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ORIGINAL ARTICLE

Do bright-light shock exposures during breaks reduce subjective sleepiness in night workers?

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Abstract

Night work has many harmful effects on the health, efficiency and safety of workers. This study evaluates the effects of bright-light exposure (BL) on subjective sleepiness during night work. Ninety night workers who have more than a year's experience at a metallurgy production plant volunteered to participate in this clinical pilot study. Workers were divided into two groups and every group was exposed to either bright light (2500–3000 lux) or normal light (300 lux) during break times at night for two consecutive nights. Fifteen-minute breaks were initiated at 22.00 h (before starting work) 24.00 h, 02.00 h and 04.00 h. The range of subjective sleepiness was assessed by the Stanford Sleepiness Scale (SSS) at 23.00 h, 01.00 h, 03.00 h and 05.00 h. We used SPSS 11.5 for data analysis. The result demonstrated that there were significant differences in the rate of sleepiness between the two groups by paired *t*-test analysis ($P < 0.001$). These findings suggest that photic stimulation in industrial settings could increase adaptation to night work.

Key words: bright-light exposure, shift work, sleepiness, Stanford Sleepiness Scale.

INTRODUCTION

Many critical aspects of modern life, including medical care, power generation, the military and law enforcement depend on shift workers, as do important commercial sectors such as manufacturing and public transportation.[1–4] It is estimated that between 15 and 30% of the workforce in developed countries operates outside standard daytime hours.[5,6]

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The most prominent effects of shift work are associated with disturbed sleep. Working at night typically results in subjective sleepiness, reduced performance, increased numbers of accidents and health problems.[7,8] Many factors can be involved in lack of adjustment among night workers. The light exposure which a large number of night workers receive after work has been proposed as major factor in preventing adaptation to the circadian rhythm.[9] Without relating to the time of the sleep–wake cycle, light can regulate circadian rhythms.[10,11] The effect of light is dependent on the timing of exposure relative to the nadir of the endogenous body temperature rhythm, which is usually located 1–2 h before the habitual time of awakening.[12] Light exposures before the nadir induce a phase delay, whereas exposures after the nadir induce a phase advance.[13]

Bright light has been proposed as a countermeasure to physiological maladaptation to shifted sleep–wake schedules based on a number of previous laboratory investigations.[14–17] Doses of bright light administered at the beginning of the shift period have ranged from 6 h of very bright light (5000–12000 lux) to more moderate bright light (1230–2000 lux) in short or intermittent segments.[18–20] Various studies supported the efficacy of bright light during the night shift, although some negative results have been reported.[17,21] A recent study of operators in a truck production plant in Sweden revealed a beneficial effect of bright light on reducing subjective sleepiness and melatonin levels during night shifts, and no detrimental effects on sleep on days off.[22] Similar observations were reported for oil workers on rotating shifts.[23] Indeed, nurses working permanent nights who presented adaptive phase delays also tended to expose themselves to light more during the night (and evening) and less during the day than non-adapted nurses.[24] The use of bright light for shift workers was not supported by all studies. One study, using a short (120-min) BL for night workers on an oil platform, concluded that the adaptation to night work was not significantly enhanced by the exposure. Instead, the normal indoor light appeared sufficient for rapid adaptation as the workers were isolated from the outdoor light.[25] Thus, in the present study, we wanted to evaluate whether short (15-min) exposure to bright light throughout regular breaks would decrease subjective sleepiness during the night shift.

METHODS

This is a two-period trial crossover study which has been done among metal production operators in Iran. The study population was 93 shift workers who volunteered to participate in the investigation. Subjects were asked to sign the consent form, confirming that they understood the goals, risks, and potential benefits of the study and their right to withdraw from the study at any time. The Tehran University of Medical Sciences Committee for Ethics approved the study. Ninety of the workers were included in the ultimate analysis and three subjects were excluded from the study because of disease and long-term drug use.

