Bright Light Exposure at Night and Light Attenuation in the Morning Improve Adaptation of Night Shift Workers

In-Young Yoon MD, PhD,[1] Do-Un Jeong MD, PhD,[2] Ki-Bum Kwon MD,[1] Sang-Bum Kang MD,[1] and Byoung-Gun Song MD[1]

[1]Yong-In Mental Hospital; [2]Department of Neuropsychiatry and Division of Sleep Studies and Clinical Research Institute, Seoul National University Hospital

Summary: With practical applicability in mind, we wanted to observe whether nocturnal alertness, performance, and daytime sleep could be improved by light exposure of tolerable intensity and duration in a real work place. We also evaluated whether attenuating morning light was important in adaptation of real night shift workers. Twelve night shift nurses participated in this study. The study consisted of three different treatment procedures: Room Light (RL), Bright Light (BL), and Bright Light with Sunglasses (BL/S). In RL, room light exposure was given during the night shift and followed by 1 hr exposure to sunlight or 10,000 lux light the next morning (from 08:30 to 09:30). In BL, a 4-hour nocturnal light exposure of 4,000-6,000 lux (from 01:00 to 05:00) was applied and followed by the same morning light exposure as in RL. In BL/S, the same nocturnal light exposure as in BL was done with light attenuation in the morning. Each treatment procedure was continued for 4 days in a repeated measures, cross-over design. Nocturnal alertness was measured by a visual analog scale. Computerized performance tests were done. Daytime sleep was recorded with actigraphy. The most significant overall improvement of sleep was noted in BL/S. BL showed less improvement than BL/S but more than RL. Comparison of nocturnal alertness among the 3 treatments produced similar results: during BL/S, the subjects were most alert, followed by BL and then by RL.

Real night shift workers can improve nocturnal alertness and daytime sleep by bright light exposure in their work place. These improvements can be maximized by attenuating morning light on the way home.

Key words: night shift worker; alertness; sleep; bright light; sunglasses

INTRODUCTION

THE NIGHT SHIFT WORK SYSTEMS, WHICH ARE NOW COMMONLY PRACTICED,[1] CAUSE DECLINES IN ALERTNESS AND COGNITIVE FUNCTION DURING THE NIGHT SHIFT, AND SLEEP DISTURBANCES IN THE DAYTIME.[2,3] That is because endogenous circadian rhythms may not synchronize with the sleep-wake pattern which is artificially reversed by working conditions.

To facilitate night shift adaptation, there have been several attempts to delay endogenous circadian rhythms by providing light at night.[4,5,6] As most of these studies have been performed in laboratories or under artificially controlled conditions, applying previous methods in real situations may not be feasible. For example, exposing subjects to 10,000 lux light for seven hours[4] at night or making subjects have a baseline as long as 10 days[5] is burdensome and hardly practical. Providing less than 50 lux light during simulated night shifts except during the light exposure time[6] could not be practical in a real workplace where illumination at times approaches 800 lux. The human circadian pacemaker is sufficiently sensitive to light that phase-shifts reaching could be influenced by indoor light of even 200 lux.[7]

For these reasons, it is important to validate light exposure effects in real shift workers. If night shift workers were exposed to light of 4,000 ~ 6,000 lux at night, their alertness and performance would be expected to be improved, due to the alerting effect of light.[8] We can expect that maintaining alertness at night would also improve daytime sleep. Attenuating morning light by using sunglasses[5] is proposed to play a role in night shift adaptation by maintaining phase-delay during night, as morning light could induce phase-advance on the phase response curve (PRC).[9,10]

With practical applicability in mind, the aims of this study were: first, to observe whether nocturnal alertness and daytime sleep are improved by light exposure of tolerable intensity and duration in a real workplace; and second, to evaluate whether attenuating morning light is important in adaptation of real night shift workers.

