Association of Working Hours with Biological Indices Related to the Cardiovascular System among Engineers in a Machinery Manufacturing Company

Takeshi SASAKI^{1*}, Kenji IWASAKI¹, Tatsuo OKA¹ and Naomi HISANAGA²

¹ Division of Work Stress Control,

² Division of Hazard Assessment, National Institute of Industrial Health, 21-1, Nagao 6-chome, Tama-ku, Kawasaki 214-8585, Japan

Received July 9, 1999 and accepted August 31, 1999

Abstract: A field survey of 278 engineers (20–59 years) in a machinery manufacturing company was conducted to investigate the association of working hours with biological indices related to the cardiovascular system (heart rate variability, blood pressure and serum levels of magnesium, dehydroepiandrosterone sulfate <DHEA-S> and cholesterol). Average working hours (defined as <“hours at workplace” + “half a commuting time”>) and sleeping hours in this study were 60.2 ± 6.3 hr/week and 6.6 ± 0.8 hr/day respectively. There were no significant relationships between working hours and biological indices related to the cardiovascular system, but sleeping hours was closely related to working hours negatively. Furthermore, the serum DHEA-S level was significantly related to sleeping hours positively. Combining these two results, it appeared that long working hours might lower the serum DHEA-S level due to the reduction of sleeping hours.

Key words: Working hours, Sleeping hours, Cardiovascular disease, Heart rate variability, Dehydroepiandrosterone sulfate, Fatigue

Introduction

In Japan there is the problem of health hazards with which work overload is associated. Long working hours is thought to be one of the main factors in work overload^{1–4}. In order to establish health management guidelines on long working hours, we have been investigating the association of working hours with biological indices and confounding factors such as age and lifestyle.

In our previous papers^{5,6} we reported field surveys of 71 male salesmen (in a machinery manufacturing company) and 147 male engineers (in an electronics manufacturing company) on the relationship between working hours and biological indices related to the cardiovascular system. In

this paper we will report the third field survey with a purpose and method similar to those of the previous studies. We have made an effort to increase the number of subjects ($n=278$ in this study). Furthermore, we partially changed the content of biological indices to be examined as follows: (1) the serum levels of dehydroepiandrosterone sulfate (DHEA-S) and magnesium (Mg) were measured for the first time, and (2) the data on total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-C) were obtained for all of the subjects. It has been suggested that DHEA-S and Mg are related to cardiovascular diseases^{7–9}. Our previous report⁵ on salesmen suggested that long working hours might lower the TC level.

*To whom correspondence should be addressed.

Subjects and Methods

Subjects

The subjects were 376 male engineers (20–59 years of age) in a machinery manufacturing company. They regularly worked 8 hours (8:30–17:15, lunch time=45 minutes) a day, 5 days a week. Those who were under medical care and/or took medicines on the survey day ($n=59$), and those who were lacking any data in the survey ($n=39$) were excluded from the study. Finally, the number of the subjects for an analytical study was 278 and their age was 36.7 ± 9.4 years (mean $\pm$ SD).

Procedure for field study

Surveys were made on 3 consecutive working days in June 1998. Each subject was examined on one of the survey days. The survey consisted of (1) a self-reported questionnaire (working hours, health conditions and lifestyle, and fatigue), (2) measurement of heart rate variability (HRV) at rest, and (3) data on systolic blood pressure (SBP), diastolic blood pressure (DBP), TC, HDL-C and body mass index (BMI) determined on the occasion of a regular health check conducted in June 1998. Blood samples for the determination of serum DHEA-S and Mg were obtained at the regular health check mentioned above with informed consent. The DHEA-S (RIA method) and Mg (xylydyl blue method) levels were analyzed by SRL Inc. (Japan). A questionnaire on working hours, health conditions and lifestyle during the latest full month was filled out on each survey day or the day before the survey day. Investigation by questionnaire on fatigue and measurement of HRV was conducted on each survey day. A questionnaire on subjective fatigue defined by the Japan Association of Industrial Health¹⁰ was filled out twice on the survey day in the morning (before leaving home) and in the afternoon (just before measurement of HRV). In this questionnaire, subjective fatigue at the time of writing the answers was asked about. HRV was measured in the afternoon (15:00–18:00) at the workplace. Before the measurement the subjects took a rest for 5 min or more. The R-R interval data were recorded by means of a heart rate monitor LRR-03 (GMS Co. Ltd., Japan) for 3 min in a sitting position with respiration controlled to once every 5 sec (0.2 Hz).

