Original Article

Influence of Night Shift Work on Psychologic State and Cardiovascular and Neuroendocrine Responses in Healthy Nurses

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Night shift work has often been associated with increasing degree and frequency of various psychologic complaints. The study examined whether psychologic states after night work are related to adaptive alterations of the cardiovascular and neuroendocrine systems. We studied 18 healthy nurses (age 29±2 years) engaged in a modified rapid shift rotation system (day work, 8:15-17:15; evening work, 16:00-22:00; night work, 21:30-8:30). Blood pressure, heart rate, RR interval variability (L/H and HF power spectrum for sympathetic and vagal activities), and physical activity were measured using a multibiomedical recorder for 24 h from the start of work during the night and day shifts. Plasma ACTH and cortisol concentrations were measured at the end of each shift and at 8:30 AM on a day of rest. Each subject's psychologic state was assessed using a validated questionnaire. Among the parameters measured, scores for confusion, depression, anger-hostility, fatigue and tension-anxiety were highest, and scores for vigor lowest, after a night shift. Systolic blood pressure and heart rate during work were lower during night shift than during day shift (119±2 vs. 123±1 mmHg, p<0.05 and 75±1 vs. 84±2 bpm, p<0.001, respectively). Both parameters were lower still (p<0.005 and p<0.05) when measured outside of the hospital under waking conditions following a night shift than following a day shift, even though the levels of physical activity were similar. The HF power spectrum of RR interval variability was greater not only during work (24.2±2.1 vs. 18.5±1.8 ms, p<0.005) but also during the awake period (29.1±2.5 vs. 24.4±2.6 ms, p<0.005) after the night shift compared with the day shift. Plasma ACTH and cortisol concentrations were lower after night work than in the day of rest (7.3±1.2 vs. 11.5±2.3 pg/ml, p<0.1 and 11.1±1 vs. 14.4±1.1 mg/dl, p<0.05). Systolic and diastolic blood pressures during night shift work and the subsequent awake period correlated positively with scores for vigor and negatively with scores for confusion (p<0.05). Plasma ACTH and cortisol concentrations did not correlate with any psychologic scores. We conclude that psychologic disturbances after night work were associated with altered cardiovascular and endocrine responses in healthy nurses. Some of the psychologic complaints may be attributable to lower waking blood pressure. (Hypertens Res 2001; 24: 25-31)

Key Words: shift work, psychologic state, blood pressure, autonomic nervous system, endocrine system

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Introduction
Night shift work dissociates physical activity from neuroendocrine rhythms, and has been associated with more intense feelings of fatigue than daytime work (1, 2). A government study in 1997 disclosed that 6.7 million employees were engaged in night shift work in Japan. The number of night-shift workers in 1992 has been supposed to be about 3 million (3), suggesting that the frequency of night-shift work has increased dramatically in Japan.

Women have been reported to have more psychosomatic complaints and increased absenteeism during night shift work than men (4). Furthermore, the prevalence of sleep disturbances and drowsiness at work is higher among female shift workers (5). The accumulation of mental and physical fatigue impairs the quality of life of workers, and may be hazardous to their health (6). It is thus crucial to understand the mechanisms underlying the various complaints associated with night shift work in order to establish a more comfortable shift work environment.

There are significant individual differences in the tolerance to shift work (7). It remains to be clarified whether the cause of the individual tolerance variability is linked to physiologic mechanisms. It has been reported that diurnal changes in blood pressure show almost immediate adaptation to phase-shifts in activity and sleep (8-10), although different patterns of such adaptation have been reported (11-13). Furthermore, the pattern of cortisol secretion may be altered by night shift work (14, 15). We hypothesize that differences in the adaptive patterns of blood pressure or cortisol rhythms may reflect individual variability in tolerance to shift work.