SUBJECTS AND METHODS

Subjects

Twelve female nurses assigned to night shift work schedules in Yong-In Mental Hospital participated in the study and each subject signed an informed consent. For precise control of study processes, the subjects were recruited from nurses who lived in the hospital dormitory, located a five-minute drive away. Suspected depressive subjects who scored more than 16 points on Beck Depression Inventory (BDI) were excluded. Based on the morningness-eveningness questionnaire of Horne and Östberg,[11] definitely morning and evening types were excluded. The age of subjects was 21-24 years. They had worked on rotating schedules comprising day-shift, evening shift, and night shift for six months to three years, and each shift went on for three to four days. Their shift had been in counterclockwise direction, that is, night shift to day shift to evening-shift. This direction gave more free time to the nurses compared to clockwise direction, which is known to

Disclosure Statement
Nothing to disclose.

Submitted for publication December 2000
Accepted for publication January 2002
Address correspondence to: Do-Un Jeong MD, PhD, Department of Neuropsychiatry and Division of Sleep Studies and Clinical Research Institute, Seoul National University Hospital, 28 Yongon-dong, Chongnogu, Seoul, 110-744, Republic of Korea; Tel: 82-2-760-2294; Fax: 82-2-766-1592; E-mail: jeongdu@snu.ac.kr

