[28], job strain, BMI and waist to hip ratio (WHR) showed dose-response relation and 95% confidence intervals of BMI and WHR according to stress levels were 1.17–1.73 and 1.17–1.61 respectively, considering age, gender and social position as covariates. However, this cross-sectional study did not find any significant difference in body composition of BMI, WHR and body fat percentage according to levels of job demand between the two groups at the investigating time. In addition, as general characteristics of age, height and body weight and VO_2max and AT meaning cardiovascular endurance also did not have a significant difference between the groups, two groups could be thought to have same physical characteristics.

Heart rate during exercise plays a role of moving oxygen to active muscles. A growing heart rate during exercise increases stroke output and cardiac output but generally persons exercising continuously showed a relatively lower heart rate at the same submaximal exercise intensity[29]. In addition, the increase of heart rate during exercise is related to interaction of autonomic nervous system activating sympathetic nerves and inhibiting parasympathetic nerves[30], Balogun and Ladipo[31] reported that maximal heart rates of persons with hypertension were significantly lower than those of ones with normal blood pressure and Franz[32] revealed that at the same exercise intensity heart rates of persons with hypertension were higher than those of ones with normal pressure. According to the study of Riese *et al.*[17], social support did not affect heart rate and heart rate variability during walking and there was no difference in physiological recovery after work and leisure. Steptoe *et al.*[33] also found that levels of job stress did not affect working days. Although this study was not same with these previous researches in ways of laying a physiological burden, it also revealed that responses of heart rates were not different according to burdens on a body following different levels of job stress.

For blood pressure, systolic pressure increases with growing exercise intensity and diastolic pressure does not change largely. Like these responses of blood pressure during general exercises, those in this study also went up with higher exercise intensity. In addition, previous studies[16, 17] comparing blood pressure during work, activities and ambulatory according to job stress found that there was a significant difference although types of stress was changed according to day or night. In particular, the study conducted by Light *et al*.[34] showed a difference even in diastolic blood pressure between job strain and ambulatory work blood pressure but did not reveal any difference among groups with increasing exercise stage or exercise intensity. However, for the systolic blood pressure, the difference among the groups was larger in high exercise intensity compared to in low exercise intensity so that the difference according to job demand became significant at exercise stage 7 and 8. Because exercise stage 7 and 8 were corresponded to the stages needed over AT (28.7 mg/kg/min) of all groups, physical fatigue was accumulated physiologically and increase of blood pressure became larger at the point of starting anaerobic metabolism. That meant that high job demand was related with poor adjustment of blood pressure to a physiological effort. That was considered to be a factor making persons with high job stress have high systolic blood pressure[12] for a long term.

As cardiac muscles have 3–4 times more oxygen availability compared to skeletal muscles and blood flows of coronary arteries increase during exercise, more oxygen needed for cardiac muscles can be provided[35]. When activities of heart increase due to exercise, blood flows of coronary arteries, volume and size of cardiac ventricles, contraction time, heart rate and blood pressure affect the metabolic demand laid on a heart and MVO_2 goes up. Methods measuring these are divided into direct and indirect ones, and among them RPP calculated by multiplying heart rate by systolic blood pressure is known to be a realistic index showing MVO_2[36]. In addition, as ST segment depression (≥1 mm) significantly related with exercise-induced chest pain observed in patients with ischemic heart diseases, occurs at a same RPP[29], a larger level means lower energy efficiency of myocardium. Moreover, a study on hearts of subjects with obesity[37] found that higher cardiac output demanded more oxygen from a heart and increased pressure of left ventricle and heart rate so that it provoked structural and functional changes of a heart to induce hypertension and heart diseases.

Therefore, as shown in this study, the difference of RPP or MVO_2 according to levels of job demand suggested that the high job demand group had lower energy efficiency of myocardium compared to the low job demand group and the lower efficiency made their heart work more at the same exercise intensity than in the low job demand group.

In conclusion, these results meant that job demand affected systolic pressure in physical activities or at exercise intensity over AT and reduced energy efficiency of myocardium during physical activities. The results suggest that high job demand may be a risk factor of cardiovascular diseases. Furthermore, longitudinal study is necessary to confirm which a long-term exposure to high job demand could be a factor resulting in structural and functional changes of a heart.

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