

## Association between Job Stress on Heart Rate Variability and Metabolic Syndrome in Shipyard Male Workers

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A growing body of literature has documented that job stress is associated with the development of cardiovascular disease. Nevertheless, the pathophysiological mechanism of this association remains unclear. The purpose of this study is to elucidate the relationship between job stress, heart rate variability, and metabolic syndrome. The study design was cross-sectional, and a total of 169 industrial workers were recruited. A structured-questionnaire was used to assess the general characteristics and job characteristics (work demand, decision latitude). Heart rate variability (HRV) was recorded using SA-2000 (medi-core), and was assessed by time-domain and by frequency-domain analyses. Time domain analysis was performed using SDNN (Standard Deviation of normal to normal interval), and spectral analysis using low-frequency (LF), high-frequency (HF), and total frequency power. Metabolic syndrome was defined on the basis of risk factors being clustered when three or more of the following cardiovascular risk factors were included in the fifth quintile: glucose, systolic blood pressure, high-density lipoprotein cholesterol (bottom quintile), triglyceride, and waist-hip ratio. The results showed that job characteristics were not associated with cardiovascular risk factors. Compared to the lower strain group (low strain+passive+active group), the high strain group had a less favorable cardiovascular risk profile with higher levels of blood pressure, glucose, homocysteine, and clotting factor, but the difference was not statistically significant. The SDNN of HRV was

significantly lower in the high strain group than in the low strain group. The prevalence of metabolic syndrome in the lower strain group and high strain group was 13.2% and 23.8%, respectively. In the high strain group, the metabolic syndrome was significantly related to a decreased SDNN. However, we could not find a significant association in LF/HF ratio. This result suggests that decreased HRV found in the high-strain group are not a direct indicator of disease. However, it can induce cardiovascular abnormalities or dysfunctions related to the onset of heart disease among high risk groups.

**Key Words:** Stress, heart rate variability, metabolic syndrome

### INTRODUCTION

Faced with diversified society, workers are experiencing changes in almost every aspect of their lives. The changes in their life style and interpersonal aspects of human relations have a significant impact on their state of health. The industrial environment, in particular, poses a threat to the health of workers as it sometimes involves toxic organic solvents, chemicals, heavy metal, noise, and dust, not to mention other working conditions such as shift work and over workload.<sup>1,2</sup> The job stress caused by changes in the working environment, including a negative impact of automation on workers, plays a great role in increasing the incidence of job-related accidents, job dissatisfaction, and absenteeism, and can eventually grow into risk factors for illnesses, including cardiovascular and musculoskeletal diseases, cancer, and mental distress.<sup>3</sup>

Cardiovascular disease is particularly associated

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with high prevalence and high mortality, spurring medical research on the effects of stress, which is known for its triggering function in eliciting cardiovascular diseases or arteriosclerosis.<sup>4,6</sup> It is well known that job stress is one of the leading causes of cardiovascular disease<sup>7</sup> and that high strain groups were found to be at a greater risk for cardiovascular diseases in several studies.<sup>8,9</sup> Yet, the pathophysiological mechanism of the association between occupational stress and cardiovascular disease is still elusive.

In order to prevent stress-induced cardiovascular disease, the analysis of risk factors for disease and the role of stress is essential. In fact, many investigators have assessed the relationship between stress and the onset of cardiovascular risk factors such as high blood pressure, hyperlipidemia, and smoking.<sup>10-12</sup> There was a significant relationship between stress and coagulation factors (Factor VII, Factor VIII).<sup>13,14</sup> In addition, other parameters, such as plasma fibrinogen concentrations and tissue plasminogen activator(t-PA), were assessed in relation to cardiovascular diseases to ensure the significant effects of stress.<sup>9,15</sup> Plasma homocysteine was identified as an independent risk factor for cardiovascular diseases because it accelerates coagulation or platelet aggregation in the injured blood vessel, hinders the action of anti-clotting agents, and eventually speed up arteriosclerosis and thrombus formation.<sup>16-18</sup>

These cardiovascular risk factors that were identified in recent studies are closely linked to stress-induced overactivity of the sympathetic nervous system. That is, an environmental stressor evokes a cerebral process in the frontal lobes that determines whether activity occurs in the frontocortical-brainstem pathway. The activity in this pathway results in dual autonomic outflow and inhibits homeostatic reflexes. The projected autonomic activity, either alone or in combination with myocardial infarction, triggers the initiation of ventricular fibrillation.<sup>19,20</sup> The heart rate variability (HRV) is used as an indicator to measure cardiovascular regulation. HRV is a measurement of the interaction in the automatic nerve systems and reflects all physiological factors that modulate the normal rhythm of the heart. Generally, those with high levels of stress have seen their HRV reduce as a result of sympathetic overactivity.