The subjects' work schedule was 2 days on morning shift (06.00 h to 14.00 h), 2 days on evening shift (14.00 h to 22.00 h), 2 days on night shift (22.00 h to 6.00 h), 2 days off work, and then the schedule was repeated. The workers are permitted four short breaks each night (fifteen minutes long on average), at 22.00 h, 24.00 h, 02.00 h and 04.00 h.

Consenting participants were randomized into two groups, labelled as Group 1 and Group 2. The forty-five participants in Group 1 received bright light during the two consecutive night shifts. The 45 participants in Group 2 were exposed to normal light during the two night shifts. Then measurements were performed by examiners based on the exact time schedules. After a 6-day "washout" period (used in accordance with former studies), Groups 1 and 2 were interchanged and the experiment was repeated. All of the workers participated in both stages. Figure 1 shows the schematic diagram of study sequences.

Two similar rooms were designed for the breaks. One of them was for bright light and the other was for normal light. A row of 3 fluorescent light bulbs at a distance of 2 meters from one another was installed in the wall in the normal room. Each fluorescent tube produced white light with a mean luminance level of

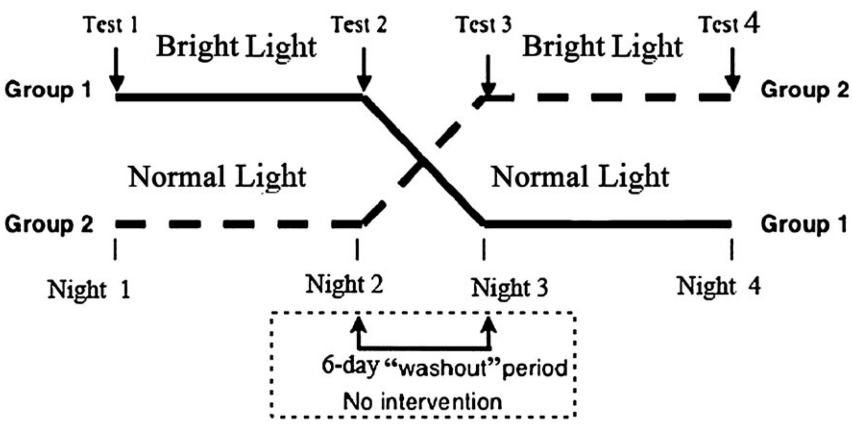

Figure 1 The schematic diagram of the study sequences.

300 lux, which was almost equal to the average brightness in the subjects' workplace. To increase the luminance in the other room to test bright-light intervention, 10 fluorescent bulbs with 3 lamps each were embedded in the ceiling in five double rows, with a distance of 1 m between bulbs. This generated a mean exposure of 2500–3000 lux. Past studies indicate that this is a suitable amount of light. Group 1 went to the bright-light room for all breaks during the first stage, while Group 2 went to the room with normal illumination. The two groups switched rooms for the second stage (i.e. Group 2 took breaks in the bright-light room and Group 1 took them in the normally illuminated room).

The Stanford Sleepiness Scale was used to obtain ratings of sleepiness. The SSS is an eight-point verbal scale. The subjective sleepiness rating of subjects was assessed every 2 h during night shift (at 23.00 h, 01.00 h, .03.00 h and 05.00 h). Exposure to BL or NL was initiated at 22.00 h (before starting work), 24.00 h, 02.00 h and 04.00 h during break times.

We used SPSS 11.5 for statistical analysis. When the Kolmogorov–Smirnov test confirmed normality, non-parametric tests were carried out. Using the paired *t*-test, we compared subjective sleepiness between two conditions (with bright light and with normal light). A repeated measure ANOVA showed interaction between independent variables in this study. The level of significance was defined at $P < 0.05$.

RESULTS

This study was completed with 45 subjects in Group 1 and 45 in Group 2. In both conditions of normal light and bright light, four scheduled breaks were allowed to the workers during their night shift. These breaks had a mean length of 15 ± 1 min. There was no significant difference between the timing of breaks for the bright-light and normal-light conditions.

All members of the study population were males aged between 30 and 36 years. Table 1 shows the demographic characteristics of the subjects. As observed, there was no significant difference between the mean ages of the two groups. The differences in the means of BMI, duration of employment in shift work and smoking between Groups 1 and 2 were also not statistically significant (Table 1).

