Light Exposure and Sleep-Wake Pattern in Rapidly Rotating Shift Nurses

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Objectives: Shift workers are at risk for various sleep and health-related problems. To investigate light exposure and sleep-wake pattern according to shift schedules in shift workers.

Methods: We enrolled 12 full-time, rapidly rotating three-shift female nurses (age 26.4±4.01 years). They completed sleep logs and actigraphy monitoring of sleep-wake parameters, light exposure, and activity levels for over 14 days (mean numbers of night shifts 2.5).

Results: Before beginning shift work, participants were healthy and had no history of hypnotics. One third of participants (33.3%) had clinically significant insomnia-related symptoms (insomnia severity index ≥15, mean 14.0). Reported health problems were irregular menstruation cycles (75%), nightmares (25%), and irritable bowel syndrome (16.7%). Mean sleep time was less than 6 h regardless of the shift periods and wakefulness after sleep onset was prolonged more than 30 min. Light exposure in night-shift periods was the lowest during working hours and the highest during non-working hours. Activity levels were not different during working hours throughout the schedules.

Conclusions: Fast-rotating shift nurses sleep less and unsatisfactorily. Health-related problems were frequent in shift nurses. Rapidly rotating shift schedules and related inappropriate light exposure may be detrimental to sleep and health in shift workers.

J Sleep Med 2016;13(1):8-14

Key Words: Shift work, Light exposure, Sleep, Health, Actigraphy.
monitoring. In addition, we compared light and activities quantitatively in each shift schedule that might explain sleep-wake problems in shift workers.

Methods

Participants

Thirteen fast-rotating shift nurses (mean age 26.4 ± 4.01 years, all females) were recruited from a metropolitan hospital. To minimize confounding variables including work place and workload condition, participants were enrolled from single admission unit. The exclusion criteria were current use of hypnotics or central nervous system stimulants and history of psychiatric illness or major systemic disease. Participants who had no night-shift periods during the study were excluded. All participants experienced worked day-, evening-, or night-shift periods. One subject was excluded from analysis because of missing data. Finally, 12 participants were included. They completed all study procedures. No one wears sunglasses after night-shift.

Procedure

Data was collected exclusively during summer season (June–August 2014) to limit the effect of variance of natural light amount according to seasons. Demographic data included age, years of education and work, and current comorbid disease-related symptoms. Each subject wore an activity monitoring device and completed a sleep diary and work condition (work hours and duties) for 2 weeks. This period included three shifts. Participants completed the Insomnia Severity Index (ISI) immediately after completing their sleep diaries.

Table 1. Characteristics of three-shift nurses

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n (%)</th>
<th>Mean±SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td></td>
<td>26.42±4.01</td>
<td>23–34</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>10 (83.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>2 (16.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work experience, months</td>
<td></td>
<td>44.83±48.61</td>
<td>4–144</td>
</tr>
<tr>
<td>Comorbidity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritable bowel syndrome</td>
<td>2 (16.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-I trouble</td>
<td>2 (16.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irregular menstruation</td>
<td>9 (75)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nightmare during last 2 weeks</td>
<td>3 (25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISI</td>
<td></td>
<td>14.00±3.13</td>
<td>9–19</td>
</tr>
<tr>
<td>Sleep disturbance (ISI ≥15)</td>
<td>4 (33.3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ISI: Insomnia Severity Index

Wrist actigraphy

Sleep-wake parameters were measured by wrist activity monitoring on the non-dominant wrist using an Actiwatch Spectrum device (Respironics, Murrysville, PA, USA) and a sleep diary. Participants were instructed to wear the activity monitor at all times on the outside of clothing, except when showering and swimming for 2 weeks. Wrist activity data were analyzed using Actiware version 5.70 sleep software. Sleep variables recorded by Actiwatch were calculated from the period between self-reported bedtimes to the time of awakening in bed (time in bed, TIB) from the sleep diary. Sleep variables estimated by actigraphy were sleep start (sleep onset), sleep end (wake time), sleep time (total sleep time), sleep latency (difference between bedtime and sleep start), and sleep efficiency (sleep time divided by total TIB). Sleep start was defined as the first 10-min period in which no more than one epoch was scored as ‘mobile’. Sleep end was defined as the last 10-min period in which no more than one epoch was scored as ‘immobile’. Actigraphy estimated sleep time was defined as the amount of time between sleep start and sleep end, that was scored as ‘sleep’. Participants were also instructed to complete a daily sleep diary upon awakening from which bedtime, wake time, TIB and estimated sleep duration were determined.

