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Regular Overtime and Cardiovascular Functions

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Abstract: It was concluded that there was sufficient evidence about a possible link between long working hours particularly exceeding 50 a week and the risk of significant health outcomes, including cardiovascular disease from literature review by Spurgeon et al.. This study was conducted to find out the single effect of regular overtime work on the cardiovascular functions through objective biological indices such as blood pressure or heart rate variability. We conducted a field survey of 238 male engineers who were working at the department of research & development of three electronics manufacturing companies in S. Korea. The field survey consisted of (1) self-report questionnaire (working hours and health conditions, and fatigue) and (2) measurements of blood pressure and heart rate variability. By multivariate analyses we could show the relationship between overtime work and some cardiovascular functions after controlling the effects of major confounders such as age and sleeping hours, which were pointed out by Iwasaki et al. (1998) and Sasaki et al. (1999). Especially, low frequency component (power in the low frequency range, 0.04–0.15 Hz) of the heart rate variability during work might be used as early objective biological indices for chronic effect of regular overtime work on cardiovascular functions. However, we should confirm those effect through the well-designed prospective study.

Key words: Overtime, Long working hours, Cardiovascular function, Blood pressure, Heart rate variability

Introduction

Dr. Uehata defined Karoshi as sudden death from ischemic heart disease or cerebrovascular disease mainly due to physiologically demanding work conditions such as long working hours or shiftwork[1)].

In Korea, the cases of the cerebro or cardiovascular diseases due to overwork has been compensated by Industrial Accident Compensation Insurance Act. Recently they occupy a half of the total compensated occupational diseases in Korea[2)]. All the cases do match the definition of Karoshi by Dr. Uehata, but it is true that Korean workers work longer than Japanese workers. Based on the ILO Labor Statistics in 1997, the weekly working hour for Korea was 48.8 compared to 38.2 for Japan and 37.4 for Germany[2)].

From literature review Spurgeon et al. concluded that there was sufficient evidence about a possible link between long working hours particularly exceeding 50 a week and the risk of significant health outcomes, including cardiovascular disease[3)].

However, at present, there are a few reports on any pathophysiologic effects of overtime work. Recently, Iwasaki *et al.* reported the effect of long working hours on cardiovascular functions[4)], but they could not prove the independent effect of long working hours because of the limitation of the data analysis method.

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Thus, this study was conducted to find out the independent effect of regular overtime work on the cardiovascular functions after controlling the effects of major confounders such as age and sleeping hours, which were pointed out by Iwasaki *et al.*[4] and Sasaki *et al.*[5].

Methods

Study subject

The analyzed subjects were 238 engineers, exclusive of female, the persons with abnormal EKG, the sick at survey (common cold, asthma, liver disease etc.), and the persons who took medicine at survey among 311 surveyed persons in the department of research and development (R&D) of 3 Electronics Manufacturing Companies in Korea.

Study contents

Surveys were made on each five working days in April, July and September of 1998 according to the situation of the three companies, respectively. The workers in the companies worked in the temperature and humidity-controlled offices.

The study contents were as follows:

First, we surveyed (1) weekly working hours (WWH) and health conditions etc. during the last month (2) subjective fatigue before-work at home in the morning and during-work at office in the afternoon, and (3) stress response during the last month by self-report questionnaire. WWH is the mean value of daily working hours which were calculated by time interval from the arrival at the office to the departure of the office from Monday to Saturday during the last one month.

We used the subjective fatigue questionnare proposed by the Japanese Association for Industrial Health in 1971[6] and the stress questionnaire proposed by Haratani in 1996.

Second, we measured urinary noradrenaline (NA) and adrenaline (Ad) level in the afternoon of the survey day at the workplace. Urine was collected into 500ml urine sampler at the time of two hours after complete evacuation of the bladder after lunch.

