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Brief Morning Exposure to Bright Light Improves Subjective Symptoms and Performance in Nurses with Rapidly Rotating Shifts

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Abstract: Brief Morning Exposure to Bright Light Improves Subjective Symptoms and Performance in Nurses with Rapidly Rotating Shifts: Katsutoshi TANAKA, *et al*. Department of Occupational Mental Health, Graduate School of Medical Sciences, Kitasato University—Objective: To investigate whether or not brief bright light (BL) exposure on workday mornings can improve health, performance and safety in nurses with rapidly rotating shifts. **Methods:** We conducted a randomized crossover study involving registered nurses at a teaching hospital working a two-shift system including the night shift. Participants were instructed to expose themselves to BL for 10 min on workday mornings. **Results:** A total of 61 participants were enrolled in the present study. Thirty-one participants received BL exposure in the first month, and the other 30 received it in the second month. Significant improvements were noted in the BL periods compared with the non-BL periods for self-assessed sleepiness at 10:00 on day-shift days evaluated using the Karolinska Sleepiness Scale, self-assessment of night sleep for day-shift days using the Visual Analogue Scale and for fatigue assessed using the Checklist Individual Strength Questionnaire. The estimated mean difference for each scale (95% confidence interval) was –0.55 (–0.91, –0.20), 0.37 (0.04, 0.70) and –2.13 (–3.78, –0.48), respectively. Mean response time evaluated using the psychomotor vigilance task test (PVT) showed significant improvement in the BL periods compared with the non-BL periods. No statistically significant differences were observed for sleepiness at 14:00, depression, number of PVT lapses or frequency of perceived adverse events and near misses. **Conclusion:** Our findings suggest that brief BL exposure on mornings preceding a day shift is effective in improving sleepiness and performance during day-shift work, subjective nighttime sleep on day-shift days, and perceived fatigue for the preceding two weeks in rapidly rotating shift nurses.
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Key words: Bright light, Nurse, Shift work, Sleepiness, Randomized crossover study

Working the night shift is a recognized risk factor affecting health, safety and social well-being[1–3]. Studies suggest that night-shift work contributes to a misalignment between the circadian rhythm and the normal sleep-wake schedule, disturbed physiological rhythms and sleep debt, subsequently resulting in development of a number of symptoms including fatigue and an increased risk of committing errors in the workplace[4, 5]. Previous studies in the medical field have shown that nurses working rotating shifts including night shifts are overall less healthy and more frequently make medical errors than day shift nurses not working rotating shifts[6–8].

To prevent detrimental effects to health and safety, several studies have developed countermeasures, primarily focusing on improving alertness and performance during night-shift work. Findings indicate that planned napping during a night shift improves fatigue, alertness and performance among night shift nurses[9–11]. Nighttime exposure to bright light (BL) has also been shown to be effective in improving alertness and performance during night-shift work[12–14]. BL exposure before the endogenous

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body temperature nadir induces a phase delay[15]. Delaying the phase position of one's circadian rhythm by nighttime BL exposure can promote adaptation to night-shift work, thereby enabling workers to remain alert and active during the night shift. However, nighttime BL exposure can delay circadian rhythm recovery on returning to a schedule of night sleep and day work[16, 17] and may increase the risk of breast cancer[18].

Under most shift rotation schedules, nurses are typically assigned more non-night shifts than night shifts. Attention must therefore be focused not solely on adapting to night shifts, but on reducing the negative effects of working night shifts on day life and on improving alertness and performance on day shifts.

Morning BL exposure may be able to reduce the negative effects caused by working night shifts. Night-shift work, artificial lights and activity at night have been shown to contribute to a phase delay in circadian rhythm and induce fatigue and sleep disturbances[8, 19]. In contrast to nighttime BL exposure, morning exposure after the endogenous body temperature nadir has been shown to induce phase advance[15, 20], thereby resolving misalignment between the circadian rhythm and the normal sleep-wake schedule and improving disturbed sleep. Bjorvatn *et al*. suggested that daytime BL exposure following a period of night work facilitated readaptation to day life[21]. Other studies have found that BL exposure at any point can directly improve alertness and performance for several hours[22–24].

Here, to assess the effects of brief workday morning BL exposure on daytime sleepiness, nighttime sleep, fatigue, safety and performance of shift workers, we conducted a randomized crossover study among nurses working rapid rotation schedules including a night shift.