The sympathetic nervous system has been considered to play an important role in the modulation of diurnal changes in blood pressure. However, there has been only report examining the changes in sympathetic nervous activities during night-shift work (13). Moreover, no information is available concerning diurnal changes in vagal activity during such work. In order to clarify the physiologic mechanisms of cardiovascular system adaptation to shift work, information is needed on both components of autonomic nervous system. Recently, Tochikubo et al. developed a sophisticated device to simultaneously monitor blood pressure, heart rate, physical activity, and autonomic nervous activities (16). This device quantifies both sympathetic and vagal activities through spectral analysis of heart rate variability. The aim of the present study was to examine the influence of night shift work on the psychologic state and the cardiovascular, autonomic and endocrine systems in healthy nurses engaged in a modified, rapid shift rotation system using this new methodology.

Subjects and Methods

Subjects
We studied 18 healthy female nurses working in a ward for hypertension and cardiovascular and respiratory diseases at Tohoku Rosai Hospital. Their ages ranged from 22 to 44 years (mean, 29 years) and they had from 0.5 to 20 years’ shift work experience (mean, 9.3 years). Twelve were single, 6 were married, 4 had children and 5 were smokers. The ward had 53 beds, including 2 intensive care unit beds. The study protocol was approved by the Ethics Committee of Tohoku Rosai Hospital and informed consent was obtained from all subjects.

Shift Work Schedule
The nurses were engaged in the following continuous, modified rapid shift rotation schedule: day work, 8:15-17:15; evening work, 16:00-22:00; night work, 21:30-8:30. They were required twice monthly to work 2 successive night shifts, which were combined with 2 previous and at least 1 subsequent day of rest. They worked an additional 2 or 3 successive day shifts and 2 successive evening shifts with at least 8 days of rest per month. The nurses were examined while working the second day of successive night shifts, the second day of 2 or 3 successive day shifts, and in the morning on the day of rest.

Ambulatory Blood Pressure Monitoring
Ambulatory blood pressure monitoring was performed twice each night and day shift using a multibiomedical recorder (TM 2425; A&D, Tokyo, Japan) which simultaneously measures blood pressure, heart rate, autonomic nervous activity, and physical activity (16). Clinical application of this device has been reported previously (17, 18). The blood pressure and heart rate were measured every 30 min using the oscillometric method. This device has been reported to satisfy the accuracy levels recommended by the Association for the Advancement of Medical Instrumentation and British Hypertension Society (16). Electrocardiogram (ECG) data was recorded using a precordial lead (V5). Indirect measures of autonomic nervous activity were examined by spectral analysis of RR interval variability. The details of this analysis have been described previously (16). In brief, the occurrence of an R wave was estimated from a 2-ms sampling interval of the ECG tracing. We made 512 consecutive RR measurements at 30-min intervals. Ecotropic beats or artifacts, which considerably affect spectral components of RR interval variability, were automatically deleted from the time series data. The irregular and discrete event series were interpolated using Lagrange's equation and resam-
Table 1. Psychological Measures after Night and Day Shifts and on the Control Day of Rest

<table>
<thead>
<tr>
<th></th>
<th>Night shift</th>
<th>Day shift</th>
<th>Control day</th>
<th>F-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confusion</td>
<td>52.2±1.5</td>
<td>47.0±1.6</td>
<td>44.0±1.4</td>
<td>10.65</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Depression</td>
<td>46.7±1.4</td>
<td>43.6±0.4</td>
<td>42.9±0.8</td>
<td>5.93</td>
<td>0.006</td>
</tr>
<tr>
<td>Anger-hostility</td>
<td>45.1±1.2</td>
<td>43.2±0.8</td>
<td>40.3±0.7</td>
<td>8.15</td>
<td>0.001</td>
</tr>
<tr>
<td>Fatigue</td>
<td>55.0±2.2</td>
<td>51.6±2.2</td>
<td>41.1±0.9</td>
<td>20.57</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tension-anxiety</td>
<td>49.4±1.7</td>
<td>45.3±1.9</td>
<td>40.5±1.2</td>
<td>9.05</td>
<td>0.001</td>
</tr>
<tr>
<td>Vigor</td>
<td>39.2±1.7</td>
<td>40.6±1.7</td>
<td>43.8±1.5</td>
<td>3.15</td>
<td>0.056</td>
</tr>
</tbody>
</table>

