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Effects of red light on sleep quality in cardiac intensive care unit patients: A randomized controlled trial

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ABSTRACT

Background & Aim: Sleep disturbances are prevalent in cardiac intensive care units. Due to the side effects of sleep medications, this study aimed to assess the impact of red light on the sleep quality of patients in cardiac intensive care units.
Methods & Materials: In a randomized clinical trial, 80 patients in both study groups admitted to the coronary care unit of Shahid Beheshti Hospital in Kashan, Iran. In the intervention group, red light replaced the white light in the room for two consecutive nights. The sleep quality, insomnia severity, and frequency of insomnia causes of the patients in both groups were assessed before the intervention and on the first and second days after the intervention using the St. Mary's Hospital Sleep Quality Questionnaire.
Results: The sleep quality score of patients in the intervention group was higher after the intervention than in the control group (p=0.001). A statistically significant difference was observed between the two groups in the first and second days after that for sleep quality score and frequency of insomnia, and insomnia severity (P= 0.001). Comparing the scores of the dimensions of Sleep Quality Questionnaire before and after the intervention in the two groups showed that the two groups did not have a statistically significant difference in these dimensions (p>0.017).
Conclusion: Red light led to an improvement in sleep quality scores and a reduction in the severity and frequency of insomnia in patients admitted to the cardiac intensive care units. Its simplicity and low cost make it a recommended approach for improving their sleep.

Introduction

Sleep disturbances are common among critically ill patients (1). Disruption in the sleep-wake cycle affects other physiological functions of the body, including reduced appetite, fatigue, lack of concentration, symptoms intensification, and physical health issues (2,3). Sleep disturbances manifest as insomnia or hypersomnia. Insomnia includes difficulties in falling asleep, maintaining sleep, frequent awakenings, early morning awakenings, or a combination of these conditions. Hypersomnia involves excessive or insufficient sleep, poor quality sleep, difficulties in falling asleep, frequent awakenings, and breathing problems during sleep (4). Studies have also shown that patients in intensive care units (ICUs) consider sleep disturbances as a major source of stress during their hospitalization (2,5). Poor sleep quality, as a stress-inducing condition, leads to the release of epinephrine and norepinephrine, which increase heart rate, respiratory rate, blood pressure, myocardial oxygen demand, cardiac dysrhythmias, and reduce renal blood flow, ultimately exacerbating ischemia and myocardial infarction. Internal factors such as pain, discomfort, medications, anxiety, stress, aging, and external factors like environmental noise, monitor alarms, lighting, room temperature, and nursing and medical care contribute to the low sleep quality in ICUs (6). Madsen et al. (2019) found that patients

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experienced poor sleep quality during the first three days of hospitalization after acute coronary syndrome (7). Despite general recommendations emphasizing non-pharmacological methods for improving sleep, sedative medications are still used to treat sleep problems. Considering the side effects of these medications, including impaired cognitive function and memory, increased risk of falls, amnesia, respiratory depression, and the additional costs associated with their use, complementary medicine methods such as pleasant auditory stimuli, music therapy, thermal therapy, hypnosis, acupuncture, acupressure, relaxation and mindfulness techniques, and light therapy are recommended (8). One of the lights used is the red light. Red light can reduce sleep-wake cycle disturbances at night and improve sleep more than white light (9). In the ICU, however, light is necessary to facilitate nursing activities, and the white ambient light is maintained continuously throughout the day and night (10). Multiple studies have shown that white light at night disrupts sleep quality in patients (11–13).

Studies have indicated that white light is a significant factor disrupting sleep, as it disturbs the circadian rhythm, suppresses melatonin secretion, and consequently leads to sleep deprivation and a slower recovery process (12, 13). Several studies have mentioned that red is the best light color for sleeping (11, 12). These studies indicate that red light has a wavelength of over 600 nanometers, which is effective in reducing sleep disturbances (9, 12). Wright et al. (2001) found that red light positively affects sleep onset and duration (14). In a study by Ho Mein et al. (2014), it was noted that red light has specific advantages in initiating sleep compared to white light, as it resets the melatonin rhythm through photoreceptors (15). Wu et al. (2023) reported that individuals exposed to red light experienced a significant improvement in sleep disturbances (16). Zhang et al. conducted a study on mice demonstrating that 20 lux of red light had significant hypnotic effects and altered sleep duration compared to the control group exposed to white light (17). In the above studies, red light has a wavelength of more than 600 nanometers (nm), which is effective in reducing sleep disorders (9, 12). Contrary to the present study's findings, Figueiro et al. (2020) showed that red light (610 nm and 660 nm) enhanced alertness in rotating shift workers (18). Xie et al. (2020) found that using red light (600 nm) in individuals with insomnia increased anxiety and negative mood (19). Similarly, Askari Pour et al. (2019) discovered that red light (more than 600 nm) increased alertness compared to white light (20).