Participants and Methods

Participants

A total of 276 registered nurses at a teaching hospital working a two-shift system were invited to participate in the present study from April to May 2006. The day shift at the hospital was 08:00–17:00, while the night shift was 16:30–08:30; the night shift included a 2-hour nap/break period between 00:00 and 04:00. According to hospital protocol, night shifts were limited to a maximum of two consecutive nights, and workers were required to take one or more days off after completing a night shift. Participants worked under a rapidly rotating shift schedule, which usually comprised a cycle of two or three consecutive day shifts, a day off and then a night shift or two consecutive night shifts followed by a day off. In order to meet the needs of staff members, the schedule was not strictly regular. The hospital had a policy requiring nurses to keep overtime hours to a minimum.

Eligible participants were men and women aged 20 to 60 yr working a two-shift system including the night shift. Individuals with sensitivity to bright light, eye disorders including asthenopia or who reported headaches or mood disorders were excluded from participation. The senior nursing officers were also excluded from the study because they were not primarily involved in nursing cases.

The methods involved in the present study were explained verbally and in writing, and participants submitted written consent after being informed that participation was strictly voluntary and that they would not be penalized for nonparticipation or for withdrawing after agreeing to participate.

Study design

The present study was an open-label, crossover, randomized, controlled trial. The participants were randomly assigned to one of two groups: a group for BL exposure in the first half of the study and a group for BL exposure in the second half. Random assignment was performed using a permuted block method with a block size of four. No stratification was performed. A random number sequence was generated by a computer. A research assistant with no direct contact with participants was responsible for generating the random numbers.

The intervention period was from the beginning of June to the beginning of August 2006. The first-half BL exposure group was instructed to perform BL exposure for all day-shift workdays for one month, at 10 min/session in the period before beginning their shift (07:30–08:00). To enhance the effectiveness of BL exposure, participants were further urged to consistently perform BL exposure on the first day that they worked the day shift after having worked the night shift. Aside from exposing themselves to morning BL on day-shift days, participants were asked to continue with their normal home lifestyles and social activities without any restrictions on activities such as napping or being exposed to daylight while returning home after working a night shift. During this same period, the second-half BL exposure group was instructed to continue their lifestyles as usual.

After a washout period of one week, the two groups switched roles, and the second-half BL exposure group performed morning BL exposure for all day-shift workdays for one month. All participants were instructed to withdraw from the study immediately and to notify a researcher if they experienced any adverse effects due to bright light exposure.

The study protocol was approved by the Institutional Ethics Committees of Showa and Kitasato Universities.

BL exposure

Given how busy their schedules are before work even begins, nurses have little time to spare for morning BL exposure. Although several reports have cited success in utilizing BL exposure times exceeding 30 min[25], shorter implementation times are desirable. In the present study,

participants were instructed to receive BL exposure for 10 min on workday mornings using a BL device (Travelite; Northern Light Technologies, Montreal, Canada). The light source was placed in the staff lounge at the nurses' station. With regard to the specific conditions of exposure, the mean (SD) illumination at 30 cm from the light source was 8,826 (104) lux and was 5,444 (44) lux at 40 cm from the light source. Brightness was measured with a lux meter (Illuminance meter T-10; Konica Minolta, Tokyo, Japan) three times. Instead of looking directly at the light source, participants were instructed to sit approximately 30–40 cm from the light source with their eyes gently closed or while reading documents placed on a desk. The nurses' station was a windowless room lit only by regular room lighting. The daytime and nighttime mean (SD) brightness as measured with a lux meter placed on the table in this room was 648 (24) and 530 (21) lux, respectively.

BL exposure was scheduled only on workday mornings to maintain consistency in condition of exposure among participants, ensure accurate records of exposure and avoid interference with participants' lifestyles. However, given that intervention was implemented in the actual workplace in the present study, we made efforts to avoid excessive inconvenience and informed participants that they did not need to force themselves to receive the intervention if they could not secure sufficient time to receive BL exposure. Further, we did not ask participants their reasons for not receiving BL exposure.

Outcome measures

The primary objective of the present study was to assess the effect of morning BL exposure on sleepiness during the working period on day-shift days. Daytime sleepiness is a typical symptom of sleep disturbance and a fundamental issue related to performance and safety in the workplace. Sleepiness during day-shift working hours was assessed using the Karolinska Sleepiness Scale (KSS), which uses a 9-point Likert scale of sleepiness validated against alpha and theta electroencephalographic activity as well as eye movement-associated electrooculographic activity to assess degree of sleepiness[26, 27]. Higher scores indicate a greater degree of sleepiness. For day-shift days, participants were instructed to complete the KSS at approximately 10:00 and 14:00.

