

# The effectiveness of bright light exposure in shift-worker nurses: A systematic review and meta-analysis

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## ABSTRACT

Bright light exposure is as one of the non-pharmacological measures to sleep management in shift-worker. This study was conducted to determine the effectiveness of bright light exposure in shift-worker nurses. We performed a systematic review and meta-analysis according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement and using existing literature in the following databases: Cochrane Library, Embase, PubMed, Scopus, Web of Science, to examine any eligible and relevant interventional (randomized controlled trial, experimental and quasi-experimental studies) which were published by December 31, 2018. The obtained documents were analyzed using Stata 14.1 and Cochrane Collaboration's RevMan 5.3. Five studies met eligibility criteria. Results from fixed-effect meta-analysis of the included studies revealed that the exposure could decrease the sleepiness levels, complaints related to shift-work, insomnia and increased the psychomotor error (95% confidence interval (CI): -0.87,-0.43,  $p=0.000$ ,  $I^2=98.6\%$ ), alertness and daytime sleep duration following night shifts (95% CI: 0.08,0.99,  $p=0.000$ ,  $I^2=92.7\%$ ). However, in the random effects model, none of them were statistically significant. Although the results of fixed-effect are in favor of beneficial effects of bright light exposure in shift-worker nurses, the random effects could not approve these findings. Maybe because of either large heterogeneity or insufficiency of the number of studies. Besides, because of the low number of studies, it was impossible to deal with high amount of heterogeneity using subgroup analysis or meta-regression. So the controversy on this topic continues to persist, which highlights the need for more well-designed randomized control trials with larger sample sizes in the future.

**Keywords:** Sleep Initiation and Maintenance Disorders; Sleep Stages; Systematic Review; Nurse; Shift Work Schedule.

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## INTRODUCTION

On average, one-third of the human lifetime is spent in sleep. Sleep and sufficient rest are one of the basic needs for human and the basis for physical and mental health, as the sleep deprivation can reduce people's productive behavior<sup>1</sup>. Shift-work is considered as a condition in which people work in times other than the usual time of work in an organization such as evening, night or a combination of these two that changes periodically. The night shift is considered as the hardest part of the shift-work that can interfere with the circadian and homeostatic regulation of sleep<sup>2-4</sup>. Almost 20-25% of the general population's work around the world is as the shift-worker. Shift-work as an occupational and safety hazard is common in jobs (protection services such as police, healthcare, and transport) that directly affect the health and safety of others. However, the health, quality of life and safety of shift-worker is affected by their job<sup>5-7</sup>.

The health of shift-worker who works non-standard hours is threatened by problems such as cardiovascular diseases, digestive problems, fatigue, cancer, especially breast cancer, peptic ulcer disease, type 2 diabetes, rheumatoid arthritis, anxiety, depression and sleep problems<sup>8-10</sup>. In fact, the sleep disorders is the most challenging issue among people with variable and circulating shift-work such as nurses. Nurses experience sleepiness and napping during shift-work and they are forced to devote many hours to sleep at home, in order to compensate for the sleep shortage and improve the quality of their sleep<sup>11-13</sup>.

Also, sleep disturbance and deprivation caused by shift-work can affect the cognitive performance, skills such as memory, learning, logical reasoning, mathematics calculation, recognition patterns, complex verbal processing and decision making of nurses that lead to increased risk of work injuries, decreased job performance and affects the outcome, health and safety of patients<sup>11,12,14,15</sup>. Although the experience of shift-work is inevitable in the nursing profession such as police and firemen; but having a high-quality sleep is considered as the primary rights of nurses and part of high-quality care chain of patients<sup>16</sup>.

For adaptation to shift-work as the significant need of nurses, there are pharmacological and non-pharmacological measures and solutions which shift-worker nurses can use to have better sleep management. However, studies have shown pharmaceutical solutions have the relative impact with numerous adverse effects<sup>5,17-20</sup>.

Bright light exposure was considered as one of the preventive and non-pharmacological measures that affects the melatonin secretion and helps the circadian rhythm adaptation and sleep management process in shift-workers. It can influence the biological clock, cognitive performance, and alertness<sup>21</sup>. The results of some studies suggest a beneficial effect of brief exposure to bright light for shift-worker nurse<sup>22-25</sup>. However, there is limited and scarce systematic review and meta-analysis studies that provide clear information about the effect of bright light exposure for shift-worker, especially nurses. This study is the first systematic review and meta-analysis which

was conducted to determine the effectiveness of bright light exposure in shift-worker nurses until December 31, 2018.