Due to the prevalence of sleep disorders among patients in the cardiac intensive care unit and the necessity to address these issues to enhance their health, as well as the conflicting findings regarding the impact of red light on sleep disorders and the scarcity of research in Iran, this study was conducted to determine the effects of red light on the sleep quality of patients admitted to the cardiac ICU.

Methods

Study design

The study was carried out as a clinical trial in 2024 on 80 patients admitted to the coronary care unit (CCU) of Shahid Beheshti Hospital in Kashan, Iran. The research protocol was registered with the clinical registry trial under the code IRCT20111210008348N43.

Samples and inclusion criteria

The sampling method was convenience sampling. The inclusion criteria were age between 30 and 75 years, written consent to participate in the study, the ability to speak and understand the language and be conscious, a minimum of 24 hours after admission to the CCU, no intubation, Hospitalized patients with myocardial infarction, unstable angina, and class II heart failure, and a minimum score on the MMSE test. Exclusion criteria included incomplete responses to questionnaires, early discharge before the end of the intervention,

resuscitation procedures, irregular use of red light during the intervention, and taking sleep medications.

At the beginning of the intervention, each patient, their companion, and their nurse were asked whether the presence of a red light was problematic for them or not. If the answer was negative, they were included in the study. If the patient, their companion, or the nurse felt discomfort with the red light, they were excluded from the study. In general, efforts were made to ensure that the patient, their companion, and the nurse felt comfortable while using the red light.

Sample size

The sample size was calculated using Cohen's formula with assumptions of $\alpha = 0.05$, $\beta = 0.2$, and $d = 0.5$, resulting in a sample size of 37 per group. Accounting for an approximate 10% dropout rate, the final sample size was set at 40 patients per group. Initially, 100 patients were selected, of whom 12 did not meet the inclusion criteria, and eight declined to participate. The remaining 80 patients were randomly assigned to two groups (intervention and control) using stratified randomization. In follow-up, none of the participants withdrew, and 40 patients in each group were analyzed (Figure 1).