Thus, the HRV is deemed as a predictor of heart disease that is as effective as other risk factors. Also, low HRV is associated with cardiac arrhythmia, cardiac mortality, and all cause mortality after myocardial infarction.<sup>21</sup>

Nevertheless, a strong link was found between job stress and metabolic syndrome, which is identified by the presence of three or more of components among blood pressure, fasting glucose, blood triglycerides, high-density lipoprotein (HDL) cholesterol, and waist-hip ratio in the upper 5th quintile of the distribution (the lower 5th quintile for cholesterol).<sup>22</sup> Belkic<sup>23</sup> suggested that work stress increases blood pressure, glucose and triglyceride levels, and their catecholamine levels remain high, which means that sympathetic overactivity triggers an increase in heart rates, accelerates peripheral resistance, increases mucosity, and affects the production of the metabolic hormone. The increased incidences of cardiovascular disorders among workers who have maintained normal blood pressure without symptoms for a specific illness suggest that the approach to identifying potential risks like those components used as criteria for metabolic syndrome would contribute to the development of another mechanism of stress-induced cardiovascular disease.

Therefore, the investigation into whether the metabolic syndrome is correlated with HRV is important in understanding the mechanism of stress-induced cardiovascular disease. We attempted to elucidate the relationship between job stress, heart rate variability, and metabolic syndrome.

## MATERIALS AND METHODS

### Study subjects

Subjects consisted of 169 male workers aged over 40 and employed in a shipbuilding industry located in Gyeongsangnam-do, a southeast province of Korea. In order to collect the general characteristics and job characteristics of the subjects, a questionnaire was performed during the period from August 1 to October 30, 2003 when their health examinations were being performed.

## Procedures

Subjects were instructed to not consume any alcohol the night before the measurement of HRV and to not smoke for half an hour prior to the measurement. HRV was recorded using the SA-2000E model (manufactured by Medi-core, 2002). Each subject was comfortably seated on a chair, and electrodes were placed on their wrists and left foot to derive HRV for five minutes. Their blood samples were collected in a lab as a last step of the survey process.

## Measures

### *Job stress (Job strain)*

The two dimensions of job characteristics, work demand (5 items) and decision latitude (9 items), were used by Job Content Questionnaire (JCQ).<sup>8</sup> For each question, the respondents rated the degree to which they agreed or disagreed with statements describing their job or job environment. A high score represented a high level of perceived work demand or high level of perceived decision latitude over the job.

### *Heart rate variability*

The changes in HRV were analyzed in both the time domain and frequency domain

#### Time domain analysis

- ① SDNN; Standard deviation of normal to normal(NN) interval
- ② RMSSD; the square root of the mean squared differences of successive NN interval

#### Frequency domain analysis

The HRV spectrum contains three major components-high frequency (HF), low frequency (LH), and very low frequency (VLF). The total power in the HRV frequency spectrum was assessed to analyze the overall HRV change. Normalized LF, normalized HF, and LF/HF ratio were calculated as indexes of cardiac parasympathetic nervous activity.

### *Cardiovascular risk factors*

Several variables (body mass index, waist-hip ratio, hypertension, hyperlipidemia, homocystinu-

ria, glucose, and blood coagulation factors VII, VIII) were included as cardiovascular risk factors.