The secondary objective was to asses the effect of BL on self-assessment of nighttime sleep satisfaction on day-shift days, fatigue, frequency of perceived error-related adverse events and near misses and nurse performance. Self-assessment of night sleep for day-shift days was assessed using a visual analogue scale (VAS; scores from 0 to 10, with 0=unable to sleep at all and 10=able to sleep very well). Participants were instructed to note their self-assessment of night sleep for day-shift days on the following morning. Fatigue was assessed using the Checklist Individual Strength (CIS) questionnaire[28, 29]. The CIS questionnaire consists of 20 statements referring to aspects of fatigue experienced over the previous 2 wk, and participants were instructed to select their response on a 7-point Likert scale. Higher total CIS scores indicate a higher degree of fatigue. Participants were instructed to provide responses to the CIS questionnaires in the third or fourth weeks of both the BL and non-BL periods. The frequency of perceived adverse events and near misses in the previous month was inquired about at the end of the BL and non-BL periods. An unanticipated and undesirable outcome caused by medical errors is often categorized as either an "adverse event" (accidents or harmful events) or a "near miss" (close misses or potential adverse events)[30]. An adverse event caused by error was defined as an unanticipated incident in which a self-error was made and harm occurred to a patient[31]. To assess the frequency of perceived adverse events in the previous month, the questionnaire inquired, "In the previous month, how often do you feel a patient experienced injuries or disadvantages due to an error on your part?" A near miss caused by error was defined as an unanticipated incident in which an error was made but no harm occurred[32, 33], and the questionnaire inquired into the frequency of near misses with the question, "In the previous month, how often do you feel you experienced a self-error-related near miss, in which an error was made but no harm occurred to a patient?"

The effect of BL on nurse performance was assessed using the psychomotor vigilance task (PVT) test. Volunteers were recruited from among the study participants to perform the test using a PVT-192 unit (Ambulatory Monitoring, Inc., Ardsley, NY, USA). Testing was performed during the afternoon break period of the day shift (approximately 14:00–15:00) twice each for both the BL and non-BL periods (four trials total), with a setting of five minutes for each test. Results were evaluated using mean response time (RT) and number of lapses (number of times RT exceeded 500 msec).

In addition to the above assessments, participants were asked to freely describe anything they noticed about BL exposure at the end of the intervention period.

At the beginning of the study, participants were asked to complete a self-report questionnaire to assess demographic characteristics and lifestyle habits. At the end of the BL and non-BL periods, the number of shifts per month, day-shift and night-shift caffeine consumption (cups per day), frequencies of alcohol intake (mean times per week), whether or not the participant takes a routine night shift nap and use of sleep-affecting drugs during the study period were investigated. During exposure, participants were asked to record duration of BL exposure and distance from the light source to the subject's eye (distance measured by personal sense in reference to marks of 30 cm and 40 cm from the light source). Mean length and mean distance from the light source to the subject's eye as well as total number of instances of BL exposure

was inquired about using a self-report questionnaire at the end of the BL period. In addition to the above items, participants were asked to keep a sleep diary.

Sample size

To calculate the required sample size easily, a two-tailed paired t-test (α=0.05) was used to assess differences in KSS points between the BL and non-BL periods, a main outcome of our study. We assumed a mean difference of 1.0 point between the BL and non-BL periods, a standard deviation (SD) of 2.5 for the KSS point for each period and correlation coefficients of 0.5 for KSS points in both the BL and non-BL periods from the previous studies[26, 27]. Taking these assumptions into account, we calculated that a sample size of 51 would be required to ensure a statistical power of 80%. For this reason, we sought to recruit about 60 participants.

Statistical analysis

Between-group analysis with regard to BL exposure was performed based on intent to treat, comparing the mean KSS score for 10:00 and 14:00 for the day shift, mean VAS score representing the self-assessment of night sleep for day-shift days, CIS score, number of near misses and adverse events and PVT, mean RT and number of lapses (>500 msec) for day-shift days. Since the mean could be subject to outliers, the means of the RTs were transformed to reciprocal RTs (1/mean RT), and the numbers of lapses were transformed as, $\sqrt{(x)}+\sqrt{(x+1)}$ where x is the concerting number[34]. Mean values for the BL and non-BL periods were compared using a linear mixed-effect model with BL, order and BL × order interaction as the fixed effects and individuals as the random effects. All analyses were performed using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA).

Results

Of the 276 registered nurses initially approached, 61 agreed to participate in the present study, all of whom were found to be eligible for participation. Using the permuted-block randomization, 31 participants were assigned to receive BL exposure for the first month, and the remaining 30 were assigned to receive exposure for the second month. No participants dropped out or were excluded from the study.

Table 1 shows the demographic characteristics of the study participants. All participants were female, and the mean (SD) age was 29.7 (8.6) yr, age range was 20–60 yr and mean number of years of experience was 7.5 (6.9) yr. Eight participants were receiving some form of medical treatment (three with allergic rhinitis, and one each with atopic dermatitis, hypertension, chronic rheumatoid arthritis, chronic gastritis and infectious mastitis).