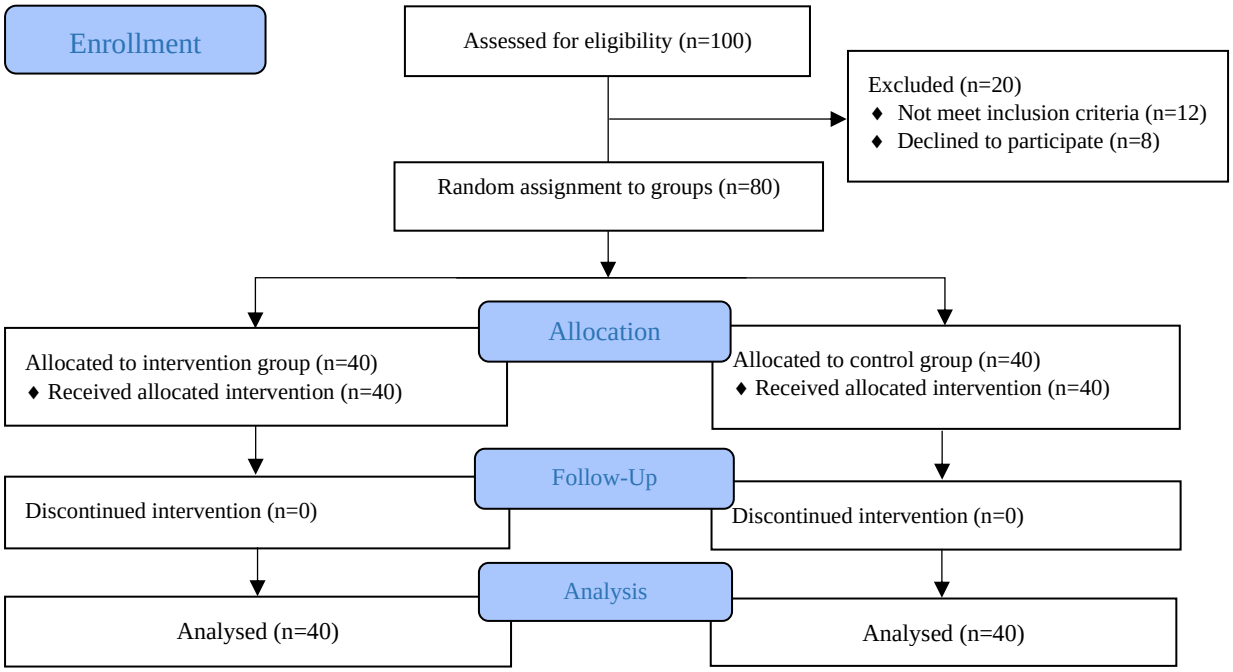

Figure 1. Flow diagram of the study

Randomization

Patients were initially selected using convenience sampling, and then block randomization assigned them to intervention and control groups. The randomization utilized a block randomization method consisting of 10 blocks of 8 participants each. This randomization list was created in collaboration with a statistician and utilized an online randomization tool (https://www.sealedenvelope.com/simplerandomiser/v1/lists). Participants were assigned to either the intervention group (40 samples) or the control group (40 samples). The two groups were matched regarding physician and prescribed medications, and type of disease.

Procedure

Intervention group

In the intervention group, room lights were turned off, and curtains were drawn to block white light from the corridors. The room lighting was changed to red using a desk lamp (Karimzadeh Industries, model DL 113) equipped with a 50-watt infrared bulb with a red filter and no visible light (wavelength above 700 nm-Lucky Herp). Red light at a wavelength of 700 nm was chosen because studies showed that wavelengths over 600 nm effectively reduce sleep disorders (9, 12). An agreement was made with the staff (nurses, nursing assistants, and doctors) and the patients to use only the desk lamp with a red bulb in the patient's room during the intervention (two consecutive nights). It should be noted that the red light was used individually for each patient from 10 PM to 6 AM for two consecutive nights (12). Patients were monitored for cardiac activity before, during, and after the intervention. Patients and their companions were informed to notify the nurses if they noticed any discomfort or changes in the patient's condition so that the intervention could be halted. Nurses were instructed to monitor the patients during the intervention without disturbing their sleep. Additionally, nurses and patient companions were trained to open and close the room door only when necessary. No intervention was conducted during the day, and patients used natural light or room lights for illumination. If necessary for safety reasons or based on patient preference, the room lighting could be reverted to white light, and such cases were excluded from the study. The room's light intensity was measured before and after the intervention using a WINTACT digital lux meter, model WT81. It is worth mentioning that the room's light intensity was set to 500 lux, based on the standard light intensity for typical work environments (21).

Control group

No changes were made to the room lighting in the control group. So that the room's door remained open at night, allowing white light from the hallway inside, while the open window curtains let in light from the yard lights.

Outcomes

Data were collected using demographic information questionnaires, which included age, gender, marital status, occupation, education, and underlying medical conditions, and the St. Mary's Hospital Sleep Quality Questionnaire (SMHSQ) was used for sleep quality assessment. This 14-question questionnaire assesses sleep quality, sleep latency, sleep period time, awake onset latency, total sleep duration, and napping habits. It is comprised of quantitative (questions 1, 2, 3, 4, 7, 8, and 14) and qualitative sections. The quantitative questions address the aforementioned sleep variables. Questions 5, 6, 9, 10, 11, 12, and 13 form the qualitative section, with scores from 6 to 38 indicating severe (6-16), moderate (17-27), or mild (28-38) insomnia. The frequency of insomnia in the two groups at three times before, on the first and second day after the intervention was assessed in the patients with one question. This questionnaire was validated and its reliability confirmed in a study by Atiaa Tolba et al. (2021) (22). The SMHSQ was administered in the coronary care unit at 8 am on the morning before the intervention and again at 8 am on the second and third days after the intervention. In the case of literate individuals, the questionnaire was completed by the patient, and as for illiterate individuals, it was completed by the first researcher.