Light and activity

Illuminance and activity data were obtained from the 14 consecutive days of actigraphy data. Each day was reviewed and tabulated for all participants. Invalid light and activity data, such as instances where the device was removed or covered, were discarded. Daytime recordings indicating no activi-
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For more than 30 consecutive min and days with more than 10% missing data were excluded. Participants with fewer than 2 days of data were also excluded. Sleep diaries, activity and light data were used to estimate sleep-wake timing, including bedtime, wake time and out of bedtime. Light and activity data were averaged into 2-min intervals. For the analysis of the daily profile of light exposure, data were first analyzed as lux and then were log-transformed if necessary.

**ISI**

A Korean version of the 7-item subjectively reported ISI assessing the severity of insomnia symptoms (difficulty falling asleep, difficulty maintaining sleep or early morning awakening) was used. The ISI queried satisfaction with current sleep-wake patterns, interference with daytime functioning, how noticeable the sleep impairment was to others, and the degree of worry or distress related to the sleep problems in the past 2 weeks. Participants graded each question between minimal (0 points) to very severe (4 points). The final score ranged from 0–28 points, with higher numbers indicating the severity of insomnia. An ISI score \( \geq 15 \) was considered as clinically significant insomnia.17

**Statistical analyses**

All statistical analyses were conducted using the Statistical Package for Social Science (SPSS) for Windows, Version 18.0 (SPSS Inc., Chicago, IL, USA). The alpha level for statistical significance was set at \( p<0.05 \). Descriptive statistics (mean\( \pm \) standard deviation) and number (percentage) are summarized in Table 1 and 2. Due to sample size and potential deviations from normality, statistical analyses comprised the Kruskal-Wallis test and Wilcoxon signed rank test with post hoc Bonferroni’s correction.

**Ethics statement**

This study protocol was approved by the Institutional Review Board of the Samsung Medical Center (IRB No. 2014-05-004). Informed consent was confirmed by the IRB and obtained from all participants.

**Results**

**Participants’ characteristics**

The average length of work as a rotating shift nurse was 44.8 months (range, 4–144 months). Mean ISI score was 14.0, with 4/12 (33.3%) of participants having clinically significant insomnia. All participants with insomnia symptoms experienced one or more of the followings: difficulty falling asleep, difficulty staying asleep, or problem waking up too early. Two (16.7%) participants reported irritable bowel syndrome and 9/12 (77.0%) participants had irregular menstruation symptoms (Table 1).

**Work duration and sleep-wake patterns according to shift schedules**

Day-shift periods made up 29.7% of those shift schedules, 45.0% were evening-shift periods, and 25.3% were night-shift periods. Shift schedules of participants are presented in Fig. 1. Participants work the irregular sequence of shift periods with irregular intervals between shifts. Regular working hours are 7.5 h for day-shift period, 8 h for evening-shift period, and 9 h for night-shift period in this hospital. However,

**Table 2. Working condition and sleep pattern of participants**

<table>
<thead>
<tr>
<th>Working condition</th>
<th>Day-shift period (n=27)</th>
<th>Evening-shift periods (n=41)</th>
<th>Night-shift periods (n=23)</th>
<th>p</th>
<th>Post-hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start time of work</td>
<td>6.40±0.50</td>
<td>13.75±2.00</td>
<td>21.67±1.03</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Finish time of work</td>
<td>16.93±2.13</td>
<td>23.97±0.50</td>
<td>8.20±0.53</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Working hours</td>
<td>9.82±0.87</td>
<td>9.92±1.43</td>
<td>10.52±1.43</td>
<td>0.162</td>
<td></td>
</tr>
<tr>
<td>Time to bed, h</td>
<td>23.48±1.45</td>
<td>3.30±1.49</td>
<td>11.72±2.38</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Time out of bed, h</td>
<td>5.40±1.17</td>
<td>10.60±1.73</td>
<td>17.21±2.20</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Time in bed, h</td>
<td>6.47±1.61</td>
<td>7.14±1.73</td>
<td>6.07±2.19</td>
<td>0.026</td>
<td>E&gt;N</td>
</tr>
<tr>
<td>Total sleep time, h</td>
<td>5.55±1.45</td>
<td>5.94±1.38</td>
<td>5.20±2.01</td>
<td>0.080</td>
<td></td>
</tr>
<tr>
<td>Sleep efficiency, %</td>
<td>86.24±8.73</td>
<td>83.94±8.92</td>
<td>84.67±7.72</td>
<td>0.499</td>
<td></td>
</tr>
<tr>
<td>Sleep latency, min</td>
<td>7.19±14.96</td>
<td>6.68±10.87</td>
<td>5.22±8.24</td>
<td>0.930</td>
<td></td>
</tr>
<tr>
<td>WASO, min</td>
<td>37.40±28.79</td>
<td>50.34±38.07</td>
<td>31.48±15.57</td>
<td>0.161</td>
<td></td>
</tr>
<tr>
<td>Number of arousal, n</td>
<td>10.22±5.40</td>
<td>13.98±7.35</td>
<td>9.52±3.92</td>
<td>0.045</td>
<td>E&gt;N</td>
</tr>
</tbody>
</table>

*Number of shifts. WASO: wakefulness after sleep onset
the actual working times were about 2 hours longer than the pre-set working hours (Table 2). TIB and number of arousals during sleep in each shift schedule were significantly different \((p<0.05)\). During evening-shift periods, participants had longer TIB and more arousals than day- or night-shift periods. Total sleep time of all shift periods were shorter than 6 h and wakefulness after sleep onset (WASO) was prolonged more than 30 min. However, sleep variables including total sleep time and WASO were not significantly different according to shift schedules.