According to the SSS, which was completed at 23.00 h, 01.00 h, 03.00 h and 05.00 h by both groups, the amount of subjective sleepiness increased during night work in Groups 1 and 2, peaking at 05.00 h and 03.00 h. This increase in subjective sleepiness was consistent over all of the study nights. Table 2 shows the mean score of subjective sleepiness among the study population during night work before intervention. As indicated, the mean score of subjective sleepiness is statistically the same in Group 1 as in Group 2 before intervention. An increase of subjective sleepiness is also observed in the course of the night shift (Table 2).

The study had two stages. In the first night of stage 1, the mean scores of Group 1 sleepiness at 23.00 h and 01.00 h were 2.04 and 2.71, respectively, and the mean scores of Group 2 sleepiness were 1.89 and 2.96 at the same times. There was no statistical difference between these mean scores at this time. In contrast, sleepiness was significantly reduced in the BL condition at 03.00 h and 05.00 h in this night of the study. Also the total mean of the subjective sleepiness scores during the first night in the BL group was 2.533, but in the NL group it was 3.144, and the difference between them was statistically significant ($P < 0.001$).The subjects in Group 1

Table 1 Demographic characteristics of the study population ($n = 90$)

		Group 1 ($n = 45$)	Group 2 ($n = 45$)	*P*-value
Age Mean (SD)		30.34 ± 6.34	30.49 ± 5.81	0.85
BMI Mean (SD)		24.30 ± 3.19	23.83 ± 2.81	0.46
Duration of employment in shift work Mean (SD)		4.75 ± 3.32	6.27 ± 3.72	0.055
Smoking	Smokers	12 (26.7)	12 (26.7)	NS
n (%)	Non-smokers	33 (73.3)	33 (73.3)	NS
Marital Status	Single	10 (22.2)	9 (20)	NS
n (%)	Married	35 (77.8)	36 (80)	NS

Table 2 The mean score of sleepiness among study population during night work before intervention ($n = 90$)

Study population	Night work hours 23.00 h	01.00 h	03.00 h	05.00 h
Group 1 Mean (SD)	1.38 ± 0.57	3.02 ± 0.75	3.58 ± 0.65	4.55 ± 0.74
Group 2 Mean (SD)	1.62 ± 0.49	2.83 ± 0.81	3.8 ± 0.81	4.36 ± 0.1
P-value	NS	NS	NS	NS