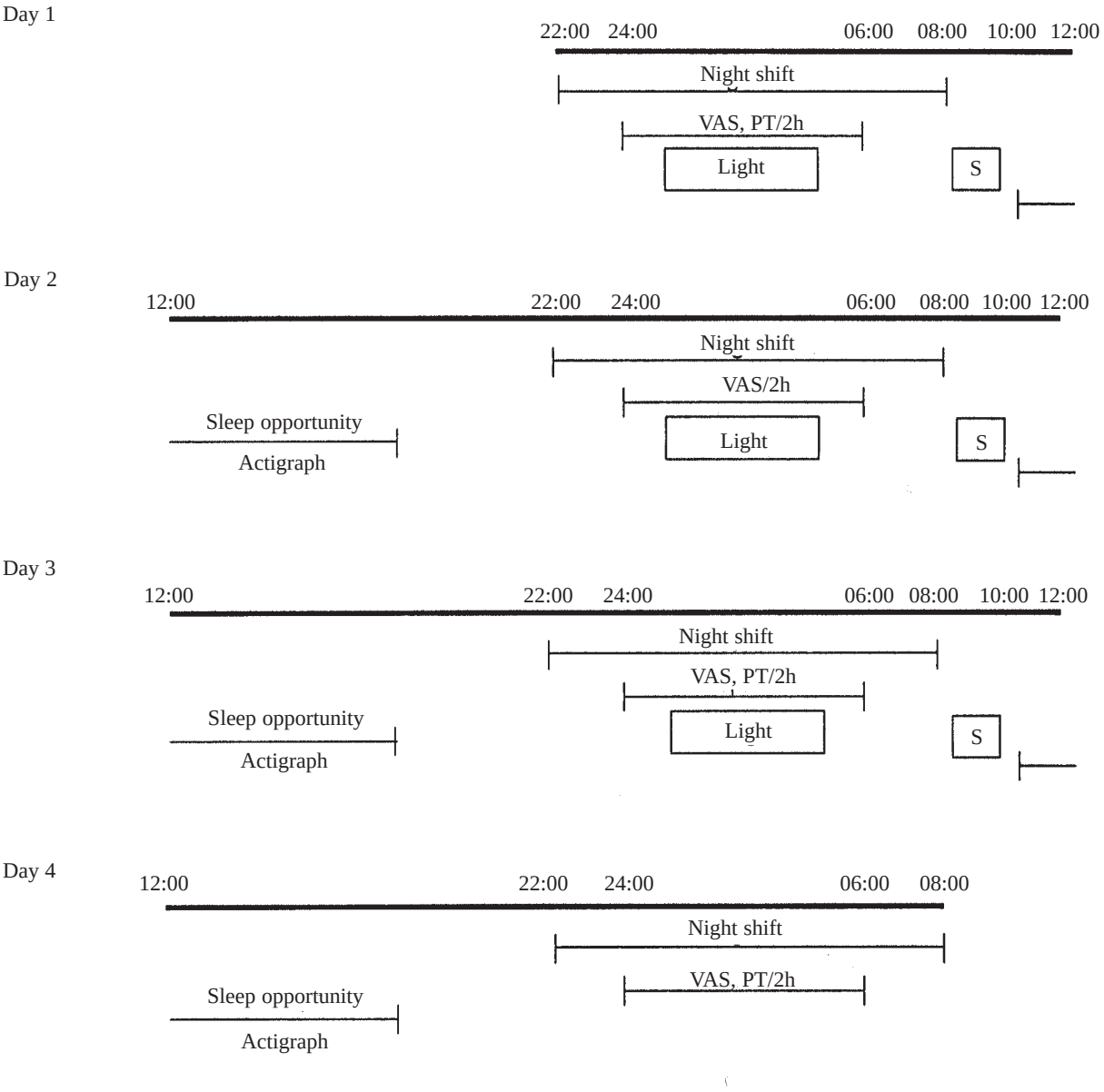

Figure 1—Schematic presentation of the study process. Light: bright light exposure from 01:00 to 05:00 during bright light treatment (BL), and bright light treatment with sunglasses (BL/S). S: sunlight from 08:30 to 09:30 during room light treatment (RL) and BL, or sunglasses worn when going home during BL/S. VAS: visual analog scale for alertness, PT: performance test.

be more favorable for night shift adaptation.

METHODS

Overall design

This study compared three different treatment procedures, each of which continued for four days of night shift, and each was scheduled one month apart from one another. Subjects were not allowed to work on night-shifts (from 22:00 to 08:00) for five days before each of the three treatment procedures to maintain normal sleep-wake and endogenous circadian rhythms. After finishing each treatment procedure, they returned to their original shift schedule with counterclockwise direction. Each subject received three treatments—Room Light (RL), Bright Light (BL), and Bright Light with Sunglasses (BL/S). RL was defined as the treatment in which there was only room light exposure at night with one hour exposure to morning light (see below). BL included nocturnal bright light exposure and morning light. BL/S included the same bright nocturnal light, and sunglasses were worn the next morning to maintain any phase-delay possibly induced by nocturnal light exposure. To control sequence effects, two subjects were allocated to each of six sequences: 1) RL-BL-BL/S, 2) RL-BL/S-BL, 3) BL-RL-BL/S, 4) BL-BL/S-RL, 5) BL/S-RL-BL, and 6) BL/S-BL-RL.

Light exposure protocol

Nocturnal light exposure. Light exposure of 4,000 to 6,000 lux for a four hour duration from 01:00 to 05:00 was done during BL and BL/S. Light was delivered by the Apollo Brite Lite III, which was 60.6cm X 32.5cm X 11.9cm. Each light box contained