Blood pressure was taken as the average of two measurements after 5 minutes of rest in a sitting position using a standard mercury manometer. For blood analysis, respondents were subjected to fasting for at least 10 hours. Blood (3 ml) was sampled from the venae brachiales of subjects and was transferred to two different tubes with or without anticoagulants such as sodium citrate/EDTA. After centrifugation at 3500 rpm for 15 min, coagulation factors (factor VII and factor VIII) and total homocystein were measured in the plasma, whereas total cholesterol, HDL cholesterol, and triglyceride were measured in the serum. Factor VII and factor VIII were analyzed using a one-stage assay based on prothrombin time. Briefly, the factor VII or VIII-deficient plasma was mixed with serially diluted normal plasma and was incubated for 2 min at room temperature. Then, coagulation time was measured when thromboplastin and CaCl<sub>2</sub> were added to the mixture. The levels of the coagulation factors in the plasma were calculated from concentration-coagulation time standard curves.

### *Metabolic syndrome*

The investigations had a tendency to deal with the cardiovascular risk factors independently. Recent studies have claimed that risk factors collectively have an impact on cardiovascular disorders as defined as metabolic syndrome-associated cardiovascular diseases. This study focused on assessing the metabolic syndrome as a mix of metabolic risk factors rather than looking into the individual components. The metabolic syndrome was defined on the basis of clustering risk factors, when three or more of the following cardiovascular risk factors were included in the fifth quintile: glucose, systolic blood pressure, HDL-cholesterol (bottom quintile), triglyceride, and waist-hip ratio.<sup>22</sup>

## Statistical analysis

Subjects were dichotomized into the high-strain group (high work demand and low decision latitude) and the lower strain group which combined the three groups-low strain group, passive group,

and active group - with the median of work demands and decision latitude. We estimated the relationship between job strain and HRV using t-test. The measurements of HRV had a distribution skewed to the right, so the data were log transformed. The odds ratio and 95% confidence intervals were calculated for the metabolic syndrome by job strain. Changes in HRV were assessed after categorizing job strain according to the presence and absence of potential risk factors such as metabolic syndromes.

## RESULTS

Study subjects consisted of male workers aged over 40 with a mean age of 46.7. 127 (67.2%) subjects were working on production lines, and among them, 24 were supervisors. 41 (21.7%) subjects was office workers.

The results showed that the group with a high level of work demands accounted for 57.1% of all subjects, and the group with low decision latitude made up 50.9%. All subjects were divided into two groups according to the postulation of the strain model: 121(72.5%) in a lower-strain group (low strain + passive + active group) and 46 (27.5%) in a high-strain group (Table 1).

There was a strong correlation between time domain HRV parameters of SDNN and RMSSD. There was also a significant correlation between total power and SDNN. HRV was also analyzed within a 5 minute period, and the LF/HF ratio, LF, and HF were measured in normalized units. There was a negative correlation between normalized LF, the LF/HF ratio, and SDNN (Table 2).

The high-strain group showed higher levels of glucose, homocysteine, coagulation factors, and blood pressure, but the differences were not statistically significant. A significantly lower SDNN value was found in the high-strain group. The frequency domain HRV indexes were also low in the same group, but the differences were not significant. The LF/HF ratio, a measurement of sympathetic activity, rose in the high-strain group but were not statistically significant (Table 3).

19.4% of the group with a high level of work demands had metabolic syndrome, compared with 11.8% of the group with a low level of work

**Table 1.** General Characteristics and Job Characteristics of Study Subjects

Variables	N	%
Age (year)		
41-44	45	26.9
45-49	84	50.3
50-54	32	19.2
≥55	6	3.6
Occupation		
Field worker	127	67.2
Office worker	41	21.7
Job demand		
Low	72	42.9
High	96	57.1
Decision latitude		
Low	85	50.9
High	82	49.1
Social support		
Low	70	41.9
High	97	58.1
Job strain		
Lower strain group*	121	72.5
High strain group	46	27.5

\*Lower strain group; low strain+passive group+active group.

demands. On the other hand, the difference was not significant (OR; 1.77, 95% CI; 0.72 - 4.38). The group with low decision latitude (19.2%) and high decision latitude (12.8%) showed insignificant differences in metabolic syndrome (OR; 0.62, 95% CI; 0.26 - 1.48). The metabolic syndrome was present in 23.8% of the high-strain group, which was the highest when compared with the lower-strain group (13.2%), but the difference was not significant (OR; 2.06, 95% CI; 0.84 - 5.04). (Table 4)

The HRV was assessed by categorizing job strain according to the presence and absence of metabolic syndrome. The SDNN value was observed to decrease significantly in the high-strain group with metabolic syndrome, compared with the low-strain group without metabolic syndrome.