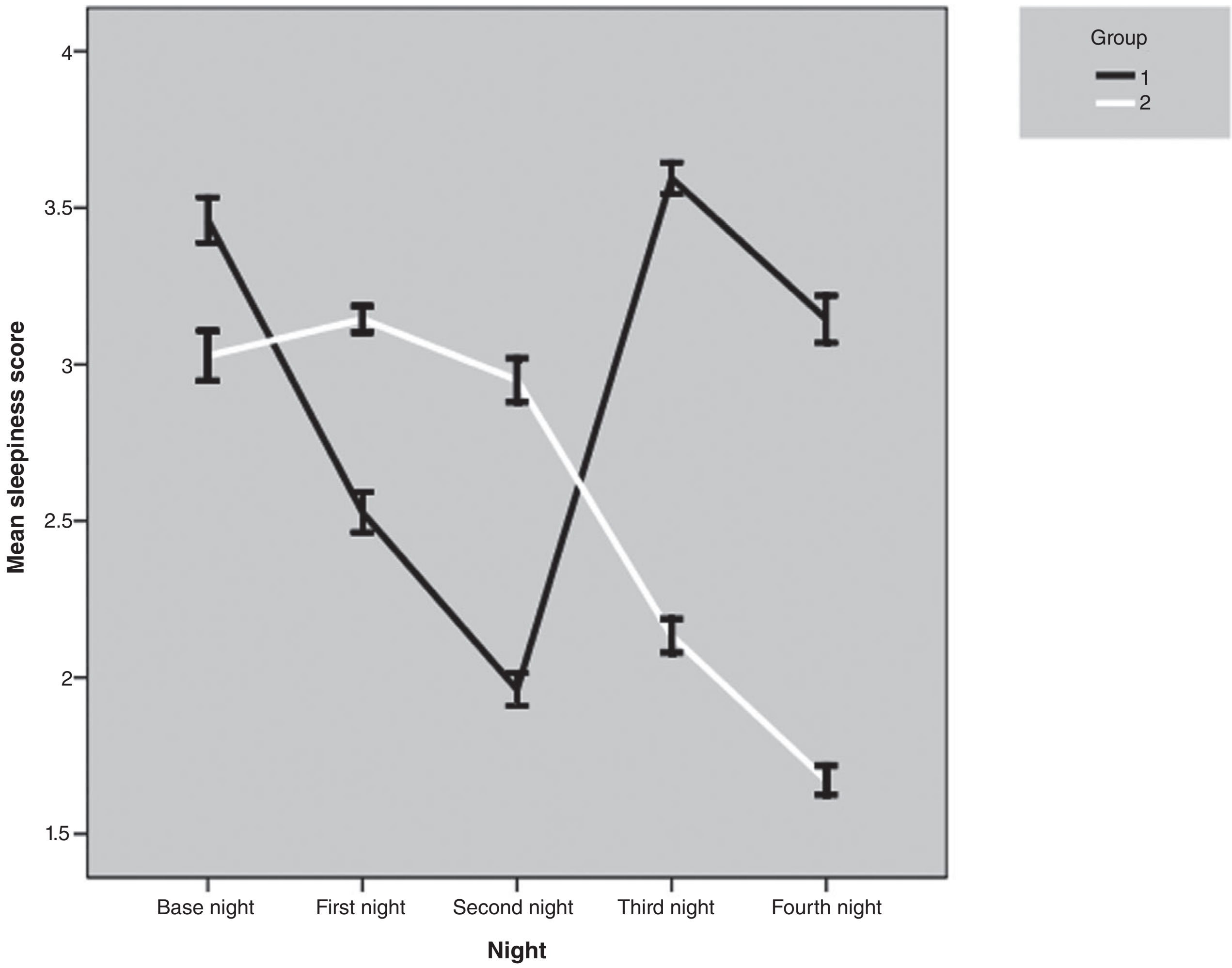

Figure 2 Sleepiness trend among two groups in the different nights of the study. Error bars: ± 1 SE.

also indicated lower sleepiness than those in Group 2 all through the second night in the first stage, and the difference in the mean score of subjective sleepiness between the two groups was statistically significant. After the 6-day "washout", stage two was started and the treatment of the two groups was interchanged. The SSS then showed that the mean score of subjective sleepiness in Group 2 was reduced during the third and fourth nights of the study. The mean score of subjective sleepiness in Group 1 increased at the same time, and the difference was statistically significant ($P < 0.001$) (Fig. 2).