As shown in Table 2, all nurses worked a two-shift system of 16 h of night-shift work. The mean (SD) number of night shifts was closely similar between the BL and non-BL periods, with respective frequencies of 4.7 (0.7) and 4.8 (0.9) shifts. The mean number of day shifts was also closely similar between the two periods. Although the mean number of day shifts during the BL period was 11.3, the mean number of instances of BL exposure was 8.5 times (SD=3.7; median=9.0, range=2–13 times). The mean (SD) exposure time for each instance was 7.8 (3.9) min, and the mean (SD) distance from the light source to the subject's eye position was 35.8 (10.3) cm. After study completion, measurement of brightness under the same conditions as BL exposure in the study showed the mean (SD) illumination to be 6,666 (160) lux at a distance of 36 cm from the light source. Consumption of caffeinated beverages for both day- and night-shift days, and frequency of use of hypnotic drugs and sleep-affecting medications other than hypnotics were closely similar for both the BL and non-BL periods. With regard to sleep-affecting medications other than hypnotics, nearly all participants used antiallergenics. The number of participants who reported routine napping during break-time was similar between the BL and non-BL periods, with the respective values being 42 (68.9%) and 40 (65.6%).

Table 3 describes the differences between the BL and non-BL periods with regard to the KSS scores between

Table 1. Demographic characteristics of participants (N=61, all female)

	Mean (SD)
Age (yr)	29.7 (8.6)
Years of experience	7.5 (6.9)
Workplace[1)]	Number (%)
Surgical ward	14 (23.0%)
Internal ward	23 (37.7%)
Emergency room and intensive care unit	12 (19.7%)
Other	12 (19.7%)
Current smoker	
Yes	11 (18.0%)
No	50 (82.0%)
Currently receiving treatment for an illness	
Yes	8 (13.1%)
No	53 (86.9%)

SD: standard deviation. [1)] The internal ward included internal medicine, dermatology, neurology and rehabilitation. The surgical ward included pediatrics, obstetrics, gynecology, ophthalmology, urology, otorhinology, anesthesiology (patients are often hospitalized for surgery in these wards) and all surgical departments (cardiovascular surgery, gastrointestinal surgery, respiratory surgery, cerebral surgery, orthopedic surgery and plastic surgery). The emergency room and intensive care unit included the pediatric and neonatal intensive care units and the operating room.

Table 2. Differences in condition between the BL and non-BL periods

	Non-BL period	BL period
	Mean (SD)	
Number of night work shifts per month	4.8 (0.9)	4.7 (0.7)
Number of days worked per month	11.3 (3.3)	11.3 (3.6)
Number of instances of BL exposure per month	N/A	8.5 (3.7)
Mean exposure time to BL (min)	N/A	7.8 (3.9)
Mean distance from light source (cm)	N/A	35.8 (10.3)
Day-shift caffeine consumption (cups/day)	2.3 (1.2)	2.3 (1.3)
Night-shift caffeine consumption (cups/day)	2.3 (1.4)	2.2 (1.4)
Alcohol consumption (times/week)	2.0 (1.7)	2.0 (1.7)
Night-shift nap	Number (%)	
Routinely napped	42 (68.9%)	40 (65.6%)
Did not routinely napped	19 (31.1%)	21 (34.4%)
Hypnotic drugs		
Never used	51 (83.6%)	51 (83.6%)
Used sometimes	7 (11.5%)	8 (13.1%)
Always used	3 (4.9%)	2 (3.3%)
Sleep-affecting medication other than hypnotics		
Never used	52 (85.2%)	54 (88.5%)
Sometimes used	5 (8.2%)	4 (6.6%)
Always used	3 (4.9%)	3 (4.9%)
Data missing	1 (1.6%)	0 (0.0%)

BL: bright light, SD: standard deviation, N/A: not applicable.

10:00 and 14:00 during day-shift days, VAS scores for self-assessment of nighttime sleep on day-shift days, CIS scores and frequencies of perceived adverse events and near misses. No significant main effect of order or interaction between BL and order were found for any items. A significant improvement was noted in the BL periods compared with the non-BL periods for the 10:00 KSS score ($F[1,55.6]=9.60$, $p=0.003$), the VAS score for nighttime sleep for day-shift days ($F[1,116]=4.48$, $p=0.03$) and the CIS score reflecting fatigue in the previous two weeks ($F[1,49.6]=6.73$, $p=0.01$), with respective estimated mean differences (95% confidence interval) of –0.55 (–0.91,–0.20), 0.37 (0.04, 0.70) and –2.13 (–3.78, –0.48). Although no statistically significant difference was noted between the BL and non-BL periods for self-assessed sleepiness at 14:00 on day-shift days, a tendency towards reduction was noted in the BL periods. The frequency of perceived adverse events and near misses was also lower in the BL than in the non-BL periods, but not significantly so.