**Table 2.** Correlation Coefficients Among the Time and Frequency Domain of Heart Rate Variability

	SDNN*	RMSSD	TP	VLF	LF	HF	LFNorm	HFNorm	LF/HF	log (Tp)	log (Vlf)	log (Lf)
RMSSD <sup>†</sup>	0.74*											
TP <sup>‡</sup>	0.85*	0.60*										
VLF <sup>§</sup>	0.70*	0.34*	0.89*									
LF <sup>  </sup>	0.67*	0.47*	0.78*	0.48*								
HF <sup>¶</sup>	0.71*	0.86*	0.67*	0.35*	0.54*							
LFNorm**	-0.13	-0.50*	0.01	0.04	0.29*	-0.45*						
HFNorm <sup>††</sup>	0.13	0.50*	-0.01	-0.04	-0.29*	0.45*	-1.00*					
LF/HF <sup>§§</sup>	-0.12	-0.38*	-0.01	-0.03	0.30*	-0.31*	0.76*	-0.76*				
log (Tp) <sup>   </sup>	0.87*	0.58*	0.90*	0.81*	0.71*	0.54*	0.07	-0.07	0.06			
log (Vlf)	0.74*	0.38*	0.81*	0.89*	0.48*	0.33*	0.08	-0.08	-0.01	0.90*		
log (lf)	0.64*	0.44*	0.66*	0.41*	0.87*	0.42*	0.42*	-0.42*	0.36*	0.76*	0.49*	
log (Hf)	0.70	0.87*	0.59*	0.34*	0.47*	0.79*	-0.58*	0.58*	-0.51*	0.61*	0.37*	0.48*

\*SDNN, standard deviation of all NN interval; <sup>†</sup>RMSSD, the square roote of the mean of the sum of squares of differences between adjacent, NN intervals; <sup>‡</sup>TP, total power; <sup>§</sup>VLF, very low frequency; <sup>||</sup>LF, low frequency; <sup>¶</sup>HF, high frequency; \*\*LF Norm, normalized low frequency (LF/LF+HF); <sup>††</sup>HF Norm, normalized high frequency (HF/LF+HF); <sup>§§</sup>LF/HF, index of cardiac sympathetic activity; <sup>|||</sup>log, log transformation.

**Table 3.** Mean Values of Cardiovascular Risk Factors by Job Strain Mean (S.D.)

Variables	Job strain		p-value
	Lower strain group* (N=121)	High strain (N=46)	
Age	46.5 (3.8)	47.2 (4.0)	0.32
Body mass index	23.6 (2.6)	23.7 (2.8)	0.76
Glucose	96.1 (24.7)	99.1 (24.4)	0.49
Hemoglobin	14.8 (0.8)	14.7 (0.9)	0.63
Total cholesterol	186.2 (36.4)	186.7 (33.8)	0.92
HDL cholesterol	49.7 (10.4)	48.0 (10.3)	0.35
LDL cholesterol	112.7 (32.3)	115.7 (32.3)	0.59
Triglyceride	117.7 (72.0)	114.6 (55.8)	0.80
Homocystein	10.8 (5.0)	11.2 (5.5)	0.69
Coagulation factor VII	110.7 (21.8)	110.4 (12.7)	0.93
Coagulation factor VIII	76.0 (25.5)	78.8 (40.1)	0.60
Systolic blood pressure	119.5 (12.7)	123.1 (16.5)	0.15
Diastolic blood pressure	78.9 (8.9)	81.9 (9.3)	0.06
SDNN <sup>†</sup>	38.4 (11.3)	34.6 (9.5)	0.06
log (Tp <sup>‡</sup> )	6.9 (0.6)	6.7 (0.5)	0.12
log (Vlf <sup>§</sup> )	6.3 (0.7)	6.1 (0.7)	0.07
log (Lf <sup>  </sup> )	5.6 (0.8)	5.5 (0.7)	0.72
log (Hf <sup>¶</sup> )	4.9 (0.9)	4.7 (0.7)	0.24
LF/HF ratio**	2.5 (2.9)	2.9 (2.4)	0.63

\*Lower strain group; low strain + passive group + active group.