Collected urine samples were acidified to PH 2-3 with hydrochloric acid immediately after collection and stored at −80°C in a deep freezer until analysis. NA and Ad were analyzed with HPLC-ECD by modified Pearson's method[7] at National Institute for Industrial Health, Japan. The catecholamine level in urine was expressed as ng/mg creatinine or μg/mg creatinine.

Third, we measured cardiovascular functions such as blood pressure (BP) and heart rate variability (HRV). Before the determination of HRV and BP, the subjects took a rest for 5 min. or more. Smoking and caffeine-containing drinking such as coke, coffee, or green tea were prohibited for 30 minutes before the measurement. BP was measured twice with a TM-2541 hemodynamometer (A & D Co., Ltd., Japan) in the afternoon of the survey day at the workplace and the mean value was calculated. HRV was measured by means of a heart rate monitor LRR-03 (GMS Co., Ltd., Japan) for 3 minutes in a sitting position with respiration controlled to once every 5 seconds in the afternoon of the survey day at the workplace. The high frequency (HF) (power in the high frequency range, 0.15–0.30 Hz) and the low frequency (LF) (power in the low frequency range, 0.04–0.15 Hz) were obtained by analysis of frequency with MemCalc[8] (Suwa Trust Co., Japan). Mean amplitude of HF and LF were $\sqrt{(2 \times \mathrm{HF})}$ and $\sqrt{(2 \times \mathrm{LF})}$, respectively[9].

Data analysis

The data which were not normally distributed were transformed logarithmically. Also, partial correlation coefficient and multiple linear regression, which are the general method for examining the relationship between exposure and continuous health outcome variables after controlling the effect of the main confounders, were conducted. In the former analysis correlation coefficient indicates the magnitude of correlation between two continuous variables, whereas in the latter beta indicates the amount of change in the outcome variable per unit change of the exposure or confounder.

Stress response and subjective symptoms analyzed in the partial correlation to just confirm the correlation with cardiovascular function indices were not included in the multiple regression because they were not objective indices for the study purpose.

Results

Based on the self-report questionnaire data and the measurements, Table 1 gives the descriptive statistics of demographic, clinical, and laboratory features of study subjects. According to table 1, the study subjects tend to work long (over than 52 hours per week at the minimum) and sleep short (less than 8 hour a day at the maximum) in general. There was no significant difference on the statistics of all variables according to whether a study subject smoke or not / do exercise regularly or not.

Based on the partial correlation coefficients after adjusting for age and sleeping hour variables, Table 2 shows that WWH has significant positive correlations with stress response score

Table 1. Descriptive statistics of all variables

VAR		N	Statistics
Mean age (yrs)		238	32 (22–46)
Mean WWH (hrs)		238	**69.3 ± 6.7 (52.1–88.8)***
Mean Sleeping hours (hrs)		233	**6.2 ± 0.6 (4.5–8.0)**
Proportion of smoker (%)		231	**68.0**
Proportion of regular** exercise (%)		231	**16.5**
Mean stress response score		231	7.7 ± 4.2 (0–22)
Mean % score of Subjective Fatigue complaints	before work	238	22.0 ± 18.6 (0–100)
	during work	238	16.7 ± 16.2 (0–100)
Mean BP (mmHg)	Systolic	238	127 ± 14 (99–172)
	Diastolic	238	77 ± 10 (57–106)
Mean HRV	LF (msec)	227	26.9 ± 12.1 (7.7–75.9)
	HF (msec)	227	32.4 ± 16.6 (5.0–92.5)
	LF/HF	227	1.3 ± 1.7 (0.1–12.7)
Mean level of urinary catecholamine (ng/mg Creatinine)	NA	238	21.4 ± 5.9 (9.1–49.4)
	Ad	238	7.4 ± 3.5 (1.9–23.1)

*Mean ± S.D. (Minimum − Maximum). **over than 3 times per week.