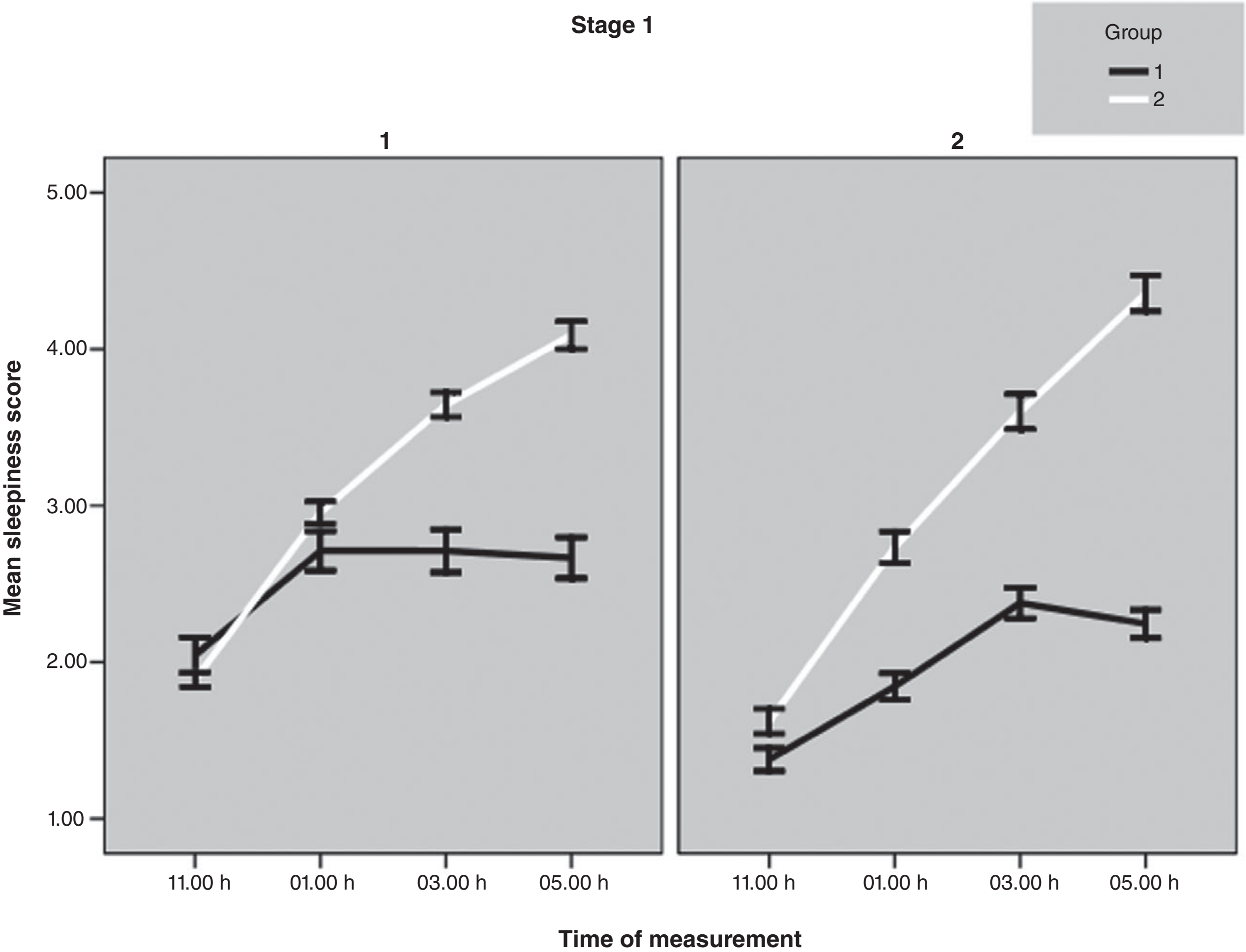

Figure 3 Mean of sleepiness score during different hours of the first and second nights for the bright-light condition and the normal-light condition. Error bars: ± 1 SE.

Table 3 indicates the mean of SSS in the BL and NL conditions in the two stages among the study population. As shown, subjects in the BL condition showed reduced SSS scores in both stages of the study (Table 3). Figures 3 and 4 illustrate the mean subjective sleepiness scores during night work for the BL condition and the NL condition in both stages. As shown, there are obvious differences in the subjects' sleepiness scores in the BL and NL conditions.

The treatment effect which showed light effectiveness on subjects was statistically significant ($P < 0.001$). However, the period effect was not statistically significant (0.923). Moreover, the "washout" period (6 nights) between the two stages was appropriate, as the statistical test shows that any carry-over effect is statistically nonsignificant (Table 4).