Table 4 shows the differences in PVT scores between the BL and non-BL periods. Of the 61 participating nurses, 11 (18%) nurses underwent PVT testing during the afternoon break period of a day shift (approximately 14:00–15:00) twice each for both the BL and non-BL periods. No significant main effect of order or interaction between BL and order were observed for any items. The mean estimated value for preconversion RTs was significantly lower in the BL periods than in the non-BL periods (236 msec vs. 264 msec; $F[1,17.0]=10.98$, $p=0.0004$), and the reciprocal RTs (1/mean RTs) were also significantly lower in the BL periods than in the non-BL periods ($F[1,57108]=7.17$, $p=0.007$). Before conversion, the number of lapses also differed significantly between periods, with 2.03 instances in the non-BL periods and 0.84 in the BL periods ($F[1,17.4]=9.97$, $p=0.006$). However, calculation following conversion found no statistically significant difference in number of lapses ($F[1, 16]=4.28$, $p=0.055$).

All participants in the present study completed their intervention and received follow-up. However, given that the interventions were implemented in busy workplaces, the planned frequency and duration were unable to be adhered to. The mean number of day shifts per month was 11.3, while the mean number of instances of BL exposure in the same period was 8.5, as described above, resulting in a rate of BL exposure implementation of 75.2% (number of instances of BL exposure/number of day shifts). Additionally, we divided the participants into three tertiles based on rate of BL exposure implementation and analyzed data for two of these subpopulations. One population excluded participants in the highest tertile (91.6–100%,

Table 3. Effects of morning exposure to BL

	Estimated mean		Difference (95% CI)	Main effect of BL	*p*	Main effect of order	*p*	Interaction between BL and order	*p*
	Non-BL period	*BL period*							
Sleepiness at 10:00[1)]	4.29	3.74	–0.55 (–0.91, –0.20)	F (1, 55.6)=9.6	< 0.01	F (1, 57.5)=0.5	0.45	F (1, 55.6)=2.2	0.14
Sleepiness at 14:00[1)]	4.28	3.93	–0.35 (–0.72, 0.01)	F (1, 55.9)=3.7	0.06	F (1, 57.6)=1.4	0.23	F (1, 55.9)=0.5	0.47
Self assessment of night sleep for day-shift days[2)]	5.94	6.30	0.37 (0.04, 0.70)	F (1, 116)=4.9	0.03	F (1, 116) =1.0	0.32	F (1, 116)=1.8	0.18
Fatigue[3)]	75.38	73.24	–2.13 (–3.78, –0.48)	F (1, 49.6)=6.7	0.01	F (1, 51.2)=0.2	0.65	F (1, 49.6)=0.2	0.67
Number of adverse events per month	0.53	0.38	–0.15 (–0.43, 0.12)	F (1, 49.2)=1.3	0.26	F (1, 51.1)=0.02	0.89	F (1, 49.2)=0.1	0.75
Number of near misses per month	1.12	0.93	–0.18 (–0.48, 0.11)	F (1, 45.6)=1.60	0.21	F (1, 48.1)=0.01	0.91	F (1, 45.6)=0.01	0.92

BL: bright light, CI: confidence interval. [1)] Assessed using the Karolinska Sleepiness Scale. [2)] Assessed using a visual analogue scale (from 0, unable to sleep at all, to 10, slept very well). [3)] Assessed using the Checklist Individual Strength questionnaire.

Table 4. Effect of bright light on reaction time and number of lapses assessed using the psychomotor vigilance task test

	Estimated mean		Difference (95% CI)	Main effect of BL	*p*	Main effect of order	*p*	Interaction between BL and order	*p*
	Non-BL period	*BL period*							
Mean RT (msec)	264	235.8	–28.2 (–46.2, –10.2)	F (1, 17.0)=11.0	< 0.01	F (1, 8.9)=0.01	0.93	F (1, 17.0)=0.7	0.42
Number of lapses[1)]	2.03	0.84	–1.19 (–1.98, –0.40)	F (1, 17.4)=10.0	< 0.01	F (1, 8.97)=0.02	0.9	F (1, 17.4)=0.4	0.56
Transformed mean RT[2)]	0.0039	0.0043	0.0004 (0.0001, 0.0007)	F (1, 57108)=7.2	< 0.01	F (1, 3545)=0.25	0.62	F (1, 13537)=0.1	0.78
Transformed number of lapses[3)]	2.75	1.96	–0.79 (–1.60, 0.02)	F (1, 16)=4.3	0.06	F (1, 19)=0.23	0.64	F (1, 17)=0.4	0.56