Ethical consideration

This study was approved by Kashan University of Medical Sciences, Institutional Review Board and the Ethics Committee (code: IR.KAUMS.NUHEPM.REC.1399.008). The study was registered in the Iranian Registry of Clinical Trials (code: IRCT20111210008348N43). Informed consent was obtained from all study participants before the research.

Data analysis

Data were analyzed using SPSS version 19. The chi-square test was used to compare categorical variables, and the t-test was used to compare continuous variables between two groups for demographic information and variables of questionnaire variables at baseline. The repeated measures ANOVA test was used to compare sleep quality over time. The Friedman test was used to compare the frequency of insomnia severity in the two groups in three consecutive nights. Frequency of insomnia in the two groups at three times was assessed by the Cochran and Chi-square tests. The significance level was set at 0.05 for all tests. However, when the time*group interaction was significant, the two groups were compared at three time points using independent t-tests. To control for Type I error due to multiple comparisons, a Bonferroni correction was applied, and an adjusted significance level of less than 0.017 was considered statistically significant.

Results

In total, 65% of the intervention group and 55% of the control group were male. Additionally, 90% of the intervention group and 97.5% of the control group were married. The mean age of the intervention and control groups was 59.70 ± 11.39 and 58.50 ± 11.83 years, respectively. There were no statistically significant differences in demographic variables such as age, gender, marital status, education level, occupation, and underlying diseases between the two groups (P>0.05) (Table 1).

Table 1. Demographic information of the research participants in the two groups

Variable		Intervention group		Control group		Statistical test
		n	%	n	%	
Sex	Female	14	35	18	45	*P=0.361
	Male	26	65	22	55	
Marital status	Single	4	10	1	2.5	**P=0.359
	Married	36	90	39	97.5	
Job	Worker	7	17.5	4	10	*P=0.254
	Employee	2	5	0	0	
	Housekeeper	10	25	18	45	
	Retired	15	37.5	13	32.5	
	Unemployed	0	0	0	0	
	Other jobs	6	15	5	12.5	
Education level	Illiterate	6	15	12	30	**P=0.111
	Under diploma	24	60	15	37.5	
	Diploma	6	15	11	27.5	
	University education	4	10	2	5	
Known underlying disease	Have	16	40	17	42.5	*P=0.820
	Don't have	24	60	23	57.5	
Age	Mean±SD	59.70 ± 11.39		58.5 ± 11.83		***P=0.64

*Chi-Square, **Chi-Square (Exact), ***Independent t-test

There was no significant difference in sleep quality between the two groups at baseline. Figure 2 shows that after the intervention, the sleep quality scores of patients in the intervention group (at T2 and T3) were higher than those in the control group (p< 0.001). Table 2 presents the scores for Sleep Latency, Awake Onset Latency, the duration of the entire sleep process, and napping at T1, T2, and T3 for both groups. Because the time*group interaction was significant for Sleep Quality and Sleep Latency (p<0.001), comparisons between the two groups' means were conducted using independent t-tests with Bonferroni correction.

The severity of insomnia differed significantly between the two groups on the first and second day post-intervention (p< 0.001) (Table 3). There was also no significant difference in the proportion of insomnia between the two groups at each time point (p> 0.017). However, the absolute and relative frequency of insomnia within each group across the three time points showed a significant difference (p< 0.001) (Table 4).