DISCUSSION

In the present investigation, the increasing trend of the extent of drowsiness was apparent during the study. Also it is deduced that the highest level of drowsiness in all the studied four nights occurs at 03.00 h and 05.00 h. This is consistent with other studies which report the highest degree of drowsiness at 02.00 h, 04.00 h, and 06.00 h.[22]

The average of sleepiness in the first and second nights of the first stage showed significant differences between Groups 1 and 2 at all hours except 23.00 h and 01.00 h. All in all, our results show that there is considerable difference between the degree of subjective sleepiness in first and second stages between the two groups. These results are in conformity with the results

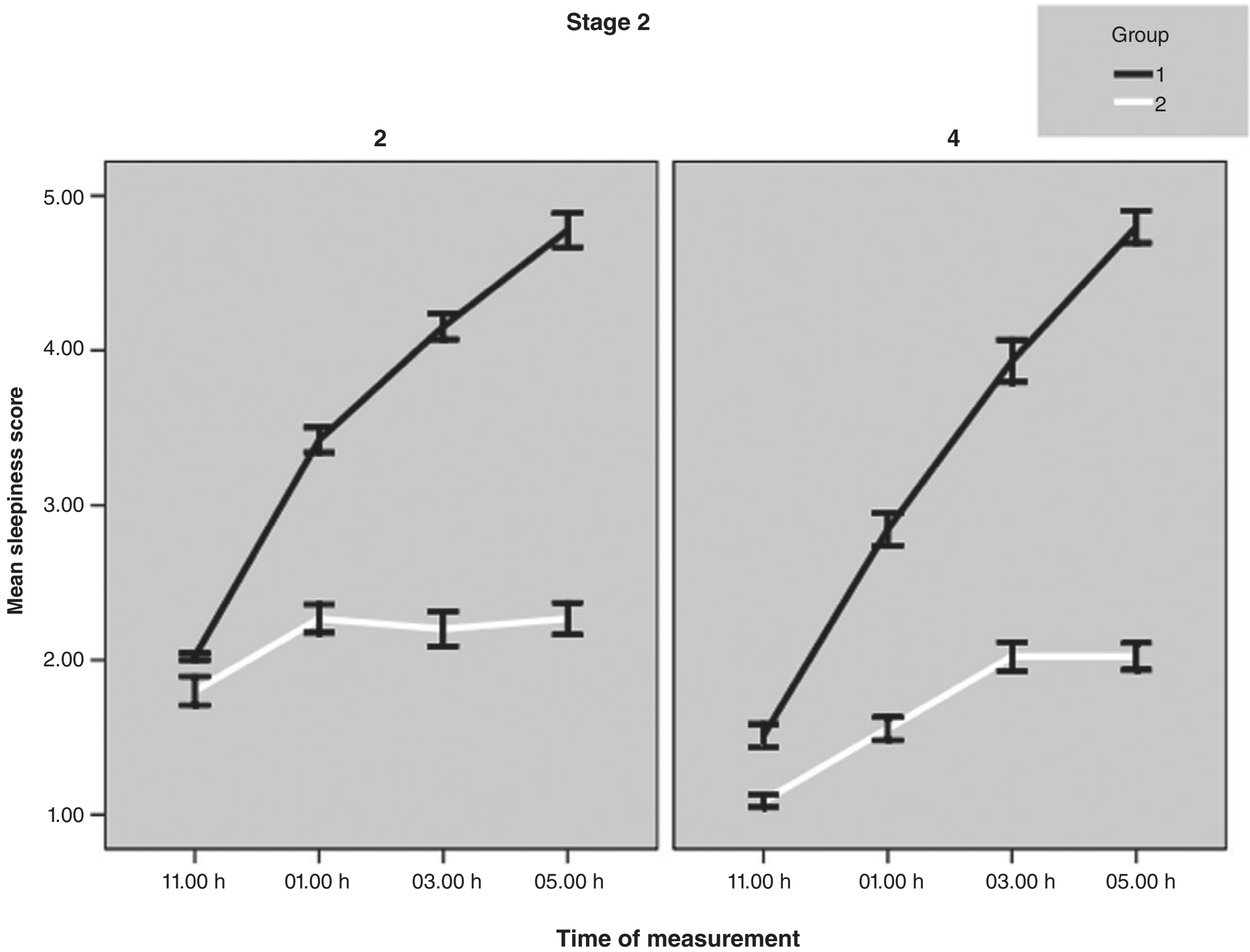

Figure 4 Mean of sleepiness score during different hours of the third and fourth nights for the bright-light condition and the normal-light condition. Error bars: ± 1 SE.