**Figure 1.** Shift schedules of rapidly rotating nurses. Participants work the irregular sequence of shifts. The white, black-rimmed box indicates day-shift period; the gray box is evening-shift period; the black box is night-shift period; and the striped box depicts free day.

**Figure 2.** Light exposure and activity level according to shift schedules. (A) During working hours, participants’ day-shift periods were significantly more exposed to light than evening- or night-shift periods \((p<0.01)\). When not in the work place, participants’ night-shift periods were exposed to more light than day- or evening-shift periods \((p<0.01)\). (B) During working hours, activity levels were not different among the shift schedules. During non-working hours participants’ day-shift periods were significantly more active than evening-shift periods \((p=0.002)\). *p-value<0.05.

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**Light exposure and activity level according shift schedules**

Since sleep-wake patterns and working hours vary depending on shift schedules, light and activity data were examined in relation to time since work. The every 2-min averaged cumulative amount of light exposure during workdays differed according to shifts schedules (day-shift periods, 162,431.3 lux; evening-shift periods, 232,497.4 lux; night-shift periods, 216,878.3 lux, \(p=0.005\)). Participant’s light exposure of working hours was significantly higher in day-shift periods (mean±SD, 363.67±109.94 lux) than the exposure during evening-
shift periods (205.70±103.93 lux) and night-shift periods (146.01±49.64 lux) (p<0.01, post-hoc analyses with Bonferroni’s correction) (Fig. 2A). When not working, participants’ night-shift periods were exposed to more light (402.91±654.48 lux) than day-shift (162.84±274.11 lux) and evening-shift periods (381.52±671.08 lux) (p<0.01). The cumulative activity level during working hours was not significantly different according to shift schedules (day-shift periods, 375,396.8; evening-shift periods, 357,045.8; night-shift periods, 380,800.4; p=0.156). During non-working hours, the activity level of participants’ day-shift periods (401.82±269.59) was significantly higher than evening-shift periods (344.86±268.62) (p=0.002 with Bonferroni’s correction) (Fig. 2B).

Light exposure preceding and after bedtime according to shift schedules

During the 5 h preceding time to bed, participants’ night-shift periods were exposed to significantly more light (616.43±509.72 lux) than day-shift periods (132.67±151.69 lux) or evening-shift periods (107.32±30.20 lux) (p<0.01, post-hoc analyses with Bonferroni’s comparison) (Fig. 3). During the 5 h after time to bed, participants’ night-shift periods were exposed to significantly more light (27.38±8.59 lux) than evening-shift periods (21.03±34.81 lux) or day-shift periods (6.00±8.36 lux) (p<0.01, post-hoc analyses with Bonferroni’s comparison).

**Discussion**

As expected, the sleep-wake patterns and light exposure markedly differed according to the shift schedules. Most striking finding was the extremely short mean sleep time of shift workers (5.5 h) regardless of schedules, compared to the mean sleep time of 7.2 h for the general population of Korea of similar age (20–30 years). Sleep deprivation is universal among health care providers. A study of Canadian 12-h shift nurses reported that night shift nurses slept 3 h shorter than day shift nurses. Although sleep time did not statistically different according to shift schedule in the present study, participants in night-shift periods slept an average of 5.2 h, despite having the longest working hours (10.5 h). The potential sleep deficit could lead to impaired health problems and work performance. Less than 6 h of sleep per day doubles the risk for workplace accidents compared to more than 7 h of sleep.