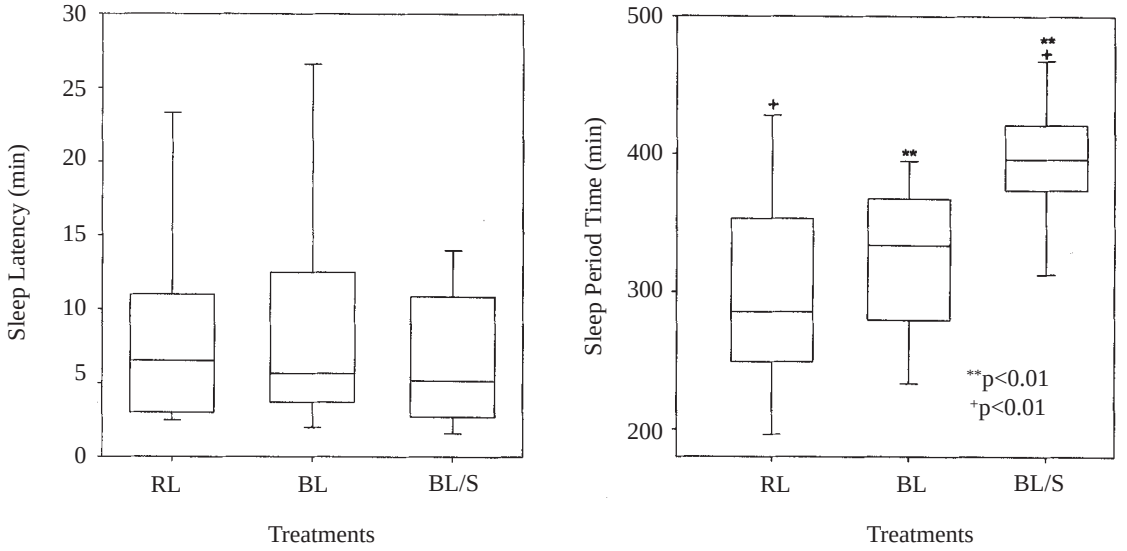

Figure 2—Sleep latency and sleep period time in relation to room light and bright light treatments. The boxes represent the median, and upper and lower quartiles. Error bars represent the 10th and 90th percentiles (RL: room light treatment, BL: bright light treatment, BL/S: bright light treatment with sunglasses).

two fluorescent lamps of "full spectrum" without ultraviolet. A light box was placed in front of each nurse just above eye level. Light exposure of 4,000 to 6,000 lux could be obtained at the distance of 80 to 100 cm between the light box and the nurse. Light intensity was measured by TES 1330 light meter. During all three treatments, the ward illumination at night was maintained as usual in the range of 100–500 lux. It reached 800 lux in the morning. During this exposure time, the subjects did charting or infrequent ward jobs, and made it a rule to look directly at the light box every 10 minutes to strengthen the light effect. The total time when light exposure was interrupted was less than 30 minutes. This light exposure treatment was done from the first to the third day of BL and BL/S.

Morning light exposure. During RL and BL, subjects were exposed to light for one hour from 08:30 to 09:30. Subjects were exposed to sunlight during their usual homeward journey, and we wanted to maintain this effect consistently. However, as it was impossible to be exposed to sunlight during rainy or cold days, subjects were exposed to 10,000 lux light indoors, based on the idea that the intensity of sunlight in the morning is about 10,000 lux.[12,13] Light intensity of 10,000 lux was provided by the above-mentioned Brite Lite III at the distance of 60cm. During BL/S, sunlight exposure was attenuated on the way home by wearing black sunglasses with transmission ranging between 15.6% and 27.5%. At the dormitory, where the illumination was less than 200 lux, subjects were asked to sleep before noon, depending on their own sleep-wake rhythm. In the afternoon, they were allowed to sleep as late as they wished, but they were advised to get out of bed as soon as they did not wish to sleep more. They were not allowed to have any fixed appointments or specific plans in the afternoon during the study days, in order not to have interrupted sleep.

In order to monitor their behaviors, subjects were asked to keep sleep diaries.

Assessment of daytime sleep, nocturnal alertness, and performance. Daytime sleep patterns were recorded objectively by the Mini-Motionlogger Actigraph made by Ambulatory Monitoring, Inc. The actigraph was worn on the subject's left wrist. Subjective alertness during the night shift was assessed by a visual analog scale (VAS). The VAS was done four times from 24:00 to 06:00 at two hour intervals on all the four days, with 100 denoting "most alert state" and 0 denoting "most sleepy state." Sleep latency (SL), sleep period time (SPT), total sleep time (TST), and sleep efficiency (SE) were derived from actigraphic data with Action3 software. Sleep efficiency (SE) was calculated by dividing TST by time in bed (TIB). We tested performance with a backward masking test (BMT) and the digit symbol substitution test (DSST) installed in a notebook computer. Subjects self-administered these tests four times from 24:00 to 06:00 at two-hour intervals. Performance tests were done on the first, third, and fourth day. To exclude confounding by any practice effect, subjects learned and practiced these test sufficiently before entering this study. Schematic presentation of the study process is shown in Figure 1.