Analysis of HRV

Analysis of the frequency with MemCalc¹¹ (Suwa Trust Co., Japan) was conducted to obtain HF (power in the high frequency range, 0.15–0.30 Hz) and LF (power in the low frequency range, 0.04–0.15 Hz). The coefficient of variation

of HRV in the high frequency range ($C-CV_{HF}$)¹² was calculated by the following equation: $C-CV_{HF} = 100 \times (HF)^{1/2} / RR$, where RR was the mean R-R interval. The LF/HF ratio was logarithmically converted to get normal distribution in statistical analysis.

Weekly working hours

The number of weekly working hours was defined by means of the following equation⁶: Working hours (WH) = “hours at workplace” + “half a commuting time”, where “hours at workplace” is hours from arrival at to leaving the workplace. From the viewpoint of workload, we considered that the commuting load was equivalent to half the actual business load.

Classification of working or sleeping hour subgroups

The subjects were divided into 3 subgroups according to the 33rd and 66th percentile of working hours (57.1 and 63.3 hr/week): short (SWH, <57.1 hr/week), medium (MWH, $57.1 \leq$, <63.3 hr/week) and long (LWH, $63.3 \text{ hr/week} \leq$) working hour subgroups (Table 3). And the subjects were divided into 3 subgroups according to the 33rd and 66th percentile of sleeping hours (6 and 7 hr/day): short (SSH, <6 hr/day), medium (MSH, $6 \leq$, <7 hr/day) and long (LSH, $7 \text{ hr/day} \leq$) sleeping hour subgroups (Table 4).

Statistics

The correlations between biological indices and age or BMI were examined in Pearson's correlation coefficient. The relations between all parameters (biological indices, fatigue complaint rates, etc.) and working/sleeping hours were examined by two-way analysis of variance (ANOVA) with age and working/sleeping hours as factors. In the ANOVA, the subjects were categorized by two factors: working/sleeping hours (abovementioned short, medium and long hour ranges) and age (20–29, 30–39, 40–49 and 50–59 year ranges). The difference in the mean values of the parameters for each working/sleeping hour subgroup was found by Fisher's least significance difference (LSD) method. Statistical significance was set at $p < 0.05$.

This study was carried out by permission of the Ethics Committee of our institute.

Results

Parameters on subjects in each age group

Parameters on subjects in each age group are shown in

Table 1. Parameters on subjects

	Age group				Overall
	20–29	30–39	40–49	50–59	
Number	78	108	53	39	278
Age (year)	26.7 ± 2.0	34.1 ± 2.9	44.5 ± 3.2	53.4 ± 2.7	36.7 ± 9.4
Working hours (sum of A+B) (hr/week)	58.7 ± 5.7	61.1 ± 6.8	61.6 ± 5.5	58.6 ± 6.4	60.2 ± 6.3
(A) Hours at workplace* ¹ (hr/week)	56.3 ± 5.4	57.7 ± 6.7	58.3 ± 5.5	55.4 ± 5.8	57.1 ± 6.0
(B) Half a commuting time (hr/week)	2.4 ± 1.8	3.4 ± 1.9	3.3 ± 1.4	3.2 ± 1.9	3.1 ± 1.8
Sleeping hours (hr/day)	6.6 ± 0.7	6.4 ± 0.8	6.7 ± 0.7	6.6 ± 0.8	6.6 ± 0.8
BMI (kg/m ²)	22.1 ± 2.9	22.7 ± 3.0	22.8 ± 2.2	23.0 ± 2.2	22.6 ± 2.7
C-CV _{HF} (%)	2.71 ± 1.34	2.17 ± 0.95	2.01 ± 0.94	1.59 ± 0.93	2.21 ± 1.12
log (LF/HF)	− 0.16 ± 0.36	− 0.01 ± 0.38	− 0.12 ± 0.39	− 0.07 ± 0.52	− 0.08 ± 0.40
SBP (mmHg)	124 ± 11	124 ± 14	125 ± 14	127 ± 15	124 ± 14
DBP (mmHg)	71 ± 7	74 ± 9	79 ± 10	81 ± 8	75 ± 9
Mg (mg/dl)	2.1 ± 0.1	2.2 ± 0.1	2.2 ± 0.1	2.2 ± 0.1	2.2 ± 0.1
DHEA-S (μg/ml)	3.09 ± 0.95	2.94 ± 0.97	2.48 ± 0.89	2.04 ± 0.95	2.77 ± 1.01
TC (mg/dl)	184 ± 29	204 ± 33	218 ± 38	213 ± 33	202 ± 35
HDL-C (mg/dl)	60 ± 12	59 ± 14	62 ± 15	63 ± 15	60 ± 14
Fatigue complaint rate I* ² (Drowsiness and dullness)					
Morning (%)	30.9 ± 19.7	28.2 ± 23.9	25.3 ± 25.9	19.0 ± 21.0	27.1 ± 23.0
Afternoon (%)	16.5 ± 19.2	16.9 ± 20.6	14.9 ± 18.0	13.8 ± 18.0	16.0 ± 19.3
Fatigue complaint rate II (Difficulty in concentrating attention)					
Morning (%)	18.5 ± 22.6	16.5 ± 22.6	21.7 ± 27.6	19.5 ± 23.8	18.5 ± 23.7
Afternoon (%)	12.8 ± 21.5	11.9 ± 21.9	17.4 ± 22.9	17.2 ± 27.2	13.9 ± 22.8
Fatigue complaint rate III (Feeling of local physical abnormality)					
Morning (%)	10.1 ± 11.8	9.1 ± 12.3	10.4 ± 13.9	11.0 ± 13.1	9.9 ± 12.5
Afternoon (%)	6.5 ± 8.9	9.2 ± 13.2	8.5 ± 12.5	7.9 ± 13.0	8.1 ± 12.0