## MATERIAL AND METHODS

### Selection criteria

**Eligible studies:** Included randomized controlled trial (RCT), experimental and quasi-experimental study designs and,

**Eligible participants:** Shift-worker nurses that work in the form of night shift or rotating shift and,

**Eligible interventions:** Effectiveness of bright light exposure that can be used with or without dark goggles and,

**Eligible outcome measures:** Studies that used bright light indicator included the sleep time, sleepiness level and performance and measured these items using valid scales and device (Shift-Work Complaints, Karolinska Sleepiness Scale, Insomnia Severity Index, Stanford Sleepiness Scale, Psychomotor Vigilance Test and nightcap device) were considered.

### Search strategy and selection criteria

A systematic search of literature was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement<sup>26</sup> and using existing literature in the following databases: Embase, Cochrane Library, PubMed, Scopus, Web of Science, to examine any eligible and relevant interventional (randomized controlled trial (RCT), experimental and quasi-experimental studies) which were published until December 31, 2018. In this study, all the steps including search, identification, quality assessment, and data extraction were independently done by two reviewers and disagreements were solved through discussion and mutual agreement between authors. We searched the English language studies according to the following Medical Subject Heading (MeSH) terms and keywords ("nurses"[MeSH Terms] OR "nurses" OR "nurse") AND (shift-work OR ("shift work schedule"[MeSH Terms] OR ("shift" AND "work" AND "schedule") OR "shift work schedule" OR ("night" AND "shift" AND "work") OR "night shift work") OR ("shift work schedule"[MeSH Terms] OR ("shift" AND "work" AND "schedule") OR "shift work schedule" OR ("rotating" AND "shift" AND "work") OR "rotating shift work")) AND (bright AND ("light"[MeSH Terms] OR "light")) that investigated the effectiveness of bright light exposure in shift-worker nurses. All book chapters, systematic and literature reviews, anonymous studies, letters to the editor, historical articles were excluded (Figure 1).

### Evaluation of methodological quality

Two authors independently assessed the publication bias of the included studies by using the criteria of the Cochrane Handbook for Systematic Reviews of Interventions<sup>27</sup> that evaluated: random sequence generation; allocation concealment; blinding of participants and personnel; blinding of outcome assessment; incomplete outcome data; selective reporting; and other bias. In this assessment, each item was graded as 'low', 'high' or 'unclear' risk of bias.