BL: bright light, CI: confidence interval, RT: reaction time. [1)] Number of times that RT exceeded 500 msec in 5 min. [2)] Means of the RTs were transformed to reciprocal RTs (1/mean RT). [3)] Numbers of lapses were transformed as $\sqrt{(x)}+\sqrt{(x+1)}$, where x is the concerting number.

n=20), and the other excluded participants in the lowest tertile (18.2–35.4%, n=19). We obtained results similar to those shown in Table 3, although a statistically significant difference was not noted for self-assessed night sleep (p=0.07 and 0.05, respectively) due to low statistical power (data not shown). The PVT values were excluded from the analysis since the PVT was administered to only 11 participants.

Side effects likely related to BL

While no participants reported adverse events typically associated with BL exposure, such as headache, eye strain, irritability or nausea, 10 stated in the self-administered questionnaires that they occasionally felt sleepy sooner than usual when returning home after working the day shift on days that they performed BL exposure.

Discussion

In the present study, we found that short-term exposure to BL in the mornings before working the day shift significantly improved self-assessed sleepiness at 10:00 and reduced PVT mean response time during day-shift work, improved subjective nighttime sleep on day-shift days and improved perceived fatigue for the preceding two weeks.

We believe that the observations made in the present study were derived due to a combination of several effects. First, BL exposure may have exerted a direct effect on improving waking and performance. Previous studies have shown that daytime BL exposure can improve alertness and performance for several hours[22–24], findings which support our observation of reduced sleepiness at 10:00 AM and improved PVT performance in the afternoon following morning BL exposure.

Further, our findings suggest that an accelerated return to a normal circadian rhythm from any potential phase delays induced by working the night shift improved sleep and performance and reduced fatigue. Morning BL exposure is capable of correcting the misalignment between circadian rhythm and sleep/awake schedule and improving disturbed physiological rhythms and sleep[15]. Since BL exposure after the body temperature reaches its nadir can induce phase advance[15, 20], morning BL exposure may facilitate entrainment to a schedule of sleeping at night and working during the day after completing a night shift and improve sleep. Nevertheless, little data has been obtained regarding the optimum conditions of light exposure to facilitate such shift rotations[35]. In the present study, participants were instructed to undergo BL exposure for 10 min prior to the start of day shifts. In actuality, participants were exposed to 6,666-lux light for 7.8 min at each session, which was repeated on average 8.5 times a month. Whether this light dose resulted in any phase shift remains unclear, as no phase markers were measured. Previous research has demonstrated that bright light exposure of 5 h or more resets the circadian system[36], and at least 30 min of exposure can restore the circadian rhythm or improve mood disorders[37]. However, more recent reports suggest that a shorter duration (e.g., 10 to 20 min) of BL exposure may be sufficient for improving circadian rhythms and mood if received in the morning or in light-deficient conditions[19, 38]. In the present study, 10 out of the 61 (16%) participating nurses reported experiencing sleepiness earlier than normal on days when they were exposed to BL, an observation which could be seen as a sign of phase advance.

As another possible factor, better quality of subsequent sleep at night during the BL period may have improved the levels of daytime wakefulness, fatigue and performance. Comparison between the BL and non-BL periods in the present study showed a significant improvement in self-assessed sleep during the BL period, an effect which we believe strongly influenced the observed improvement in degree of daytime wakefulness and fatigue.

No significant difference was observed between the BL and non-BL periods for frequency of near misses and actual incidents, possibly indicating that the one-month observation period was too short to achieve any significant success.

Several limitations of the present study warrant mention. First, given that random assignment of the order of BL exposure and participant follow-up were conducted in facilities other than the registration center, we admit that some limitation may exist in finding validity. Second, crossover design studies are known to occasionally result in somewhat exaggerated assessment results[39]. Further, open-label trials involve potential biases resulting from differences in management, intervention, or assessment of participants that may arise due to participants or investigators knowing about the assigned intervention. As described above, alertness is improved by BL for several hours after exposure, and the alignment effect on circadian rhythm is limited to the day of exposure. Further, we noted no apparent carryover of the direct effect of BL to the next day. However, we cannot rule out the possibility that washout for one week is insufficient for complete elimination of the BL effect on sleep and fatigue. Third, the time of the endogenous body temperature nadir is typically determined by assessing core body temperature. However, given the difficulty in obtaining a deep body temperature reading in active individuals, we assumed that nurses in the present study normally woke up at approximately 06:00, considering the start time of the day shift, and for this reason, 07:30–08:00 was set as the BL exposure time to coincide with the time after the body temperature nadir. Sleep diary entries confirmed that actual waking times among most participants were between 05:30–06:30. Fourth, almost all data were gathered using a self-report questionnaire, allowing for potentially biased results reporting. Additionally, the