Statistical analysis. We used SPSS 9.0 for Windows for statistical analyses. When the Kolmogorov-Smirnov test confirmed normality, parametric tests were done. Using repeated measures ANOVA, we compared sleep variables, alertness, and performance test results among the three treatments. Paired t-tests were done between two treatments, if ANOVA showed significance. To observe relationships between two variables, Pearson correlation coefficients were obtained. Significance was defined at $p<0.05$.

RESULTS

Comparison of daytime sleep. We compared daytime sleep among the three treatments on sleep latency (SL), sleep period time (SPT), total sleep time (TST), and sleep efficiency (SE) by

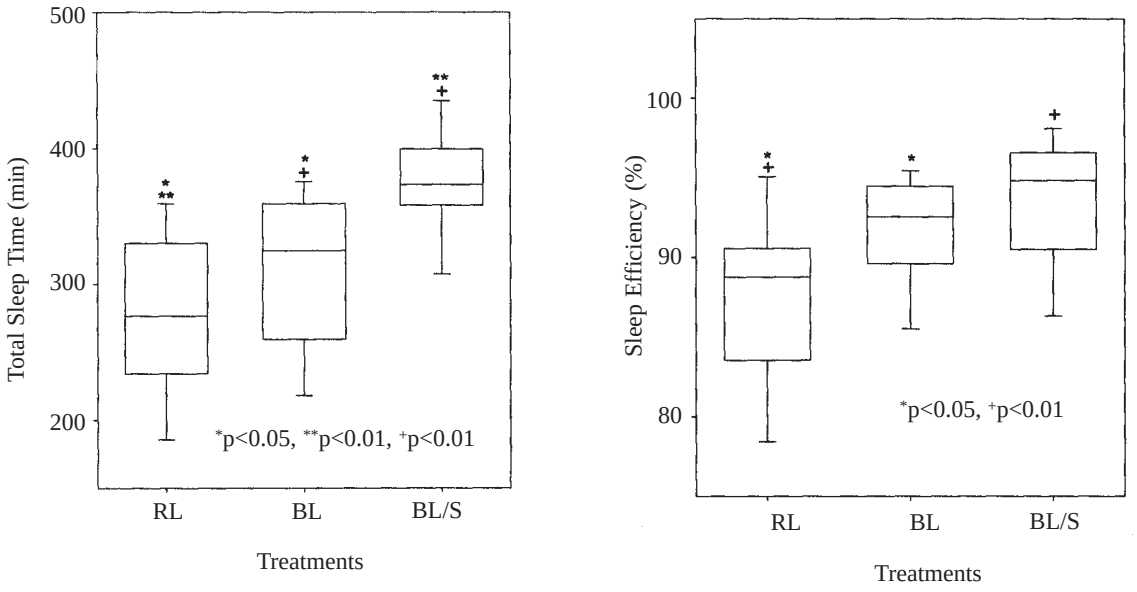

Figure 3—Total sleep time and sleep efficiency in relation to room light and bright light treatments. The boxes represent the median, and upper and lower quartiles. Error bars represent the 10th and 90th percentiles (RL: room light treatment, BL: bright light treatment, BL/S: bright light treatment with sunglasses).