Values are the mean ± SD except the number. *¹: Defined as hours from arrival at to leaving the workplace. *²: Fatigue complaint rate is (number of “yes” answer/number of questions) × 100 (%).

Table 1. Working hours was 60.2 hr/week in the overall group, and longest in the 40–49 year group (61.6 hr/week). Sleeping hours was 6.6 hr/day in the overall group, and shortest in the 30–39 year group (6.4 hr/day). Fatigue complaint rates in the overall group were fatigue I>fatigue II>fatigue III both in the morning and afternoon. Fatigue complaint rates in the morning were higher than those in the afternoon, both in each fatigue category and in each age or the overall group.

Several biological indices related to the cardiovascular system increased or decreased with age. Significant correlations between biological indices and age were found (shown in Table 2). Those were positive for DBP, Mg and TC, and negative in C-CV_{HF} and DHEA-S. Correlations between biological indices and BMI are also shown in Table 2. C-CV_{HF}, the LF/HF ratio, SBP, DBP, TC and HDL-C had significant correlations with BMI.

Relation between working hours and other parameters on subjects

The relation between working hours and other parameters

Table 2. Correlations of biological indices with age or BMI in all subjects (n=278)

	Age	BMI
BMI	0.119*	–
C-CV _{HF}	− 0.335***	− 0.191**
log (LF/HF)	0.054	0.169**
SBP	0.066	0.373***
DBP	0.355***	0.272***
Mg	0.228***	− 0.049
DHEA-S	− 0.357***	0.092
TC	0.340***	0.249***
HDL-C	0.083	− 0.290***

Values are the Pearson's correlation coefficient. *: p<0.05, **: p<0.01, ***: p<0.001.

shown in Table 3 was significant only in sleeping hours (p<0.001). On the comparison of sleeping hours among three working hour subgroups, sleeping hours for LWH was significantly shorter than those for SWH and MWH. Although no significant effects of working hours on

Table 3. Relations between all parameters and working hours (WH)