...pled every 500 ms. First, descriptive statistics (mean and SD) were computed. Then, spectral analysis of the RR interval variability was performed based on autoregressive modeling. The amplitude of the powers ranging from 0.05 to 0.15 Hz and 0.15 to 0.40 Hz were computed as a low-(LF) and high-frequency (HF) component, respectively. The LF/HF ratio (L/H) and HF component of the RR interval variability were considered as indirect measures of sympathetic and vagal activities, respectively (19). Physical activity was measured using a ceramic acceleration pick-up sensor incorporated into the blood pressure recorder. The degree of acceleration was detected at 18-ms intervals at frequencies in the range of 1-10 Hz, with a sensitivity of $4.2 \times 10^{-4}$ g per bit, and the cumulative values for 1-min intervals were recorded. This device is compact (size, $4 \times 6.5 \times 14$ cm; weight, 390 g) and does not significantly interfere with daily activities. During the monitoring, subjects were asked to attend to their routine activities, but to avoid unusual physical exercise and to keep the arm involved in the automatic blood pressure measurement extended and immobile at the time of each cuff inflation. On the day of recording, subjects were requested to keep a detailed diary including the time of meals and start and duration of naps and resting times, as well as the times and duration of sleeping at home. We did not fix their sleep periods at home. All data were recorded for 24.5 h, with the first 30-min being excluded from the analysis.

Psychologic Measures and Hormonal Examinations

All subjects were instructed to evaluate their psychologic states near the end of each night and day shift using the Profile of Mood States (20). This self-rating questionnaire evaluates the feelings of confusion, anger-hostility, fatigue, tension-anxiety, depression and vigor according to a 5-point Likert-type scale ranging from “absence” to “extremely” and has been used in various fields of medical research (21, 22). We used a Japanese version which has been validated by Yokoyama et al. (23). The $\sigma$ coefficient of Cronbach ranges from 0.779 to 0.926 for the 6 subscales. Thus the questionnaire is sufficiently reliable. Moreover, it has been shown in psychiatric outpatients that 8-week treatment with active drugs improved 4 of the 6 subscales, while use of a placebo changed none of them, suggesting a good reproducibility of the psychologic measures (24).

After the psychologic rating, blood samples were taken from the antecubital vein of subjects after 15 min of supine rest. Plasma ACTH and cortisol concentrations were measured by radioimmunoassay. Psychologic rating and blood sampling were performed at 8:30 AM on the day of rest as a control for the night shift work. Subjects were requested to sleep a sufficient number of hours on the night prior to the control study. Blood samplings were performed after at least 5 h of fasting.

Statistical Analysis

All data are expressed as the means±SE. Ambulatory monitoring data obtained during the night shift were averaged for working hours, excluding a nap period at the hospital, and waking and sleeping hours outside the hospital according to the detailed diaries of subjects. Data from the day shift were averaged for working hours at the hospital, and waking and sleeping hours outside the hospital. Differences in means were examined by ANOVA or paired t-test. The relationship between the two variables was examined by Pearson’s product-moment or Spearman’s rank-order procedures when appropriate. Values of $p$ less than 0.05 were considered to indicate statistical significance. All statistical analyses were performed using SPSS software for Windows (version 6.1; SPSS Japan, Tokyo).