Table 2. Partial correlations coefficients controlling for age and sleeping hours

VAR		WWH	
Stress response		.1305	p=.048
Subjective fatigue	ln % score before work	**.1666**	**p=.017**
	ln % score during work	.0900	p=.203
Blood pressure	SBP	− .0754	p=.255
	ln DBP	.0291	p=.255
HRV	ln LF	**− .1334**	**p=.046**
	ln HF	− .0288	p=.668
	ln LF/HF	− .0779	p=.244
Urinary catecholamine	NA	− .0343	p=.604
	Ad	.0621	p=.348

and ln % score of fatigue complaints before work. Also WWH has a significant negative correlation with ln LF component of the HRV variables.

According to multiple linear regression, long working hour decreased ln LF value of HRV and increased ln urinary adrenaline level after controlling for age, sleeping hour (Table 3).

Discussion

Overtime work is commonly thought to be stressful and fatiguing and may correlate with sleep deprivation, thereby involving two of the same mechanism hypothesized for heart disease and shift work. There are data indicating that, in

Table 3. Multiple linear regression analysis result

		Age	Sleeping hours	WWH
SBP	Beta	− .100	.036	− .080
	p-value	.132	.605	.255
ln DBP	Beta	.069	.045	.031
	p-value	**.000**	.523	.660
ln LF	Beta	− .286	− .070	− .137
	p-value	**.000**	.300	**.046**
ln HF	Beta	− .249	− .033	− .030
	p-value	**.000**	.632	.668
ln LF/HF	Beta	.027	− .024	− .084
	p-value	.691	.741	.244
NA	Beta	.042	− .519	− .066
	p-value	.530	.604	.349
ln Ad	Beta	.021	.131	.066
	p-value	.748	.348	.060

general, being at work (versus not being at work) increases blood pressure, so that longer working hours implies more time with increased blood pressure[10]. Finally, there are more recent data indicating that long hours of overtime may increase average blood pressure as measured over 24 hours[11].

However, in most studies on long hours and heart disease has focused more on stress rather than on overtime work per se[12]. Thus, the most important thing is the attempt to separate the independent effects of long hours and stress by quantitatively measuring hours worked.

Hayashi *et al.* studied 10 normotensive men working long hours (more than 60 hours overtime a month) and 11 normotensive controls (less than 30 hours overtime a month) (Group A). Blood pressure was recorded during a routine checkup. They also studied 15 exposed men and 11 controls who had mild hypertension (group B). Group A and B worked for the same company; exposed and controls were similar with respect to age, body mass, and smoking habit. Hourly blood pressure, recorded over a month and averaged, showed significantly higher blood pressure for the exposed versus controls in group A and B[11].

Iwasaki, *et al.* studied systolic blood pressure among 71 salesmen in the same company divided into two groups by length of work week in the previous month. Based on a single blood pressure measurement, the group with more hours (65 hours/week) had higher systolic blood pressure for one age group (age 50–59) than did the group with shorter working hours (57 hours/week), despite the fact that the difference in hours worked was not extreme[4].

Sasaki *et al.* studied cardiovascular-autonomic nervous functions (urinary catecholamine, HRV, and BP) among 147 engineers in an electronics manufacturing company divided into two groups by length of work week in the previous month. The group with more hours (68 hours/week) had low urinary noradrenaline level for one age group (age 30–39) than did the group with shorter working hours (58 hours/week). Furthermore, there were significant relationships both between long working hours and short sleeping hours. Summarizing those results, they suggested that long working hours might lower sympathetic nervous activity due to chronic sleep deprivation[5].

However, the study of Iwasaki *et al.* had a weak point that ‘weekly working hour’ was dealt as a categorical variable by grouping, but not as a continuous variable. In the analysis with categorical variables, the differences in the mean values among the groups can be shown, but not the correlation with the variables concerned. Moreover, they could not definitely divide into two subgroups of long-working group and not-long-working group, because they just used the median as a cut value. On the other hand, Sasaki et al. failed to show the consistent and good correlation of WWH with indices of cardiovascular functions although they got simple correlation coefficients among the variables within each age group after the age-stratification. In other words, Iwasaki and Sasaki could not detect the independent single effect of long working hours on the cardiovascular functions.