Parameter	F-value by two-way ANOVA			Mean $\pm$ SD of parameters among working hour subgroups			Multiple comparison by Fisher's LSD		
	Age	WH	Age*WH* ¹	SWH (n=92)	MWH (n=90)	LWH (n=96)	S-M* ²	M-L* ³	L-S* ⁴
Age (year)	1018.39***	0.01	1.67	36.4 $\pm$ 10.6	36.9 $\pm$ 9.2	36.8 $\pm$ 8.5			
Working hours (hr/week)	3.63*	721.40***	1.20	53.1 $\pm$ 2.8	60.0 $\pm$ 1.7	67.1 $\pm$ 2.8	***	***	***
Sleeping hours (hr/day)	2.09	13.85***	0.84	6.7 $\pm$ 0.8	6.7 $\pm$ 0.7	6.2 $\pm$ 0.7		***	***
BMI (kg/m ²)	1.34	0.55	0.32	22.8 $\pm$ 3.5	22.5 $\pm$ 2.0	22.5 $\pm$ 2.5			
C-CV _{HF} (%)	10.48***	0.11	0.52	2.20 $\pm$ 0.98	2.25 $\pm$ 1.27	2.19 $\pm$ 1.12			
log (LF/HF)	2.17 [#]	0.15	1.00	-0.10 $\pm$ 0.40	-0.09 $\pm$ 0.40	-0.06 $\pm$ 0.42			
SBP (mmHg)	0.67	0.43	1.19	125 $\pm$ 12	124 $\pm$ 15	123 $\pm$ 14			
DBP (mmHg)	14.69***	0.11	1.35	75 $\pm$ 8	75 $\pm$ 10	75 $\pm$ 10			
Mg (mg/dl)	5.94***	0.53	1.62	2.2 $\pm$ 0.1	2.2 $\pm$ 0.1	2.2 $\pm$ 0.1			
DHEA-S (μ g/ml)	13.70***	0.92	1.27	2.80 $\pm$ 1.03	2.84 $\pm$ 1.07	2.67 $\pm$ 0.94			
TC (mg/dl)	14.33***	1.68	2.84*	204 $\pm$ 36	204 $\pm$ 36	199 $\pm$ 33			
HDL-C (mg/dl)	1.00	0.34	0.29	60 $\pm$ 14	62 $\pm$ 15	60 $\pm$ 12			
Fatigue complaint rate I* ⁵ (Drowsiness and dullness)									
Morning (%)	2.53 [#]	2.14	0.38	23.6 $\pm$ 19.9	27.1 $\pm$ 22.9	30.5 $\pm$ 25.6			
Afternoon (%)	0.29	1.71	0.49	14.3 $\pm$ 18.6	14.4 $\pm$ 17.3	19.0 $\pm$ 21.5			
Fatigue complaint rate II (Difficulty in concentrating attention)									
Morning (%)	0.64	1.66	0.80	17.4 $\pm$ 21.7	15.9 $\pm$ 22.5	21.9 $\pm$ 26.5			
Afternoon (%)	1.03	1.05	1.02	12.0 $\pm$ 19.8	13.1 $\pm$ 25.6	16.6 $\pm$ 22.7			
Fatigue complaint rate III (Feeling of local physical abnormality)									
Morning (%)	0.36	1.05	0.65	8.5 $\pm$ 10.6	10.2 $\pm$ 12.0	10.9 $\pm$ 14.6			
Afternoon (%)	0.64	0.58	0.88	7.2 $\pm$ 12.6	7.9 $\pm$ 9.9	9.3 $\pm$ 13.1			

SWH: short working hour subgroup, MWH: medium working hour subgroup, LWH: long working hour subgroup. *¹: Interaction between age and WH. *²: Between SWH and MWH. *³: Between MWH and LWH. *⁴: Between LWH and SWH. *⁵: Fatigue complaint rate is (number of "yes" answer/number of questions) $\times$ 100 (%). [#]: $p < 0.1$, *: $p < 0.05$, ***: $p < 0.001$.

biological indices were found, significant interaction between age and working hours was found in TC. As shown in Table 5, the TC level for SWH was higher than those for MWH and LWH in the 40–49 year group, and the TC level for MWH was higher than those for SWH and LWH in the 30–39 year group.

Relation between sleeping hours and other parameters on subjects

The relation between sleeping hours and other parameters shown in Table 4 was significant in serum DHEA-S ($p < 0.05$) and four kinds of fatigue complaint rate ($p < 0.001$ or $p < 0.05$). The serum DHEA-S level for SSH was significantly lower than those for MSH and LSH. Results of the comparison for fatigue complaint rates among the three sleeping hour subgroups were different from those for DHEA-S. Fatigue complaint rates for SSH and MSH were significantly higher than those for LSH in fatigue I in the morning. Furthermore, three other kinds of fatigue complaint rates for MSH were significantly higher than those for LSH. There was a tendency

($p < 0.1$) in the relation between sleeping hours and TC. On the comparison of TC among the three sleeping hour subgroups, TC decreased on average with the decrease in sleeping hours. Significant interactions between age and sleeping hours were found in the LF/HF ratio and DBP. Although the LF/HF ratio for SSH was lower than those for MSH and LSH in the 30–39 year group, the LF/HF ratio for SSH was higher than those for MSH and LSH in the 50–59 year group (Table 5). As for DBP, significant differences were found between some sleeping hour subgroups in the 20–29 and 40–49 year groups (Table 5).