number of adverse events and near misses were not counted by interview or objective observation, and the time when adverse events and near misses occurred and related details were not investigated. The PVT was administered to only 11 (18%) voluntary participants, and the duration and number of tests were also restricted in order to limit the impact on work activities. Fifth, sleepiness assessment and PVT administration were only conducted in the daytime, hampering investigation of the effects of BL exposure on nighttime activity. We were unable to adequately assess what effects, if any, morning BL exposure had at night. Sixth, we were unable to estimate the exact number of working hours for individual participants, resulting in unavoidable estimation. However, based on information indicating that hospital nurses work less than 20 h of overtime and adding the 160 h of normal work time per month during the study period, the total working hours for a single nurse were estimated at 160–180 h per month. Further, no significant difference was expected between the BL and non-BL periods with regard to the number of working hours. Seventh, although participants were instructed to follow the same lifestyle (aside from appropriate BL exposure) for both the BL and non-BL periods, whether or not they actually did so was not confirmed. No investigation was conducted regarding family environment or societal factors, both important factors in the synchronization of circadian rhythm and the sleep-wake cycle. Daylight exposure conditions when returning home after working the night shift were also uninvestigated. Eighth, because the participants in this study were all relatively young women, the effects of morning BL exposure on men and the middle-aged and elderly remain unknown. Further, it should be noted that Japanese two-shift systems involving 16-hour night shifts differ from the two-shift system in other countries involving 12-hour shifts, potentially hampering extrapolation of our findings to workers in other countries. Lastly, sufficient investigation into the side effects of BL exposure may require a more thorough assessment than that obtained using a self-administered questionnaire. Individual interviews and other such efforts are needed to gather more detailed information regarding the reports of participants feeling sleepy earlier than normal and experiencing sleepiness during the night shift following morning BL exposure.

In conclusion, the results from our study suggested that brief morning BL exposure on day-shift days reduced sleepiness and improved performance during day-shift work, improved subjective nighttime sleep on day-shift days and improved perceived fatigue for the preceding two weeks in shift nurses on rapidly rotating schedules. Despite our study's limitations, we have effectively demonstrated the potential for implementation of countermeasures and prevention strategies to counteract the effects of maladaptation among night-shift workers.

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References

1) Costa G. Shift work and occupational medicine: an overview. Occup Med (Lond) 2003; 53: 83–8.
2) Folkard S, Tucker P. Shift work, safety and productivity. Occup Med (Lond) 2003; 53: 95–101.
3) Gemelli KK, Hilleshein EF, Lautert L. The effect of shift work on the health of workers: a systematic review. Rev Gaucha Enferm 2008; 29: 639–46.
4) Akerstedt T. Work hours, sleepiness and the underlying mechanisms. J Sleep Res 1995; 4: 15–22.
5) Boivin DB, Tremblay GM, James FO. Working on atypical schedules. Sleep Med 2007; 8: 578–89.
6) Gold DR, Rogacz S, Bock N, et al. Rotating shift work, sleep, and accidents related to sleepiness in hospital nurses. Am J Public Health 1992; 82: 1011–4.
7) Berger AM, Hobbs BB. Impact of shift work on the health and safety of nurses and patients. Clin J Oncol Nurs 2006; 10: 465–71.
8) Winwood PC, Winefield AH, Lushington K. Work-related fatigue and recovery: the contribution of age, domestic responsibilities and shiftwork. J Adv Nurs 2006; 56: 438–49.
9) Takahashi M, Arito H, Fukuda H. Nurses' workload associated with 16-h night shifts. II: Effects of a nap taken during the shifts. Psychiatry Clin Neurosci 1999; 53: 223–5.
10) Arora V, Dunphy C, Chang VY, et al. The effects of on-duty napping on intern sleep time and fatigue. Ann Intern Med 2006; 144: 792–8.
11) Smith-Coggins R, Howard SK, Mac DT, et al. Improving alertness and performance in emergency department physicians and nurses: the use of planned naps. Ann Emerg Med 2006; 48: 596–604.
12) Crowley SJ, Lee C, Tseng CY, et al. Complete or partial circadian re-entrainment improves performance, alertness, and mood during night-shift work. Sleep 2004; 27: 1077–87.
13) Lowden A, Akerstedt T, Wibom R. Suppression of sleepiness and melatonin by bright light exposure during breaks in night work. J Sleep Res 2004; 13: 37–43.
14) Smith MR, Eastman CI. Night shift performance is improved by a compromise circadian phase position: study 3. Circadian phase after 7 night shifts with an intervening weekend off. Sleep 2008; 31: 1639–45.
15) Dijk DJ, Boulos Z, Eastman CI, et al. Light treatment for sleep disorders: consensus report. II. Basic properties of circadian physiology and sleep regulation. J Biol Rhythms 1995; 10: 113–25.
16) Budnick LD, Lerman SE, Nicolich MJ. An evaluation of scheduled bright light and darkness on rotating shiftworkers: trial and limitations. Am J Ind Med 1995; 27: 771–82.
17) Bjorvatn B, Pallesen S. A practical approach to circadian rhythm sleep disorders. Sleep Med Rev 2009; 13: 47–60.