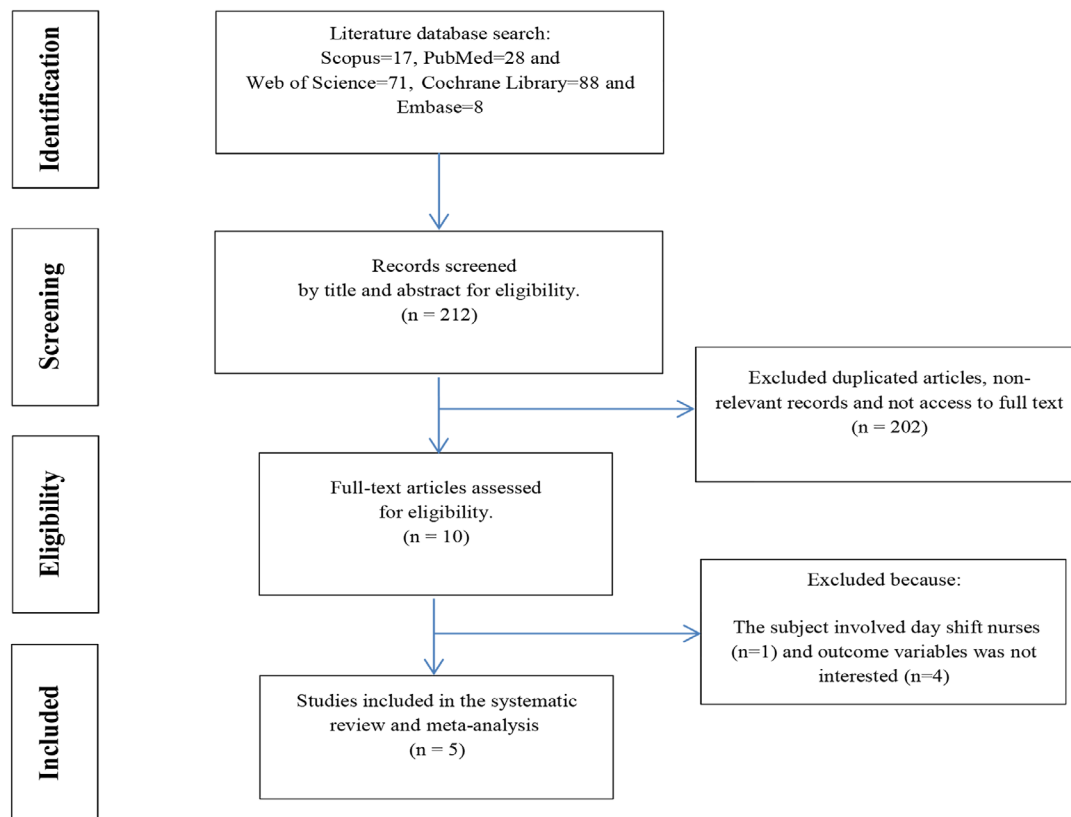


Figure 1. A flow diagram of included and excluded studies.

### Data synthesis and statistical analysis

In this review, outcomes were presented as continuous variables. Because we have the outcome on different scales, the standard mean difference (SMD) was used for continuous variables and the degree of the treatment effects was determined by the magnitude of SMD<sup>28</sup>. We used the calculation of 95% confidence interval (CI) for each effect size estimate and the I-statistic ( $I^2$ ) to examine the heterogeneity among studies. Since  $I^2$  was greater than 50% and it indicated a notable heterogeneity<sup>29</sup>, we reported a fixed-effect model in addition to random effect model. A  $p$ -value <0.05 was considered to determine statistical significance. All statistical analyses were performed using Stata 14.1 and Review Manager, version 5.3 (The Nordic Cochrane Centre, Copenhagen, Denmark).

### FINDING

Based on the exclusion and inclusion criteria, of 212 papers which were identified from the databases, five papers were included in this review. Search strategy outlines in Figure 1.

#### Characteristics of included articles

Of the five included papers, two papers had an RCT design<sup>22,24</sup> and three papers were experimental design<sup>23,30,31</sup>. All the included studies presented in English language from 2003 to 2018 and were done in different geographical areas, including Asian, European countries and USA. Sample sizes of the reported studies ranged from 14 to 86. Different lux, time, duration and distance of bright light were used in the experimental groups. Two studies used the dark goggles during

the morning commute home after bright light intervention<sup>24,31</sup> (Table 1).

### Quality appraisal

Based on the Cochrane Handbook for Systematic Reviews of Interventions, only one study reported sufficient methods in random sequence generation<sup>24</sup> and none of these studies had reported an sufficient method of allocation concealment. Also, sufficient blinding of participants and personnel was reported in one study<sup>22</sup>, while the blinding of outcome assessment was reported in two studies<sup>22,24</sup>. So, there was a high number of missing data in one study that did not provide the reason<sup>22</sup> and one study has insufficient reporting about incomplete outcome data<sup>23</sup>. Also, a high risk of selective reporting were presented in two included studies<sup>22,23</sup> and all included studies have a reason for other risks. The details are shown in Figures 2 and 3.

### Effects of bright light exposure on the shift-worker nurses

Results from fixed-effect meta-analysis of the included studies showed that bright light exposure could decrease sleepiness levels<sup>22</sup>, complaints related to shift-work<sup>30</sup> and insomnia<sup>24</sup> in shift-worker nurses. Also, the results show that the psychomotor error increased in the intervention group than control group<sup>22</sup> (SMD: -0.65, 95% CI: -0.87, -0.43,  $p=0.000$ ,  $I^2=98.6%$ ) (Figure 4a).

**Table 1.** Characteristics of included studies into a meta-analysis.

Author (year) country	Study design	Sample size	Questionnaire	Outcome	Intervention
Leppämäki et al. (2003) <sup>30</sup> Finland	Experimental (before-after)	86	Shift-Work Complaints	Complaints related to shift work	Brief periods (4 × 20 minutes) of bright light (5000 lux) at scheduled times during every night shift over a 2-week period
Kakooei et al. (2010) <sup>23</sup> Iran	Experimental (before-after)	34	Karolinska Sleepiness Scale	Alertness	Bright light (4500 lux) during 2 breaks (21:15–22:00 and 3:15–4:00) in night shift for 4 weeks
Boivin et al. (2012) <sup>31</sup> USA	Experimental	14	Nightcap device	Daytime sleep following night shifts	Bright light (3243±2274 lux) during the first 6 h of each night shift and wore dark goggles during the morning commute home
Huang et al. (2013) <sup>24</sup> Taiwan	RCT	46 (in each group)	Insomnia Severity Index	Insomnia	Bright light (7,000-10,000 lux) for ≥ 30 minutes in night shift that continued for at least 10 days. Subjects avoided daytime outdoor sun exposure after work by wearing dark sunglasses
Griepentrog et al. (2018) <sup>22</sup> USA	RCT (crossover clinical trial)	43 (in each group)	1. Stanford Sleepiness Scale 2. Psychomotor Vigilance Test	1. Sleepiness 2. Number of lapses and errors	Bright light (1500–2000 lx) for 10 h in night shift