Results

Scores of confusion, depression, anger-hostility, fatigue and tension-anxiety were highest and the score of vigor was lowest following the night work (Table 1). Systolic blood pressure and heart rate were lower ($p<0.05$ and $p<0.001$) and the HF power spectrum of RR interval variability was higher ($p<0.005$) during the night shift than during the day shift (Tables 2, 3). The mean physical activity during night work was lower than that during day work ($p<0.01$). Heart rate and systolic and diastolic blood pressures were significantly lower ($p<0.05$, $p<0.005$, and $p<0.05$, respectively) and HF power signifi-
Table 2. Cardiovascular Parameters and Physical Activity during In-Hospital Working, Out-of-Hospital Waking, and Sleeping Periods

<table>
<thead>
<tr>
<th></th>
<th>In-hospital working period</th>
<th>Out-of-hospital waking period</th>
<th>Sleeping period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Night shift</td>
<td>Day shift</td>
<td>Night shift</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>119 ± 2*</td>
<td>123 ± 2</td>
<td>116 ± 2*</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>75 ± 2</td>
<td>75 ± 2</td>
<td>72 ± 2*</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>75 ± 2*</td>
<td>84 ± 2</td>
<td>72 ± 2*</td>
</tr>
<tr>
<td>Activity (g/min)</td>
<td>0.036 ± 0.002*</td>
<td>0.041 ± 0.001</td>
<td>0.027 ± 0.004</td>
</tr>
</tbody>
</table>

SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; *p < 0.05, **p < 0.01, ***p < 0.005, ****p < 0.001, vs. day shift.

Table 3. Autonomic Nervous Parameters during In-Hospital Working, Out-of-Hospital Waking, and Sleeping Periods

<table>
<thead>
<tr>
<th></th>
<th>In-hospital working period</th>
<th>Out-of-hospital waking period</th>
<th>Sleeping period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Night shift</td>
<td>Day shift</td>
<td>Night shift</td>
</tr>
<tr>
<td>RR (ms)</td>
<td>761 ± 18**</td>
<td>656 ± 15</td>
<td>800 ± 22*</td>
</tr>
<tr>
<td>SD (ms)</td>
<td>73 ± 4*</td>
<td>60 ± 4</td>
<td>76 ± 3</td>
</tr>
<tr>
<td>LF (ms)</td>
<td>54.5 ± 4.0*</td>
<td>44.3 ± 4.2</td>
<td>53.3 ± 2.6*</td>
</tr>
<tr>
<td>HF (ms)</td>
<td>24.2 ± 2.1***</td>
<td>18.5 ± 1.8</td>
<td>29.1 ± 2.5***</td>
</tr>
<tr>
<td>L/H</td>
<td>2.4 ± 0.1</td>
<td>2.7 ± 0.2</td>
<td>2.1 ± 0.1</td>
</tr>
</tbody>
</table>

RR, RR interval; SD, standard deviation; LF, amplitude of low-frequency power of heart rate variability; HF, amplitude of high-frequency power of heart rate variability; L/H, ratio of low- and high-frequency power of heart rate variability; *p < 0.05, **p < 0.01, ***p < 0.005, vs. day shift.

Discussion

Night work has been reported to be associated with more intense feelings of fatigue than day work in shift workers (1, 2). To improve adaptation to a shift work environment, it is crucial to minimize the psychologic complaints and feelings of fatigue associated with night work. This study attempted to determine whether psychologic alterations after night work are related to altered cardiovascular or endocrine responses in healthy nurses.

Our results showed that the scores of confusion, depression, anger-hostility, fatigue, and tension-anxiety were higher, and the score of vigor lower, after night work than after day work or during a control day of rest. These data well confirmed the previous reports that psychologic disturbances and feeling of fatigue were more severe after night work.

There are several important findings to be discussed. First, waking systolic blood pressure and heart rate were significantly lower during the night shift than during the day shift. Further, waking diastolic blood pressure and heart rate outside the hospital were lower following a night shift than after a day shift. Because blood pressures and heart rate during sleep did not differ between the shifts, the present results showed that night shift work was associated with alterations of cardiovascular responses during the waking period. Our data contradict...
previous results showing that diurnal changes in blood pressures adapted almost immediately to phase-shifts in activity or sleep, and that blood pressures during night work were similar to those during day work (8, 9). Physical activity during work was significantly lower during the night shift than during the day shift, while out-of-hospital physical activity did not differ significantly. This means that the lower waking blood pressure in the night shift was attributable to reduced physical activity, but also that other factors were likely to be involved.