Discussion

Working hours of the engineers in this workplace (60.2 hr/week) was 2.9 hr/week shorter than that of the engineers in the previous survey⁶⁾ (63.1 hr/week). And sleeping hours in this survey (6.6 hr/day) was 0.4 hr/day longer than that in the previous survey⁶⁾ (6.2 hr/day). Therefore, the working conditions at the company in this study are thought to be

Table 4. Relations between all parameters and sleeping hours (SH)

Parameter	F-value by two-way ANOVA			Mean $\pm$ SD of parameters among sleeping hour subgroups			Multiple comparison by Fisher's LSD		
	Age	SH	Age*SH* ¹	SSH (n=23)	MSH (n=138)	LSH (n=117)	S-M* ²	M-L* ³	L-S* ⁴
Age (year)	1048.46***	2.93 [#]	2.16*	36.4 $\pm$ 9.5	36.2 $\pm$ 9.3	37.4 $\pm$ 9.7			
Working hours (hr/week)	4.46**	11.39***	1.90 [#]	62.4 $\pm$ 7.1	61.5 $\pm$ 6.5	58.2 $\pm$ 5.4		***	**
Sleeping hours (hr/day)	0.22	516.77***	0.51	5.2 $\pm$ 0.3	6.2 $\pm$ 0.2	7.3 $\pm$ 0.4	***	***	***
BMI (kg/m ²)	1.24	0.56	0.47	23.0 $\pm$ 3.5	22.7 $\pm$ 2.7	22.4 $\pm$ 2.6			
C-CV _{HF} (%)	10.81***	0.43	1.74	2.27 $\pm$ 1.25	2.16 $\pm$ 0.99	2.26 $\pm$ 1.25			
log (LF/HF)	2.35 [#]	0.10	4.06***	-0.08 $\pm$ 0.51	-0.07 $\pm$ 0.40	-0.10 $\pm$ 0.39			
SBP (mmHg)	0.70	0.23	1.61	125 $\pm$ 17	124 $\pm$ 13	125 $\pm$ 14			
DBP (mmHg)	15.05***	0.06	2.88**	75 $\pm$ 11	75 $\pm$ 9	75 $\pm$ 10			
Mg (mg/dl)	5.70***	0.30	1.26	2.2 $\pm$ 0.2	2.2 $\pm$ 0.1	2.2 $\pm$ 0.1			
DHEA-S (μ g/ml)	14.15***	3.33*	1.64	2.34 $\pm$ 1.04	2.86 $\pm$ 1.04	2.75 $\pm$ 0.95	*		*
TC (mg/dl)	13.08***	2.47 [#]	0.56	190 $\pm$ 29	201 $\pm$ 35	207 $\pm$ 35			
HDL-C (mg/dl)	1.04	0.99	1.67	62 $\pm$ 13	59 $\pm$ 13	62 $\pm$ 14			
Fatigue complaint rate I* ⁵ (Drowsiness and dullness)									
Morning (%)	2.60 [#]	7.83***	0.49	30.9 $\pm$ 19.3	31.8 $\pm$ 25.6	20.9 $\pm$ 18.9		***	*
Afternoon (%)	0.25	3.14*	0.16	15.7 $\pm$ 13.4	18.8 $\pm$ 22.2	12.6 $\pm$ 15.8		*	
Fatigue complaint rate II (Difficulty in concentrating attention)									
Morning (%)	0.76	3.04*	0.84	17.8 $\pm$ 18.1	21.7 $\pm$ 26.4	14.7 $\pm$ 20.9		*	
Afternoon (%)	1.06	2.68 [#]	0.44	9.1 $\pm$ 17.6	17.0 $\pm$ 26.2	11.2 $\pm$ 18.6			
Fatigue complaint rate III (Feeling of local physical abnormality)									
Morning (%)	0.32	2.57 [#]	0.43	8.3 $\pm$ 8.9	11.6 $\pm$ 13.8	8.2 $\pm$ 11.3			
Afternoon (%)	0.78	3.27*	0.52	5.2 $\pm$ 5.9	9.9 $\pm$ 13.7	6.6 $\pm$ 10.2		*	

SSH: short sleeping hour subgroup, MSH: medium sleeping hour subgroup, LSH: long sleeping hour subgroup. *¹: Interaction between age and SH. *²: Between SSH and MSH. *³: Between MSH and LSH. *⁴: Between LSH and SSH. *⁵: Fatigue complaint rate is (number of "yes" answer/number of questions) $\times$ 100 (%). #: $p < 0.1$, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

slightly better than those at the company in the previous study⁶).