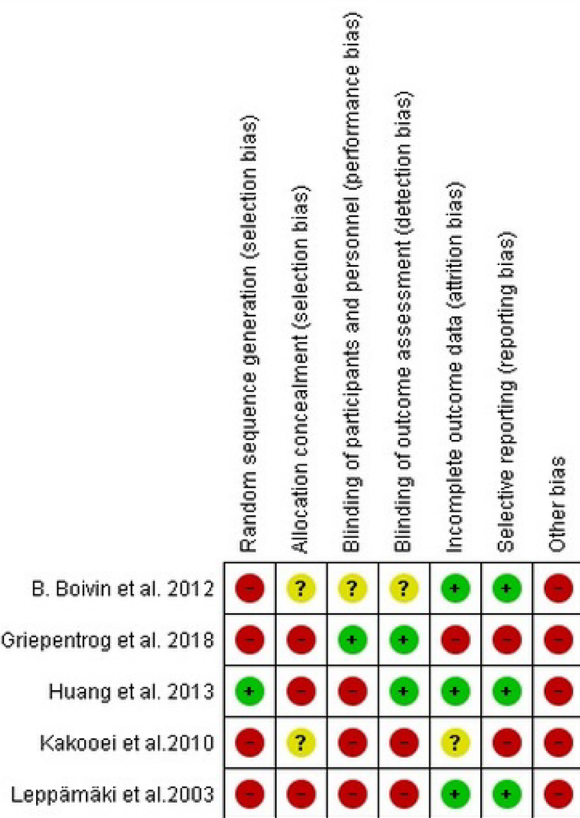
Two studies reported that the bright light exposure could increase the alertness<sup>23</sup> and daytime sleep duration following night shifts in shift-worker nurses<sup>31</sup> (SMD: 0.54, 95% CI: 0.08, 0.99,  $p=0.000$ ,  $I^2=92.7%$ ) (Figure 4b). However, in the random effects model, none of them were statistically significant.

**DISCUSSION**

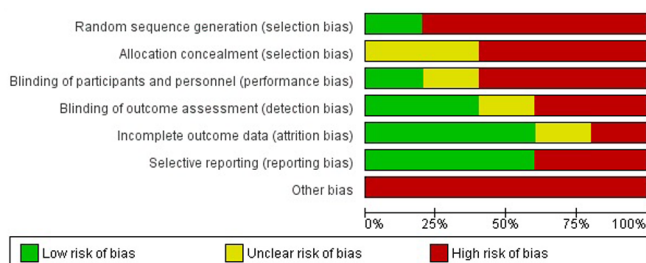
Pooled data of this meta-analysis result provided the evidence that bright light exposure decreased the sleepiness levels, complaints related to shift-work and insomnia in shift-worker nurses. Also, these exposures increased the alertness, daytime sleep duration following night shifts and psychomotor error. We expected as the bright light exposure can decrease the sleepless level, the psychomotor error would also decrease in shift-worker nurses. But, author of the study claimed alertness and overall performance are degraded as the early morning approaches in diurnal creatures such as human which can increase the susceptibility to committing errors and reduce the work efficiency<sup>22</sup>.

Nursing is a difficult job and the shift-work is considered to be an integral part of this profession and as a stressor. The stress and pressure effects of shift-work condition on personal and social relationships, health habits and outcomes of nurses can reduce the available resources and capacity of them for coping with the other stressors and problems encountered in their job and family roles. Nurses need to learn and be educated in the shift-work coping strategies as a topic in their students’ clinical education, in order to adapt and manage their sleep process in clinical settings and protect their mental and physical health<sup>7,32-34</sup>.