averaging the results over three days of each treatment. SL's were 9.1 minutes (±8.6), 9.6 minutes (±9.4), and 6.8 minutes (±5.0) in RL, BL, and BL/S, respectively, and there were no significant differences among the three treatments, with the tendency for SL in BL/S to be shortest (Figure 2). SPT's were 299.6 minutes (±84.2), 321.3 minutes (±65.8), and 393.7 minutes (±62.0) in RL, BL, and BL/S, respectively ($p<0.05$, ANOVA). SPT of BL/S was significantly lengthened, compared with that of RL and BL ($p<0.01$, $p<0.01$, paired t-tests) and SPT of BL tended to be longer than that of RL (Figure 2). TST's were 275.8 minutes (±71.8), 308.3 minutes (±65.0), and 375.2 minutes (±53.5) in RL, BL, and BL/S, respectively ($p<0.05$, ANOVA). TST of BL/S was significantly lengthened, compared with that of RL and BL ($p<0.01$, $p<0.01$, paired t-tests), and TST of BL was longer than that of RL ($p<0.05$, paired t-test) (Figure 3). There were also differences in SE's among the three treatments ($p<0.05$, ANOVA). SE's were 87.5% (±5.8), 91.4% (±4.3), 93.3% (±5.5) in RL, BL, and BL/S, respectively. SE of RL was significantly lower than that of BL/S and BL ($p<0.01$, $p<0.05$, respectively, paired t-tests) but there was no difference in SE between BL and BL/S (Figure 3). Putting these results together, sleep qualities and quantities were most prominently improved in BL/S, followed by BL.

Comparison of alertness during night shift. We compared alertness during the night shift among the three treatments by analyzing subjective VAS results. After averaging VAS scores at 02:00, 04:00, and 06:00 over the total 12 study days and averaging VAS scores at 02:00, 04:00, and 06:00 for each day, the latter divided by the former and multiplied by 100 was defined as % subjective alertness of each day. Alertness during the night shift was compared in two aspects. First, we observed how both phase-shift and alerting effects of light would influence alertness by comparing average alertness of the second and third days of RL, BL, and BL/S. Second, we observed the effects of phase-shift alone on alertness by comparing alertness of the fourth day of RL, BL, and BL/S, when there was only room light.

Percent average alertness on VAS of the second and third days of RL, BL, and BL/S were 86.1 (±19.4), 105.9 (±20.4), and 116.8 (±21.6), respectively ($p<0.05$, ANOVA). Alertness on VAS of BL and BL/S were significantly increased compared with that of RL ($p<0.05$, $p=0.01$, respectively, paired t-tests), with no difference between BL and BL/S (Table 1). Percent alertness on VAS of the fourth day of RL, BL, and BL/S were 88.0 (±18.2), 93.1 (±17.6), and 109.5 (±19.6), respectively ($p<0.05$, ANOVA). Alertness on VAS in BL/S significantly increased compared to RL ($p<0.05$, paired t-test), with no differences between RL and BL or between BL and BL/S (Table 1). Summing these results up, alertness on VAS increased most remarkably in BL/S, followed by BL.

Comparisons of performance during the night shift. As with alertness, performance of each day was presented as % of the average performance for the total study days. The backward masking test (BMT) performance was assessed by the number of correct answers to the 60 stimuli. The digit symbol substitution test (DSST) performance was assessed by the average response speed to the 90 stimuli presented for one and a half minutes (reaction time) and by % of correct answers (correction rate). To observe the effect of direct light exposure on performance, averaged test results on the first and third days of RL and BL were compared, and to observe the effects of both direct light exposure and phase-shift on performance, test results on the third day of BL and BL/S were compared. To observe the effect of phase-shifts on performance, we compared test results on the fourth day of each treatment. Both in BMT and DSST, there were no significant differences in any of the comparisons. Although differences were statistically non-significant, performances in BL and BL/S tended to improve compared to RL. Between alertness on VAS and performance test results, only reaction time was weakly cor-

Table 1—Comparison of alertness among room light and bright light treatments on visual analog scale (VAS) for alertness