In this study no significant relationships were found between working hours and biological indices related to the cardiovascular system, but sleeping hours was closely related to working hours negatively. Furthermore, the serum DHEA-S level was significantly related to sleeping hours positively. Combining these two results, it appeared that long working hours might lower the serum DHEA-S level due to the reduction in sleeping hours. This idea is supported partly by the fact that the serum DHEA-S level for LWH was lower than those for SWH and MWH on average (Table 3). It is well-known that the serum DHEA-S level decreases with age^{13, 14}. Recently the relation between the serum DHEA-S level and health has been extensively studied. Epidemiological studies^{7, 8}) have suggested that a low level of serum DHEA-S is related to cardiovascular diseases. Other studies reported that: (1) DHEA administration activated immune function in age-advanced men¹⁵), (2) DHEA administration also changed the electrophysiological indices

of the central nervous system in elderly men¹⁶), and (3) the serum DHEA-S level was lowered by perceived stress¹⁷). The serum DHEA-S level has therefore been becoming a valuable health index. To our knowledge, the association of working/sleeping hours with DHEA-S has not yet been reported at all. Further study will have to be done to confirm our present results.

In addition to DHEA-S, TC was related to sleeping (working) hours to some extent in this study. Although the relation between fatigue complaint rates and working hours was not significant, fatigue complaint rates for LWH were highest among the three working hour subgroups. TC and fatigue complaint rates are also thought to be important as measures of the effect of long working hours. The serum Mg level was not related to working/sleeping hours in this study.

In this study, significant interactions were found in TC between working hours and age, and in the LF/HF ratio and DBP between sleeping hours and age. These results mean that the association of working/sleeping hours with some

Table 5. Some biological indices in each working/sleeping hours $\times$ age subgroup

	20–29 years						30–39 years					
	Short* ¹	Medium* ²	Long* ³	Fisher's LSD			Short	Medium	Long	Fisher's LSD		
				S-M* ⁴	M-L* ⁵	L-S* ⁶				S-M	M-L	L-S
Classification by working hours												
Number	31	24	23				33	34	41			
TC (mg/dl)	187 ± 32	185 ± 29	180 ± 25				199 ± 29	216 ± 36	197 ± 31	*	*	
Classification by sleeping hours												
Number	5	39	34				13	55	40			
DHEA-S (μg/ml)	3.25 ± 0.93	3.22 ± 0.99	2.92 ± 0.91				2.20 ± 0.90	3.11 ± 0.93	2.96 ± 0.95	**		*
log (LF/HF)	−0.26 ± 0.60	−0.16 ± 0.33	−0.14 ± 0.37				−0.24 ± 0.29	0.00 ± 0.41	0.05 ± 0.36	*		*
DBP (mmHg)	65 ± 6	73 ± 8	70 ± 6	*	#		75 ± 9	74 ± 9	74 ± 10			
	40–49 years						50–59 years					
	Short	Medium	Long	Fisher's LSD			Short	Medium	Long	Fisher's LSD		
				S-M	M-L	L-S				S-M	M-L	L-S
Classification by working hours												
Number	11	21	21				17	11	11			
TC (mg/dl)	248 ± 31	207 ± 40	214 ± 34	***		**	217 ± 33	207 ± 32	214 ± 35			
Classification by sleeping hours												
Number	1	25	27				4	19	16			
DHEA-S (μg/ml)	1.67	2.27 ± 0.86	2.71 ± 0.89		#		1.86 ± 1.28	2.18 ± 1.07	1.91 ± 0.74			
log (LF/HF)	0.02	−0.06 ± 0.40	−0.19 ± 0.38				0.66 ± 0.37	−0.09 ± 0.50	−0.23 ± 0.42	***		***
DBP (mmHg)	86	75 ± 9	82 ± 9		**		83 ± 13	80 ± 7	82 ± 8			