On the other hand, due to different shift-work systems in organizations, there is no single optimum solution for sleep management process of shift-worker nurses. Some preventive and compensatory non-pharmacological measures that are suggested in studies are: exposure to the bright light, napping, shift-worker participation in shift system design, correction



**Figure 2.** Risk of bias summary.



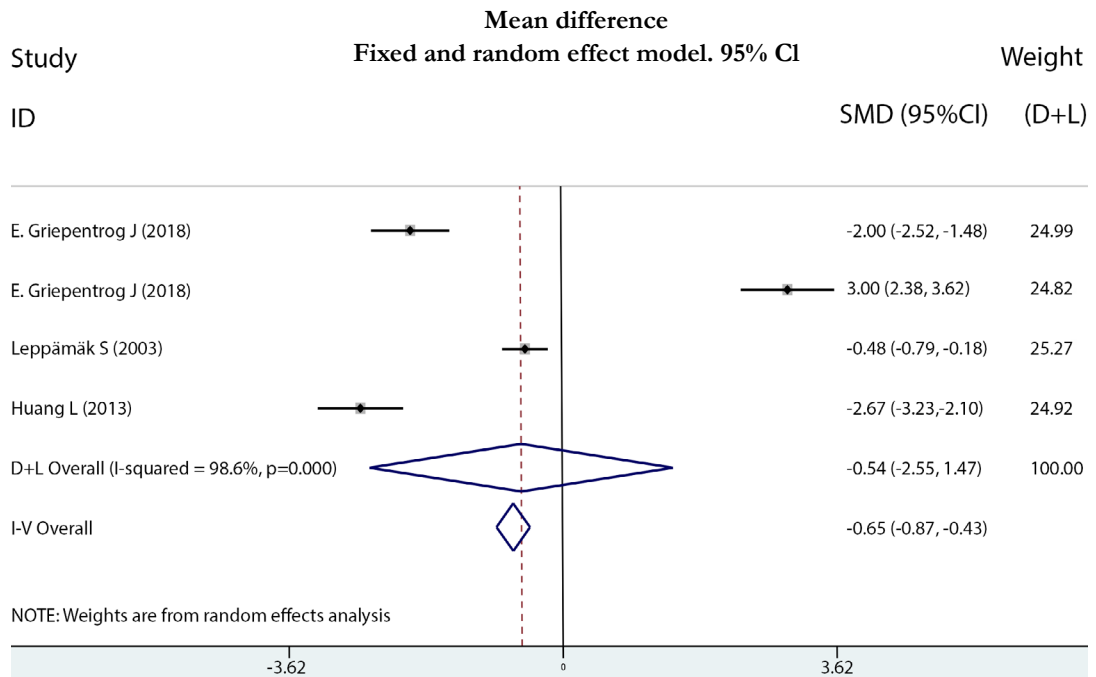
**Figure 3.** Risk of bias graph.

(a)

Study	Bright light exposure			Control			Weight	Mean difference [95% CI]
	Mean	SD	Sample	Mean	SD	Sample		
Griepentrog et al., 2018 <sup>22</sup>	2.6	0.2	43	3	0.2	43	24.99	-2.00 [-2.52,-1.48]
Griepentrog et al., 2018 <sup>22</sup>	2.3	0.2	43	1.7	0.2	43	24.82	3.00 [2.38,3.62]
Leppämäk et al., 2003 <sup>30</sup>	16.2	9.9	86	21	9.9	86	25.27	-0.48 [-0.79,-0.18]
Huang et al., 2013 <sup>24</sup>	5.7	5	46	16.9	3.2	46	24.92	-2.67 [-3.23,-2.10]

Heterogeneity: Tau<sup>2</sup>=4.130; Chi<sup>2</sup>=209.23, df=3 (p=0.000); I<sup>2</sup>=98.6%.

Test for overall effect; Z=0.53 (p=0.596).



(b)

Study	Bright light exposure			Control			Weight	Mean difference [95% CI]
	Mean	SD	Sample	Mean	SD	Sample		
Boivin et al., 2012 <sup>31</sup>	7.1	0.1	9	6.6	0.2	8	47.02	3.23 [1.73,4.72]
Kakooei et al., 2015 <sup>23</sup>	3.52	1.45	34	3.16	1.29	34	52.98	0.26 [-0.21,0.74]

Heterogeneity: Tau<sup>2</sup>=4.075; Chi<sup>2</sup>=13.68, df=1 (p=0.000); I<sup>2</sup>=92.7%.

Test for overall effect; Z=1.12 (p=0.263).