18) Kolstad HA. Nightshift work and risk of breast cancer and other cancers—a critical review of the epidemiologic evidence. Scand J Work Environ Health 2008; 34: 5–22.
19) Dumont M, Beaulieu C. Light exposure in the natural environment: relevance to mood and sleep disorders. Sleep Med 2007; 8: 557–65.
20) Rosenthal NE, Joseph-Vanderpool JR, Levendosky AA, et al. Phase-shifting effects of bright morning light as treatment for delayed sleep phase syndrome. Sleep 1990; 13: 354–61.
21) Bjorvatn B, Kecklund G, Akerstedt T. Bright light treatment used for adaptation to night work and re-adaptation back to day life. A field study at an oil platform in the North Sea. J Sleep Res 1999; 8: 105–12.
22) Phipps-Nelson J, Redman JR, Dijk DJ, et al. Daytime exposure to bright light, as compared to dim light, decreases sleepiness and improves psychomotor vigilance performance. Sleep 2003; 26: 695–700.
23) Kaida K, Takahashi M, Haratani T, et al. Indoor exposure to natural bright light prevents afternoon sleepiness. Sleep 2006; 29: 462–9.
24) Vandewalle G, Balteau E, Phillips C, et al. Daytime light exposure dynamically enhances brain responses. Curr Biol 2006; 16: 1616–21.
25) Winkler D, Pjrek E, Praschak-Rieder N, et al. Actigraphy in patients with seasonal affective disorder and healthy control subjects treated with light therapy. Biol Psychiatry 2005; 58: 331–6.
26) Akerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. Int J Neurosci 1990; 52: 29–37.
27) Kaida K, Takahashi M, Akerstedt T, et al. Validation of the Karolinska sleepiness scale against performance and EEG variables. Clin Neurophysiol 2006; 117: 1574–81.
28) Vercoulen JH, Swanink CM, Fennis JF, et al. Dimensional assessment of chronic fatigue syndrome. J Psychosom Res 1994; 38: 383–92.
29) Aratake Y, Tanaka K, Wada K, et al. Development of Japanese version of the checklist individual strength questionnaire in a working population. J Occup Health 2007; 49: 453–60.
30) Yu KH, Nation RL, Dooley MJ. Multiplicity of medication safety terms, definitions and functional meanings: when is enough enough? Qual Saf Health Care 2005; 14: 358–63.
31) Leape LL, Lawthers AG, Brennan TA, et al. Preventing medical injury. QRB Qual Rev Bull 1993; 19: 144–9.
32) Chaudhry SI, Olofinboba KA, Krumholz HM. Detection of errors by attending physicians on a general medicine service. J Gen Intern Med 2003; 18: 595–600.
33) Cuschieri A. Nature of human error: implications for surgical practice. Ann Surg 2006; 244: 642–8.
34) Dinges DF, Pack F, Williams K, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4–5 hours per night. Sleep 1997; 20: 267–77.
35) Chesson AL, Jr., Littner M, Davila D, et al. Practice parameters for the use of light therapy in the treatment of sleep disorders. Standards of Practice Committee, American Academy of Sleep Medicine. Sleep 1999; 22: 641–60.
36) Duffy JF, Czeisler CA. Effect of Light on Human Circadian Physiology. Sleep Med Clin 2009; 4: 165–77.
37) Michael T, Jiuan ST. Light therapy. In: Priciples and Practice of Sleep Medicine 4th edition. Philadelphia (PA): Elsevier; 2005. p. 1424–42.
38) Virk G, Reeves G, Rosenthal NE, et al. Short exposure to light treatment improves depression scores in patients with seasonal affective disorder: a brief report. Int J Disabil Hum Dev 2009; 8: 283–6.
39) Khan KS, Daya S, Collins JA, et al. Empirical evidence of bias in infertility research: overestimation of treatment effect in crossover trials using pregnancy as the outcome measure. Fertil Steril 1996; 65: 939–45.