Some biological indices on which effect of sleeping hours or significant interactions between age and working/sleeping hours were significant. Values of biological indices are the mean $\pm$ SD. *¹: Short working hour subgroup (SWH) or short sleeping hour subgroup (SSH). *²: Medium working hour subgroup (MWH) or medium sleeping hour subgroup (MSH). *³: Long working hour subgroup (LWH) or long sleeping hour subgroup (LSH). *⁴: Between SWH (SSH) and MWH (MSH). *⁵: Between MWH (MSH) and LWH (LSH). *⁶: Between LWH (LSH) and SWH (SSH). #: $p < 0.1$, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

biological indices depend on age. In our previous papers⁵,⁶ we reported the significant relationships of working hours with TC, SBP and urinary noradrenaline in specific age groups. These age-dependent results are thought to be very important in the effect of working/sleeping hours on health, but the number of subjects in each subgroup defined by age and working/sleeping hours was rather small. To confirm the results on the interaction obtained in this study, it is necessary to conduct another survey on a larger population.

Acknowledgement

This work was partly supported by "Cooperative System for Supporting Priority Research" of Japan Science and Technology Corporation.

References

- 1) Tokunaga Y (1994) Overwork and health injuries. The Keizai Bunseki (The Economic Analysis). **133**, 1–94 (in Japanese).
- 2) Uehata T (1993) Study of karoshi. Japan Planning Center, Tokyo (in Japanese).
- 3) Kageyama T, Nishikido N, Kobayashi T, Kurokawa Y, Kaneko T, Kabuto M (1998) Long commuting time, extensive overtime, and sympathodominant state assessed in terms of short-term heart rate variability among male white-collar workers in the Tokyo Megalopolis. *Ind Health* **36**, 209–17.
- 4) Sokejima S, Kagamimori S (1998) Working hours as a risk factor for acute myocardial infarction in Japan: case-control study. *BMJ* **317**, 775–80.
- 5) Iwasaki K, Sasaki T, Oka T, Hisanaga N (1998) Effect of working hours on biological functions related to

- cardiovascular system among salesmen in a machinery manufacturing company. *Ind Health* **36**, 361–7.
- 6) Sasaki T, Iwasaki K, Oka T, Hisanaga N, Ueda T, Takada Y, Fujiki Y (1999) Effect of working hours on cardiovascular-autonomic nervous functions among engineers in an electronics manufacturing company. *Ind Health* **37**, 55–61.
- 7) Barrett-Connor E, Khaw KT, Yen SSC (1986) A prospective study of dehydroepiandrosterone sulfate, mortality, and cardiovascular disease. *N Engl J Med* **315**, 1519–24.
- 8) Barrett-Connor E, Goodman GD (1995) The epidemiology of DHEAS and cardiovascular disease. *Ann NY Acad Sci* **774**, 259–70.
- 9) Itokawa Y, Saito N (1995) Magnesium. Koseikan, Tokyo (in Japanese).
- 10) Yoshitake H (1971) Methodological study on the inquiry into subjective symptoms of fatigue. *J Sci Labour* **47**, 797–802.
- 11) Tanaka Y (1996) User's manual of MemCalc system. Suwa Trust Co., Sapporo (in Japanese).
- 12) Hayano J (1996) Assessment of autonomic nervous function by heart rate variability. In: Cardiovascular diseases and autonomic nervous function. ed. by Inoue H, 58–88, Igakushoin, Tokyo (in Japanese).
- 13) Yamaji T, Ibayashi H (1969) Plasma dehydroepiandrosterone sulfate in normal and pathological conditions. *J Clin Endocrinol Metab* **29**, 273–8.
- 14) Orentreich N, Brind JL, Rizer RL, Vogelmann JH (1984) Age changes and sex differences in serum dehydroepiandrosterone sulfate concentrations throughout adulthood. *J Clin Endocrinol Metab* **59**, 551–5.
- 15) Khorram O, Vu L, Yen SSC (1997) Activation of immune function by dehydroepiandrosterone (DHEA) in age-advanced men. *J Gerontol Med Sci* **52**, M1–7.
- 16) Wolf OT, Naumann E, Hellhammer DH, Kirschbaum C (1998) Effects of dehydroepiandrosterone replacement in elderly men on event-related potentials, memory, and well-being. *J Gerontol Med Sci* **53**, M385–90.
- 17) Labbate LA, Fava M, Oleshansky M, Zoltec J, Littman A, Harig P (1995) Physical fitness and perceived stress. Relationships with coronary artery disease risk factors. *Psychosomatics* **36**, 555–60.