<sup>†</sup>SDNN, standard deviation of all NN interval; <sup>‡</sup>TP, total power; <sup>§</sup>VLF; very low frequency; <sup>||</sup>LF, low frequency; <sup>¶</sup>HF, high frequency;

\*\*LF/HF, index of cardiac sympathetic activity; log, log transformation.

**Table 4.** Odds Ratios and 95% Confidence Intervals for Metabolic Syndrome by Job Strain

Variables	Metabolic syndrome			OR (95% C.I.)
	No	Yes	<i>p</i> -value	
Job demand				
Low	60 (88.2)	8 (11.8)	0.21	1.00
High	72 (80.9)	17 (19.4)		1.77 (0.72 - 4.38)
Decision latitude				
Low	63 (80.8)	15 (19.2)	0.27	1.00
High	68 (87.2)	10 (12.8)		0.62 (0.26 - 1.48)
Job strain				
Lower strain group*	119 (86.8)	15 (13.2)	0.12	1.00
High strain group	32 (76.2)	10 (23.8)		2.06 (0.84 - 5.04)

\*Lower strain group; low strain+passive group+active group

**Table 5.** Relationships between Job Strain, Metabolic Syndrome, and Heart Rate Variability Mean (S.D.)

Variables	Lower strain* + Normal (N=99)	Lower strain + metabolic syndrome (N=15)	High strain + Normal (N=32)	High strain + metabolic syndrome (N=10)	<i>p</i> -value
SDNN <sup>†</sup>	39.6 (11.3)	35.9 (10.2)	35.1 (9.8)	31.1 (8.4)	0.04
log (Tp <sup>‡</sup> )	7.0 (6.1)	6.8 (0.4)	6.7 (0.6)	6.6 (0.5)	0.09
log (Vlf <sup>§</sup> )	6.4 (0.6)	6.1 (0.5)	6.1 (0.6)	5.9 (0.7)	0.04
log (Lf <sup>§</sup> )	5.6 (0.7)	5.5 (0.6)	5.5 (0.7)	5.5 (0.4)	0.87
log (Hf <sup>  </sup> )	4.9 (0.8)	4.9 (0.9)	4.8 (0.8)	4.4 (0.4)	0.45
LF/HF ratio <sup>  </sup>	2.4 (3.1)	2.8 (1.6)	2.9 (2.9)	2.9 (0.7)	0.21

\*Lower strain group; low strain + passive group + active group.

<sup>†</sup>SDNN, standard deviation of all NN interval; <sup>‡</sup>TP, total power; <sup>§</sup>VLF, very low frequency; <sup>||</sup>LF, Low frequency; <sup>||</sup>HF, high frequency;

\*\*LF/HF, index of cardiac sympathetic activity; log, log transformation Lower strain group.

The LF/HF ratio increased in the frequency domain analysis, demonstrating autonomic overactivity, but was not statistically significant (Table 5).

## DISCUSSION

There has been evidence that job stress may play an important role in contributing to the development of cardiovascular disease. The Karasek's job strain model has proved in previous studies that the jobs classified as having a high level of work demand and a low level of decision latitude increase the risk for cardiovascular disease. Despite a strong link between occupational stress and cardiovascular disease, the patho-

physiological mechanism underlying the association is still unclear. Thus, in order to clarify the responsible mechanism, this study assessed the relationship between job stress, HRV, and metabolic syndrome.