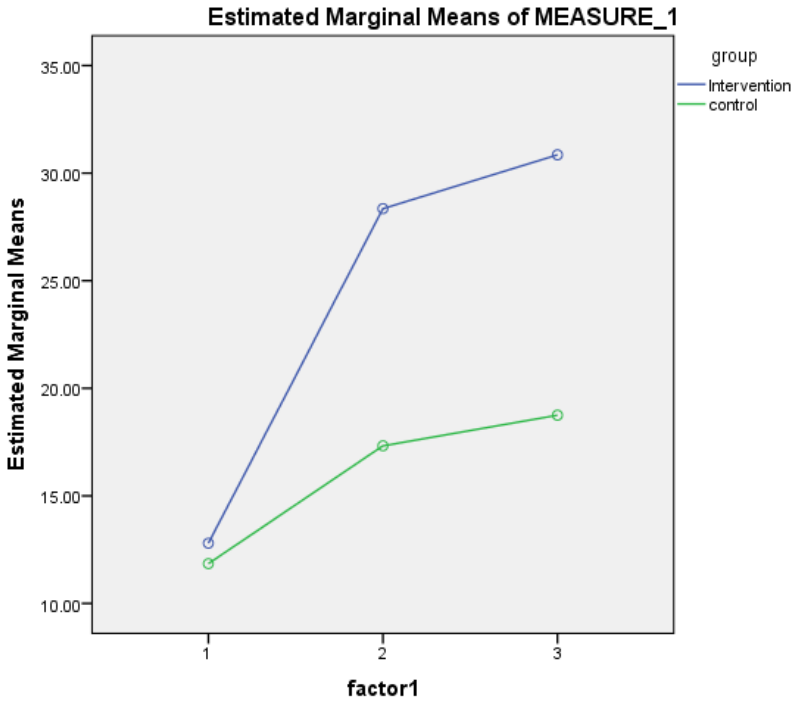

Figure 2. Comparison of sleep quality scores in the two groups at three time points

Table 2. Comparison of sleep quality scores of the two control and intervention groups in three consecutive nights

Variable	Group	Before intervention (T1)	The first day after that (T2)	The second day after that (T3)	Time factor	Time*group factor	Group factor
		Mean ± SD	Mean ± SD	Mean ± SD	P value	P value	P value
Sleep quality score	Intervention	12.80 ± 4.54	28.35 ± 7.75	30.85 ± 6.95	P< 0.001	P< 0.001	P< 0. 001
	Control	11.85 ± 4.53	17.32 ± 7.21	18.75 ± 8.04			
	**p-value	P= 0.35	P= 0.001	P= 0.001			
Sleep Latency	Intervention	1.03 ± 0.51	1.22 ± 1.22	1.68 ± 1.76	P<0.001	P=0.025	P=0.17
	Control	0.93 ± 0.40	2.15 ± 2.11	1.75 ± 1.62			
	**p-value	P= 0.34	P= 0.19	P= 0.85			
Sleep period time	Intervention	3.91 ± 2.30	5.06 ± 1.88	4.96 ± 2.12	P=0.012	P=0.20	P-0.37
	Control	4.04 ± 2.37	4.15 ± 1.97	4.90 ± 1.91			
	**p-value	P=0. 81	P=0.039	P=0.90			
Awake onset latency	Intervention	1.29 ± 1.19	0.55 ± 0.38	0.68 ± 0.61	P<0.001	P=0.31	P=0.44
	Control	1.09 ± 0.92	0.69 ± 0.65	0.53 ± 0.32			
	**p-value	P=0.40	P=0.23	P=0.17			
The duration of the entire sleep process	Intervention	6.95 ± 2.36	7.23 ± 1.48	7.65 ± 1.69	P=0.26	P=0.27	P=0.62
	Control	7.61 ± 2.48	7.18 ± 1.97	7.56± 2.20			
	**p-value	P=0.22	P=0.89	P=0.83			
Napping	Intervention	0.71 ± 0.89	0.65 ± 0.79	0.79 ± 1.02	P=0.68	P=0.47	P=0.88
	Control	0.83 ± 0.92	0.78 ± 0.81	0.83 ± 0.92			
	**p-value	P=0.56	P=0.44	P=0.84			

*Repeated measures ANOVA, **In depended t-test

Table 3. Frequency of insomnia severity in the two groups in three consecutive nights