of prior studies using 2000–2500 lux light, which have resulted in subjective reduction of drowsiness.[13] In addition, our results are consistent with results obtained previously by Lowden, who showed that two 20-min breaks with bright light at 03.00 h and 04.00 h considerably reduce subjective sleepiness.[22]

As the subjective sleepiness trend shows, both groups show less subjective sleepiness in the second day (both the second day of intervention and the second day of control) in comparison with the first day. It seems that in both conditions of intervention and control, conformity to night shift increases in subsequent nights and this conformity is greater when intervention is performed. This is consistent with the results of Lowden's study, in which conformity to night shift increased over 5 successive nights and disappeared during weekend vacations.[22] It is also implied that the effect of light on subjective sleepiness increases with time between 23.00 h and 05.00 h (effect at 05.00 h > effect at 03.00 h > effect at 01.00 h > effect at 23.00 h).

According to our results, it is clear that despite the brevity of light encounters (15 min in each break), bright light has an effect on subjective sleepiness (the treatment effect). There was no significant difference in period effect and carry-over effect, which shows that primacy or subsequence of light encounter, has no effect on the final results in both groups. In addition, it shows that the 6-night "washout" period used in the study has been a suitable one. It is worth mentioning that it would be more economical to provide rooms equipped with bright light in industrial workplaces rather than supplying the whole workplace with bright light. However, the

Table 3 The mean score of sleepiness among study population during the study nights ($n = 90$)

Night hours		First night			Second night		
		Group 1	Group 2	*P*-value	Group 1	Group 2	*P*-value
Stage 1	23:00	2.4 ± 0.77	1.89 ± 0.32	0.197	1.38 ± 0.49	1.62 ± 0.53	0.01
	1:00	2.71 ± 0.84	2.96 ± 0.47	0.117	1.84 ± 0.56	2.73 ± 0.69	$P < 0.001$
	3:00	2.71 ± 0.92	3.64 ± 0.53	$P < 0.001$	2.38 ± 0.65	3.6 ± 0.75	$P < 0.001$
	5:00	2.67 ± 0.88	4.09 ± 0.59	$P < 0.001$	2.24 ± 0.61	4.36 ± 0.77	$P < 0.001$
		$P < 0.001$	$P < 0.001$		$P < 0.001$	$P < 0.001$	
		Third night			Fourth night		
		Group 1	Group 2	*P*-value	Group 1	Group 2	*P*-value
Stage 2	23:00	1.8 ± 0.62	2.02 ± 0.15	0.024	1.09 ± 0.28	1.51 ± 0.51	$P < 0.001$
	1:00	2.27 ± 0.62	3.42 ± 0.54	$P < 0.001$	1.56 ± 0.50	2.84 ± 0.71	$P < 0.001$
	3:00	2.2 ± 0.76	4.16 ± 0.56	$P < 0.001$	2.02 ± 0.62	3.93 ± 0.91	$P < 0.001$
	5:00	2.27 ± 0.69	4.78 ± 0.73	$P < 0.001$	2.02 ± 0.58	4.8 ± 0.69	$P < 0.001$
		$P < 0.001$	0.002		$P < 0.001$	$P < 0.001$	

Table 4 The findings for treatment effect, period effect and carry-over effect of the study population

	t	df	*P*-value
Treatment effect	–21.95	89	$P < 0.001$
Carry-over effect	–0.097	89	0.923
Period effect	–0.497	89	0.423

optimal dose, intensity and timing of bright-light exposure are still undetermined and need to be verified before the utilization of bright-light stimulation in industrial workplaces.

One limitation of our study was that the participants were completely informed about the study's goals and procedures which resulted in the lack of any real placebo effect. It is possible that this may have had an effect on the results.

In conclude, our study showed the positive effect of bright light in reducing the degree of subjective sleepiness, which supports the use of light for better conformity with night-working. There is a possibility that increasing the duration of bright-light usage would improve the favorable observed results.

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