Nurses who work a rotating shift schedule commonly complain of poor sleep, particularly after night-shift periods. Core body temperature and arousal capacity are increased during the day. Urine levels of 6-sulfatoxymelatonin concentrations are reportedly 62% lower during daytime sleep of night shift workers than during nighttime sleep of day shift workers. The resulting derangement of biomarkers of circadian rhythm during daytime sleep may account for sleep onset and maintenance insomnia in night shift workers. The nurses participating in this study worked a rotating three-shift schedule in an irregular order with intervals of 1–5 days between shift periods. This rapidly changing schedule is insufficient to allow adaptation of different sleep and wake times. Time to bed and time out of bed differed according to the shift schedules. In sleep-wake parameters, the TIB and number of arousals showed statistical significance among groups. The TIB was the shortest (6.0 h) in the participants’ night-shift periods,
fluences sleep initiation and maintenance. In this study, the cumulative light exposure was the highest in participants' evening-shift periods. However, light exposure during biological nighttime (delay portion of the phase response curve) could deteriorate sleep quality. It might result in the highest arousal level during sleep in evening-shift periods. Sleep efficiency was <85% in the participants' evening- and night-shift periods, and WASO exceeded 30 min during all shift periods. This finding indicated that sleep of rotating shift nurses was impaired regardless of shift schedules.

Mean ISI score was high (14, range 9–19) with four (33.3%) reporting clinically significant insomnia. All participants denied experiencing insomnia-related symptoms before beginning rotating shift work. The overall prevalence of insomnia among Koreans is approximately 17%. Considering relative young age of the participants (mean 26.4 years), sleep-wake parameters and ISI scores suggest that rotating shift workers have serious sleep-related problems.

Light is a potent stimulus in the regulation melatonin production by the pineal gland and, more broadly, circadian rhythm in humans. Light exposure before and after sleep influences sleep initiation and maintenance. In this study, the cumulative light exposure was the highest in participants' evening-shift periods. This may be related to clock time out of bed (10.60±1.73 h) and the timework commenced (13.75±2.00 h) in participants' evening-shift periods. However, when divided into working and non-working hours, light exposure (mean lux) in participants' night-shift periods was the lowest during working hours and the highest during non-working hours. To clarify the relationship between light exposure and sleep initiation, light exposure was compared 5 h before and after time to bed among the three shift schedules. Mean 5-h light amount was highest in participants' night-shift periods than day- or evening-shift periods. When parsed out in hourly intervals, light exposure in the participants' night-shift periods was definitely higher for the 7-h window from 4 h preceding time to bed to 2 h after time to bed, compared to the day- or evening-shift periods. These findings indicate that nurses in night-shift periods work exclusively under artificial light (mostly in dimly lit patient rooms) and sleep after work in bedrooms that are not completely shielded from ambient light. Studies about light exposure in rotating shift workers have reported conflicting data. Light intensity was significantly higher during sleep for those working at night in female rotating shift nurses, however, Dumont et al. did not find any differences in median light exposure between the night-shift and the day/evening-shift periods, either during work time or over the 24 h. Between-study differences could be related to light intensity levels during night work. Light exposure during working hours in participants' night-shift periods (mean 146.01 lux) was much higher compared to previous study (mean 72.5 lux). Moreover, highest light exposure during non-working hours in night-shift periods (mean 402.9 lux) may be related to the fact that none of participants wore sunglasses during commuting time to go home after night work. The recommendations with avoidance of bright light toward the latter portion of the work period and during the morning commute home would not be for rapidly rotating shift workers. The total activity level during working hours was not different among the shift schedules. The higher activity level of participants' day-shift periods than evening-shift periods during non-working hours may be related to the earlier time after work (16:56 h in day-shift periods vs. 23:58 h in evening-shift periods).

Shift work is associated with various health problems. In this study, 75% of participants reported an irregular menstruation cycle that did not exist before shift work. Considering that the prevalence of irregular menstruation cycle is about 17% in female workers in general, the present value is extremely high. Female shift workers are at high risk for hormonal imbalance related to circadian disruption. They have higher levels of follicular stimulating hormone and luteiniz-
the final numbers of shift periods involved in the analyses were different. Lastly, we did not measure mood that might affect sleep quality or sleep duration. It seems that homogenous group with narrow age ranges (23–34 years) and same gender (all females) in this study may increase the reliability of the results and limit the generalization of the results in participants with shift work related sleep disorder. Previous studies in sleep of shift workers had mostly relied on self-reported questionnaires.\(^5\),\(^6\),\(^7\),\(^8\),\(^9\),\(^10\) The strength of this study is the measurement and comparison of light exposure and activity level according to different shift schedules in the same shift worker population. In conclusion, nurses working a shift schedule featuring short periods of the different shift hours experienced shorter and less restful sleep. Furthermore, participants’ night-shift periods featured reduced light exposure during working hours and increased exposure during non-working hours (usually TIB at home). Rapidly rotating shift schedules and related in-appropriate light exposure may be detrimental to sleep and health in shift workers.

Acknowledgments

We are thankful to Ms. Su Hwa Yun for her technical help and to all participants who actively join this project.

This research was supported by Basic Science Research Program through the National Research Foundation of Korea funded by the Ministry of Science, ICT & Future Planning, Republic of Korea (No. 2014R1A1A3049510) and by Samsung Biomedical Research Institute grant (#OTX0002111).

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