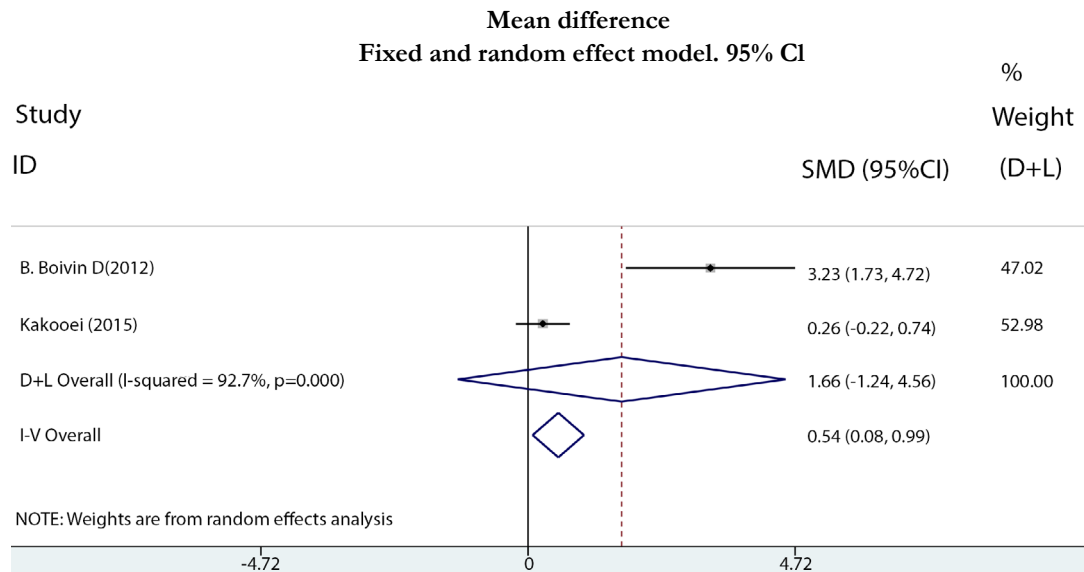


Figure 4. Forest plot for comparison of experimental versus control outcomes: (a) sleepiness levels, psychomotor error, complaints related to shift work and insomnia; (b) daytime sleep duration following night shifts and alertness. CI, confidence interval; SD, standard deviation.



of work conditions, education of managers and shift-workers, preventive health examination and medical check-up of shift-worker, non driving to and from work, familial and social support, possibility to rest and sleep before, during (nap) and after shifts at home, use of appropriate nutrition and improved physical fitness, lifestyle training, cognitive and behavioral interventions (exercise, optimal timing to rest breaks at work, social activities during breaks, sensory stimulation) and consideration of chronotype pattern of person. Nurses can use these strategies according to their conditions and discretion<sup>7,35,36</sup>.

According to our knowledge, this is the first systematic review evaluating the effects of bright light exposure in shift-worker nurses. Because shift-work in addition to sleep, can affect many aspects of the nurse's performance; many scales and tools have been used to test the treatment effect of bright light exposure in review studies. In this review, direct comparisons across interventions or amongst outcomes is difficult, because there is a different pattern of bright light exposure with regards to timing, duration, frequency, and intensity.

Also, our study has other limitations. First, due to the small number and low quality of the available RCTs, our meta-analysis results were limited. Second, our review was limited to English language studies. Third, the data identified via five main databases and maybe some of the related articles were not indexed on these five databases. Besides, some databases were not available to us such as CINAHL Nursing Journal Databases.

Although the results of fixed-effect are in favor of beneficial effects of bright light exposure in shift-worker nurses, the random effects could not approve these findings. Perhaps because of either large heterogeneity or insufficiency of the number of studies. Moreover, because of the low number of studies, it was impossible to deal with high amount of heterogeneity using subgroup analysis or meta-regression. On the other hand, the existence of clinical heterogeneity in studies such as the different baseline of selected shift-worker nurses, the different pattern of bright light with regards to timing, frequency, duration and intensity, might be affected the result.

## CONCLUSION

The results of our systematic review and meta-analysis suggested that bright light exposure may help shift-worker nurses learn better sleep management by decrease in the sleepiness levels, complaints related to shift-work, insomnia and increase in the alertness and daytime sleep duration following night shift. So the controversy on this topic continues to persist, which highlights the need for more well-designed randomized control trials with larger sample sizes to assess the non-pharmacological intervention such as bright light exposure in shift-worker nurses in the future.

Also, assess the safety of bright light exposure in shift-worker nurses is considered an important issue. It may be side-effects such as a headache, concomitant nausea, and irritation of the eye<sup>30</sup> for nurses that should be taken into account in future studies.

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