Second, the waking blood pressures correlated positively with the score of vigor and negatively with the score of confusion in the night shift, suggesting that lower waking blood pressure is associated with a less energetic and more confused psychologic state during night shift work.

Our data are consistent with a previous report showing a strong relation between low systolic blood pressure and minor psychological dysfunction in a large employed population (25). We speculate that depressed waking blood pressure could disturb psychologic conditions during night shift work. Our data, however, did not clarify the cause-effect relationship of blood pressure and the psychologic state. The converse interpretation might also be conceivable. Namely, psychologic disturbance could reduce blood pressure through depressed physical and/or mental activity. To further clarify the cause-effect relationship between blood pressure and psychologic state in night shift workers, it will be important to examine whether an interventional measure to increase waking blood pressure would improve the psychologic state of
night shift workers. Finally, both cortisol and ACTH concentrations were lower during the night shift than during the control day of rest. However, neither hormonal concentration was related to any of the psychologic parameters measured. These data suggest that altered endocrine responses associated with night shift were not related to psychologic disturbance.

The influence of night shift work on subsequent sleeping blood pressures remains debatable. Some studies have reported that sleeping blood pressures are higher in the night shift work than in the day shift work (11-13), while other studies, including the present work, have found no significant difference in sleeping blood pressures between these two types of work (8-10). One possible explanation for the discrepancy is the difference in work stress. James et al. showed that even when women work in similar occupations at the same work site, their cardiovascular responses to the work and home environments can differ substantially depending on how they perceive their environments (26). High work stress not only increases blood pressures at the office but also exerts a prolonged pressor effect on blood pressures at home. In our data, the reduced blood pressure during night work was associated with slower heart rate and heightened HF power of heart rate variability, indicating a vagal predominance.

Since cardiac vagal activity has been reported to be suppressed by mental stress (19), the present data suggest that our subjects were not subjected to serious work stress during their night shifts.

There are several other points that deserve to be mentioned. First, we examined plasma ACTH and cortisol concentrations at the end of the second day of two successive night shifts. Lower ACTH and cortisol concentrations in the night shift suggest that the pituitary-adrenocortical function promptly responded to change in the sleep-awake cycle. Second, the L/H of heart rate variability, an index of sympathetic activity, was similar during the sleeping and working periods between the shifts, while the HF component of heart rate variability while waking was greater in the night shift. These data suggest that the sympathetic and vagal nervous systems respond differently to changes in the awake-sleep cycle. However, it is important to apply these spectral analysis data cautiously, since the RR intervals were recorded in the absence of standardized environmental and behavioral conditions. Breathing frequency and amplitude could be responsible for changes in the RR interval powers, independent of changes in autonomic cardiac modulation. Since we did not monitor respiratory activity, the changes in heart rate variability may not have been solely attributable to changes in autonomic nervous activity.

Finally, other factors which can potentially affect psychologic complaints or feeling of fatigue after night work remain to be clarified. Increased workload due to gender-related household duties and child care have been suggested as factors that might decrease tolerance to night work (4). Furthermore, the degree of psychologic stress or physical load, which varies depending on the conditions of the hospital inpatients, may also be involved. We did not examine such environmental factors, which could be a limitation of this study.

In conclusion, psychologic disturbances during night shift work were associated with altered cardiovascular and endocrine responses in healthy nurses. Lower waking blood pressures were associated with a less energetic and more confused psychologic state. To further clarify the cause-effect relationship, we will need to examine whether an enhancement of waking blood pressure might improve the psychologic state of night shift workers.

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