Subj No	RL		BL		BL/S	
	Day 2-3*	Day 4+	Day 2-3*	Day 4+	Day 2-3*	Day 4+
1	108.6	106.6	108.6	91.4	108.6	99.1
2	89.5	93.5	109.1	93.5	128.5	62.4
3	85.4	112.0	90.6	74.7	117.4	112.0
4	89.2	104.9	99.7	104.9	104.9	104.9
5	47.1	47.1	113.8	109.9	168.6	117.6
6	94.8	64.0	129.2	90.0	92.5	125.6
7	51.6	83.6	105.7	93.4	132.7	142.6
8	77.3	86.0	98.9	47.3	127.8	124.6
9	99.1	95.3	95.4	106.8	108.7	106.8
10	101.4	92.9	116.2	101.4	85.6	101.4
11	105.0	81.4	102.4	110.2	106.3	99.7
12	84.4	89.0	105.9	93.8	119.5	117.2
Mean	83.1	88.0	105.9	93.1	116.8	109.5
SD	18.5	18.2	20.4	17.6	21.6	19.6

Numbers denote % alertness compared with average of total 12 study days as 100%
Day 2-3: average value of % alertness of Day 2 and Day 3
RL: room light, BL: bright light, BL/S: bright light with sunglasses
SD: standard deviation
*p<0.05, +p<0.05 (by repeated measures ANOVA)

related with alertness on VAS (r=0.20, p<0.05).

DISCUSSION

To overcome the limitations of the previous light exposure studies in practical application, this study was done in a real work place setting. The results were that in BL/S, where bright light exposure was provided at night and morning light was attenuated by wearing sunglasses, more alertness during the night shift and better daytime sleep were observed than in BL. However, subjects in BL, where both bright light exposure at night and sunlight exposure at morning were done, also felt more alert at night and slept better in the daytime than those in RL.

The reasons why daytime sleep was most improved in BL/S could be explained as follows. First, a phase-delay possibly induced by bright light exposure at night and morning light attenuation could tend to synchronize endogenous circadian and sleep-wake rhythms, leading to sleep improvement. Previous studies reported that daytime sleep is improved by phase-delay of moderate to large magnitude[4,5,6] for several days. However, in those studies, the magnitude of daily phase-delay was two to three hours, and sleep was improved from the first day after light exposure was given. Thus, it is predictable that even a small magnitude of phase-delay could improve sleep. Second, morning light exposure for one hour in RL and BL might cause poorer sleep, perhaps by suppressing melatonin, although there have been controversies about the residual alerting effect of light after light exposure. Some reported that sleep was not affected after light exposure,[14] but others reported that sleep latency was lengthened after light exposure.[15,16]

Alertness during the night shift was also remarkably improved in BL/S. A direct alerting effect of light could produce this result, perhaps as a result of melatonin suppression and temperature elevation.[17] Light exposure causes transient temperature elevation and alertness improvement,[18] which are reversed with melatonin administration. Alertness suppression might be related to the fact that melatonin lowers body temperature.[19] Circadian phase-shifts and differences in daytime sleep might also explain the difference in alertness among the three conditions.

Performance, unlike daytime sleep and alertness at night, was only slightly improved during light exposure treatments. Previous study showed more or less similar results.[20] Besides alertness, motivation, practice effects, and cognitive processes less affected by sleepiness could influence performance. This explanation is supported, since performance tests used in this study showed little or weak correlations with alertness.

As this study was done in real workplace, it was very difficult to measure circadian markers such as core body temperature (CBT) and melatonin. CBT is known to be masked by light, sleep, and activity,[21,22] which cannot be controlled while subjects work. Considering that melatonin could be suppressed by light intensities of around 300 lux,[23,24] melatonin cannot be reliably measured in real workplace setting of which light intensity is between 100 to 800 lux. With these limitations, we could not incorporate measurement of circadian markers into this study on real shift workers.

In conclusion, night shift nurses can improve nocturnal alertness and daytime sleepiness by bright light exposure of tolerable intensity and duration in their workplace. These improvements can be maximized by attenuating morning light on the way home.

ACKNOWLEDGMENTS

We thank Prof. Daniel F. Kripke for his help in revising the manuscript.

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