Insomnia Severity			Intervention group (N=40) N (%)	Control group (N=40) N (%)	P-Value
Before intervention	Mild insomnia		0	0	*P=0.785
	Moderate insomnia		9(22.5)	8(20)	
	Severe insomnia		31(77.5)	32(80)	
The first day after that	Mild insomnia		25(62.5)	6(15)	*P<0.0001
	Moderate insomnia		12(30)	14(35)	
	Severe insomnia		3(7.5)	20(50)	
The second day after that	Mild insomnia		31(77.5)	9(22.5)	*P<0.0001
	Moderate insomnia		7(17.5)	13(32.5)	
	Severe insomnia		2(5)	18(45)	
Intra-group comparison	Average rating	Before intervention	1.09	1.65	*P<0.0001
		The first day after that	2.38	2.13	
		The second day after that	2.54	2.23	
****P-Value**			**P<0.0001	**P<0.0001	

*Chi-Square **Friedman Test

Table 4. Frequency of insomnia in the two groups at three time

Frequency of insomnia		Intervention group (N=40) N (%)	Control group (N=40) N (%)	P-Value
Before intervention	No	14(35)	8(20)	*P=0.13
	Yes	26(65)	32(80)	
The first day after that	No	25(62.5)	19(47.5)	*P=0.18
	Yes	15(37.5)	21(52.5)	
The second day after that	No	26(65)	23(57.5)	*P=0.49
	Yes	14(35)	17(42.5)	
****Intragroup comparison of proportions**		**P<0.0001	**P=0.006	

*Chi-Square **Cochran Test

Discussion

The results showed that the sleep quality score of the two groups had a significant difference after the intervention. The results also showed that although sleep quality scores increased in both groups, it was higher in the intervention group, and this difference was significant. This finding contrasts with the results of Pan et al. (2023) (11). The difference in outcome may be due to the variation in the intervention methods. One of the most significant differences was in the duration of the intervention method. They implemented the intervention for 1 hour, whereas here, it was 8 hours. Therefore, it can be concluded that the duration of the intervention the night before is an influential factor, and the longer the duration of the intervention the night before, the higher the sleep quality score.

The sleep quality score on the second day after the intervention in the intervention group was higher than that in the control group. Therefore, it can be concluded that the effects of the intervention persisted on the second day. The findings also showed that, in the intervention group, the longer the duration of the intervention, the higher the sleep quality score. Consistent with the present study, participants in Martin et al. (2018) (12) received red light intervention for five weeks, and Wu et al. (2023) (16) and Zhao et al. (2012) (9), they received it for two weeks, all reporting significant improvement in sleep disturbances. These studies showed that the light-sensitive Melanopsin cells in the retina are less responsive to red light, making red light more effective than white light in alleviating sleep (9,12,16). Given that no intervention was conducted in the control group in these studies, the differences in results could be attributed to variations in the physical conditions of ICUs, the behavior of staff (doctors, nurses, aides, and other personnel), visiting hours for companions, and other conditions that might differ among ICUs in hospitals.

In the control group, patients gradually adapted to the conditions of the intensive care unit (ICU) over time, leading to an improvement in their sleep quality. However, in our study, the sleep quality score of the

control group improved at a much slower rate compared to the intervention group, which aligns with the findings of Chamanzari et al. (2016) (23). However, it does not align with Oshvandi et al. (2020) (24) and Cheraghi et al. (2014) (25). Given that no intervention was performed in the control group in these studies, the reason for the difference in results could be due to the physical conditions of the intensive care units, the behavior of the ward personnel (doctors, nurses, services, and other personnel), visiting hours for companions, and other conditions that may vary in the intensive care units of hospitals.

The difference in sleep quality scores between the two groups before the study was not significant, indicating that participants in the intervention and control groups were homogeneous with no significant differences in insomnia. However, on the first and second days after the intervention, this difference became significant, demonstrating the positive effects of red light on sleep quality in our study. The findings by Wu et al. (2023) (16), Martin et al. (2018) (12), and Zhao et al. (2012) (9) were consistent with our study. Wu et al. (2023) examined female breast cancer survivors using a red-light cap at home for two weeks from 7 pm to 8 pm (16). Martin et al. (2018) investigated elderly psychiatric ward patients over five weeks between 10 pm and 7 am, employing a heat-resistant red rubber filter with wavelengths above 600 nm (12). Zhao et al. (2012) studied female basketball players who received red light therapy at a wavelength of 658 nm and a dose of 30 J/cm² for 30 minutes each night over two weeks (9). The present study differs from previous research in its timing, wavelength, duration of red-light use, and the patients examined.