To date, the pathophysiological mechanism of cardiovascular disease and heart-related sudden death, which is associated with autonomic nerve function, has been well-known, promoting the development of tests designed to quantify autonomic nerve function in an invasive way at low costs. Among them, HRV is widely used to measure the modulation of the heart rate through the autonomic nervous system in a variety of dynamic circumstances. A decreased HRV indicates that the autonomic nerve system is not regulating the heart beat in a way that it should

due to sympathetic overactivity or parasympathetic underactivity. A decrease in HRV is deemed as an independent predictor of the death rate of patients with myocardial infarction, stable coronary artery disease, and congestive heart failure and is also seen as an important indicator of cardiovascular disorders in patients with diabetes and obesity.<sup>24-26</sup>

Given the close correlation between the time and frequency HRV indexes, the time domain index SDNN was measured for this study. The LF/HF ratio, a measurement of sympathetic nerve activity, was also utilized. There was a strong correlation between time domain measures of SDNN and RMSSD, which is a measurement of parasympathetic nerve activity obtained through the square root of the mean square difference among successive RR intervals. The RMSSD index in the time domain analysis is inversely correlated with the LF/HF ratio. At the same time, the SDNN index is closely correlated with total power, HF and LF signals processed in the frequency domain. There was an inverse correlation between the indexes of sympathetic and parasympathetic nerve activities, which support the findings of previous studies and qualifying them for an indicator of cardiovascular consequences.<sup>27,28</sup>

Although there have not been many studies dealing with HRV caused by stress, a decreased HRV was seen as an effect of stress in the few studies that have been performed. van Amelsvoort et al.<sup>29</sup> stated that shift workers exhibited decreased SDNN and that the employees exposed to high job strain or high noise levels had an increased %LF. Dishman et al.<sup>27</sup> ascertained that healthy people with higher psychological stress levels showed significantly lower HRV parameters, regardless of their age, gender, heart rate, cardiorespiratory fitness, blood pressure, and respiratory rate. They also reported that those who complained their stress levels and fatigue have a decrease in LF and HF power. Kageyama et al.<sup>30</sup> said that the stress caused by long working hours can lead to decreased HRV parameters accompanied sympathetic overactivity and parasympathetic underactivity. Vrijkotte et al.<sup>31</sup> affirmed that office workers with high stress levels had an overall decrease in RMSSD, which reflects the underactivity of the parasympathetic nerve

system. Such a decrease was particularly prevailing during working hours and was not completely reversed even after working hours.

This study also confirmed that the high-strain group exhibited decreased HRV but increased LF/HF ratio, although the increased pace was not significant, which supports the findings of other studies.

In addition, those individuals who experience chronic stress can have an abnormal metabolic syndrome that is characterized by central obesity, intolerance of glucose, lipoprotein abnormalities, and reduced fibrinolysis.<sup>32,33</sup> The research attempt to identify each metabolic risk component as an independent factor has shifted to the collective approach setting criteria for at least three of the many components, such as blood pressure, fasting glucose, blood triglycerides, HDL cholesterol, and waist-hip ratio.<sup>22</sup> In Europe, the occurrence of arteriosclerosis is detected through other features of the metabolic syndrome although there was no change in the cholesterol level and blood pressure.<sup>34</sup>

This study revealed that 23.8% of the high-strain group had metabolic syndrome compared with 13.2% of the lower strain group. The strong link between metabolic syndrome and changes in HRV was further highlighted when the high strain group was categorized according to the presence and absence of the metabolic syndrome. That is, the SDNN value significantly decreased in the high-strain group with metabolic syndrome, compared with low-strain groups. At the same time, the LF/HF ratio was high in the frequency domain analysis, indicating autonomic overactivity. Thus, high stress levels can increase potential for metabolic syndrome, which seems likely to be developed through enhanced activity of the sympathetic nervous system. Such an assumption coincides with the claim that sympathetic overactivity and parasympathetic underactivity may play a role in the predisposition of palpitation, atrial fibrillation and sudden cardiac death.<sup>35</sup> Sympathetic overactivity and decreased HRV found in the high-strain group are not direct indicators of disease, but they can be regarded as useful indicators for potential cardiovascular abnormalities or dysfunctions related to the onset of heart disease.

This study adopted the five-minute period, not 24 hours, for the measurement of HRV functioning. The study was also geographically limited as it covered subjects in a city, requiring further studies to sample subjects from a larger geographical area. Nevertheless, this study will serve as a landmark with its focus on the relationship between job stress and cardiovascular disorders because the research in the same area has been rare in Korea. This study can be particularly interpreted as a move intended to establish a useful preventive measure by assessing the likelihood of stress-induced cardiovascular disease among the normal working class.

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