We solved the above problem by using partial correlation coefficient and multiple linear regression, which are the general method for examining the relationship between exposure and continuous health outcome variables after controlling the effect of the main confounders. Thus, we could get some study results that the longer work, the lower the LF component of HRV, and higher urinary adrenaline level at work even though the magnitude is too small. However, we could not observe the effect of the long working hours on BP.

HRV reflects the beat-to-beat oscillation in the sinus rate. The major determinants of the fluctuations between consecutive heart beats is the respiratory cycle. Measurements in frequency domain (power spectral analysis) quantitate the relative contribution of various frequency bands to total variance. At baseline, the HF component (0.15–0.4 Hz) shows a significant relation to vagal tone. the LF component has been ascribed to sympathetic outflow, possibly together with some parasympathetic modulation.

The LF/HF ratio has been thought by some investigators to represent sympathetic/parasympathetic balance, such that the greater this ratio, the higher the sympathetic influence and the more parasympathetic tone withdrawn. However it is controversial[13]. Age has a major effect on HRV. O'Brien and colleagues report that the standard deviation of R-R intervals decline with age, both at rest and during activities such as deep breathing, Valsalva maneuvers, and standing[14]. Among healthy subjects there usually is circadian variation in HRV, with greater power in the LF component during the day and in the HF component at night[15].

Sasaki *et al.* suggested that long working hours might lower sympathetic nervous activity due to chronic sleep deprivation[5]. However, a reduction in HRV in our study seem to characterize the chronic or cumulative fatigue state which was induced by decreased sympathetic function due to chronic occupational conditions such as regular overtime work. because we could control the effect of sleep deprivation by multivariate analysis.

Urinary sampling of catecholamines is more suitable than plasma determinations for field studies. Hjemdahl has noted that urinary norepinephrine(NE) reflects arterial NE levels, and that changes in urinary epinephrine appear to reflect its secretion during stress, as well[16]. The relevant measures are the amounts of excreted adrenaline and NA into the urine per time unit. To obtain such measurements, it was necessary to record the exact hours of urination and to collect all the urine during a given time period. The excretion of adrenaline and NA fluctuates during the 24-hour cycle. For adrenaline, the excretion during the most active part of the day is three times higher than that during deep sleep at night. Rissler and Elgerot showed that a long-lasting period of overtime work causes not only elevated excretion of adrenaline and NA but also a delayed relaxation of the arousal function in the evening[17]. On the other hand, Sasaki *et al.* showed that the group with more hours (68 hours/week) had low urinary noradrenaline level for the group aged 30–39 than did the group with shorter working hours (58 hours/week)[5]. However, we could find the positive relationship between weekly working hours and urinary adrenaline level.

BP changes over various time frames, and the factors that cause acute changes may not be the same as those that contribute to chronic changes. The fluctuations that occur throughout the day in response to environmental circumstances have been collectively called the "phasic" component of BP; the "tonic" (long-term resting level) component changes only gradually over time[18]. Essential hypertension is defined as an elevation of the tonic component. Induction of hypertension in experimental animals requires several months of repeated exposure to stressful situations[19, 20]. These experimental results provide a biological rationale for the finding that an induction period appears to exist before exposure to job strain gives rise to an increase risk of established hypertension[21].

In spite of the limitation of the cross-sectional nature and single measurement in this study, we could show the relation of overtime work with some cardiovascular functions after controlling the effects of major confounders such as age and sleeping hours, which were pointed out by Iwasaki *et al.* and Sasaki *et al*. Especially, LF component (power in the low frequency range, 0.04–0.15 Hz) of the HRV and urinary Ad during work might be used as early objective biological index for chronic effect of regular overtime work on cardiovascular functions. However, we need to confirm those effect through the well-designed prospective study and if possible, to determine the critical point for long hours which lead to adverse health.

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