Sleep latency increased over time in the intervention group, meaning that the red light caused patients to take longer to fall asleep. However, in the control group, sleep latency on the first day after the study was longer than before the study and decreased on the second day; however, following the intervention, the difference between the groups was not statistically significant. consistent with the findings of Wu et al. (2023) (16) and not aligned with Pan et al. (2023) (11) and Van der Meijden et al. (2018) (26). The difference in results could be due to variations in the intervention methods. One of the most significant differences was the duration of the intervention before sleep; thus, it can be concluded that an intervention duration of 5 minutes to 1 hour is more effective in reducing sleep latency compared to a longer duration.

The findings showed that in the intervention group, awake onset latency decreased significantly on the first day after the intervention compared to before the intervention, then slightly increased on the second day. However, it remained much lower than before the intervention. In the control group, awake onset latency decreased over time, and patients woke up earlier in the mornings. This result aligns with Figueiro et al. (2019) (27); however, it contradicts the findings of Wu et al. (2023) (16). The difference in results may be due to variations in the intervention method. Therefore, the study environment, gender, and chronotype of participants, the type of illness, the characteristics of the red-light device (wavelength and brightness), and the duration of the intervention are influencing factors in this intervention.

There was no significant difference between the intervention and control groups in terms of sleep period time during the previous night. Martin et al. (2018) found no significant difference in the recorded sleep duration between the intervention and control groups in quantitative measurements (12), which is consistent with our study's findings. Additionally, in our study, there was no significant difference in sleep period time between the two groups before the intervention and on the first and second days after the intervention. However, there was a significant difference between the sleep period time on the first and second days after the intervention, which is not consistent with the findings of Wu et al. (2023) (16). The variation in results may be due to differences in the intervention method. Therefore, the study environment, gender, and chronotype of

participants, the type of illness, the characteristics of the red-light device (wavelength and brightness), and the duration of the intervention are influencing factors in this intervention.

The results indicated that on the first and second days after the intervention, the severity of insomnia was significantly different between the two groups. Severe insomnia was more prevalent in the control group than in the intervention group. Moreover, over time, the severity of insomnia significantly decreased in both groups. After the intervention, the two groups had a significant difference in the severity of the insomnia score. This finding is consistent with Wu et al. (2023) (16), Martin et al. (2018) (12), and Zhao et al. (2012) (9).

There was no significant difference in the proportion of insomnia between the two groups at each time point. Over time, the rate of insomnia decreased more in the intervention group compared to the control group, consistent with Wu et al. (2023) (16), Martin et al. (2018) (12), and Zhao et al. (2012) (9). Sleep deprivation is a recognized risk factor for cardiovascular diseases, and evidence links sleep disorders to coronary heart disease (28). Therefore, the findings of this study could enhance the sleep quality of these patients in the cardiac ICU.

Conclusion

The use of red light improves the sleep quality of patients in ICUs. Given the prevalence of sleep disorders among patients in cardiac intensive care units, red light therapy can be used as a simple and safe method for patients and their nurses to reduce the complications of the disease. It is recommended that complementary medicine interventions, including the use of red light, be included as a non-pharmacological method alongside other treatments and routine patient care.

Limitations and suggestions

Challenges during the study included the lack of cooperation from some nurses, patients, and their companions. The research team attempted to address this by explaining the study's objectives to gain their cooperation. Moreover, since sleep quality is a subjective concept, the reliance on the accuracy and truthfulness of the participants' responses and also not controlling for all possible environmental variables (such as noise level variations) were limitation of this study. Future studies are recommended to involve other patients with sleep disorders, with a larger sample size, longer intervention duration, and more precise measurement tools.

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Author contributions

Provided research idea, Seyed Mahdi Motahary, Neda Mirbagher Ajorpaz; Collected data and analyzed Seyed Mahdi Motahary, Amir Mohammad Barati; Supervised data collection, and analysis, Neda Mirbagher Ajorpaz; Prepared the draft original writing and edited the manuscript, Verified the methodology, Seyed Mahdi Motahary, Neda Mirbagher Ajorpaz. The authors have read and agree to publish this manuscript.

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Conflict of interest

The authors declare no competing interests.

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