Occupational Exposure to Blue Light Emitted from Neonatal Phototherapy Devices Alters the Sleep Quality of NICU Nurses

Zahra Zahadatpour (MD)[1], Sayed Mostajab Razavinejad (MD)[2], Alireza Eslaminejad (MD)[3], Hassan Vafapour (PhD Candidate)[4], Seyed Mohammad Javad Mortazavi (PhD)[4,5]*, Seyed Ali Reza Mortazavi (MD)[6]*

[1]Department of NICU, Namazi Hospital, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Department of Pediatrics, School of Medicine, Neonatal Research Center, Namazi Teaching Hospital, Shiraz University of Medical Sciences, Shiraz, Iran
[3]Student research committee, Shiraz University of Medical Sciences, Shiraz, Iran
[4]Ionizing and Non-Ionizing Radiation Protection Research Center (SUMS), Shiraz University of Medical Sciences, Shiraz, Iran
[5]Department of Medical Physics and Engineering, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran
[6]MVLS College, The University of Glasgow, Scotland, UK

ABSTRACT

Exposure to blue light, primarily from light-emitting devices like LEDs, has raised concerns regarding its potential health effects. Neonatal intensive care unit (NICU) nurses, frequently exposed to both digital screens and blue light from phototherapy devices, face particular risks. This study aimed to investigate the influence of blue light exposure from neonatal phototherapy devices on the sleep quality of NICU nurses, presenting the first examination of this issue. NICU nurses and matched controls were studied, comparing their sleep quality using the Pittsburgh Sleep Quality Index (PSQI). General health and reaction time were also assessed using standard questionnaires and benchmark software, respectively. The light intensities of active phototherapy devices were recorded. Statistical analysis included an independent t-test, with a *P*-value of ≤0.05 considered statistically significant. The study found that exposure to blue light from neonatal phototherapy devices adversely affected sleep disturbances and daytime dysfunction in NICU workers. This aligns with research indicating that reducing ambient blue light can improve cognitive performance, alertness, and sleep quality, especially for night shift workers. It also corresponds with studies linking pre-sleep use of light-emitting devices to higher rates of insomnia in various countries. Amber lenses that block blue light have been proposed as a viable solution for sleep issues. This pioneering research underscores the importance of reducing blue light exposure for NICU nurses. Encouraging the use of blue light-blocking glasses is a practical step that can be taken to mitigate the adverse effects of blue light exposure.

Keywords

Blue Light; Phototherapy; NICU; Sleep Quality; Reaction Time; Nurses

*Corresponding authors:
Seyed Mohammad Javad Mortazavi
Department of Medical Physics and Engineering, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran
E-mail: mortazavismj@gmail.com

Seyed Ali Reza Mortazavi
MVLS College, The University of Glasgow, Scotland, UK
E-mail: alireza.mortazavi.med@gmail.com

Received: D7 April 2024
Accepted: 24 September 2024

Introduction

Exposure to blue light has been associated with various health issues, including sleep disturbances, psychiatric disorders, obesity, diabetes, increased bacterial growth, and certain types of cancers [1-4]. Energy-efficient compact fluorescent light bulbs (CFLs) and widely used light-emitting diodes (LEDs) in devices like TVs, computer monitors, laptops, smartphones, and tablets emit large amounts of blue light, significantly increasing human exposure. Despite appearing to emit white light, LEDs have peak intensities

within the blue wavelength range (400-490 nm) [5]. The harmful effects of prolonged exposure to "blue-rich" LED light, compared to light sources that emit less blue light, underscore concerns, particularly for individuals using digital screens in dim lighting at night [6-8].

Nurses working in neonatal intensive care units (NICUs) not only interact with digital screens but are also consistently exposed to low levels of blue light emitted by neonatal phototherapy devices. Phototherapy has long been employed for treating neonatal jaundice as an effective method to lower bilirubin levels in the blood and prevent kernicterus, a type of brain damage resulting from elevated bilirubin levels. Kernicterus can lead to conditions such as athetoid cerebral palsy, hearing loss, vision problems, and, in some cases, intellectual disabilities [9]. Blue and greenish-blue (turquoise) light, with peak emissions around 460 and 490 nm, are the most effective components of visible light (400-700 nm) for phototherapy [10]. This condition is observed in 60% and 85% of term and preterm babies, respectively, typically becoming apparent around three days after birth and peaking after approximately one week. NICU nurses experience varying levels of blue light exposure during their night shifts.

As far as we know, this is the first study to examine how exposure to blue light from neonatal phototherapy devices affects sleep quality in NICU nurses.

Material and Methods

Participants

This study was conducted among NICU nurses working in neonatal intensive care units, who provided informed consent to participate. The research environment included NICUs in hospitals affiliated with Shiraz University of Medical Sciences (SUMS). Inclusion criteria were being a nurse or midwife, age ≤40 years, working for ≥40 hours per week in the neonatal ward, not using drugs that affect reaction time, refraining from drinking tea and coffee during night shifts, and having no psychosomatic diseases. Exclusion criteria included reluctance to cooperate, using drugs that affect reaction time, and drinking tea or coffee during night shifts. The control group consisted of individuals with the same working conditions but not in departments with active phototherapy devices, and the groups were matched for age, sex, education level, tea and coffee consumption, as well as the use of sleep aid pills or drowsiness-inducing drugs. Light intensities of active phototherapy devices were recorded at various distances and angles.

The Pittsburg Sleep Quality Index (PSQI)

Sleep patterns were evaluated using the standard Pittsburgh Sleep Quality Index (PSQI) self-rated questionnaire. This questionnaire comprises 19 individual items that generate seven "component" scores, including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction [11]. PSQI question ratings range from 0 for "no difficulty" to 3 for "severe difficulty." The sum of these seven component scores yields a global score ranging from 0 to 21, where a score below 5 indicates significant sleep disturbance [12].

General Health Questionnaire (GHQ)

A 28-item GHQ with four subscales was used in this study, assessing somatic symptoms, anxiety and insomnia, social dysfunction, and severe depression.

Reaction Time

In this study, we followed the method outlined by Mortazavi et al. [13, 14]. Reaction time was measured using benchmark software. Participants were instructed to react as quickly as possible by right-clicking a laptop mouse when a red square on the screen turned green.

To reduce the impact of biological rhythms, all tests were conducted at the same time for both groups.

Statistical Analysis

Alongside descriptive statistics, an independent t-test was applied to compare the mean scores for sleep, working memory, and reaction time between the case and control groups. A *P*-value of ≤0.05 was considered statistically significant.

Results

The mean (±SD) age of participants was 20.94±5.06 years. All 40 participants, including 20 NICU nurses and 20 matched controls, were female. Furthermore, all participants were nurses (100%) with a bachelor's degree (100%). The demographic and occupational characteristics of the participants are presented in Table 1.

Pittsburgh Sleep Quality Index (PSQI)

The average scores (±SD) for subjective sleep quality were 1.45±0.69 for NICU workers and 1.60±0.68 for the control group (*P*=0.490). Sleep latency scores were 2.15±1.04 in NICU workers and 2.7±1.26 in the control group (*P*=0.141). Sleep duration scores were 0.45±0.60 for NICU workers and 0.60±0.99 for the control group (*P*=0.569). Habitual sleep efficiency scores were 0.30±0.66 for NICU workers and 0.20±0.62 for the control group (*P*=0.622). There was a statistically significant difference in sleep disturbances, with NICU workers scoring 1.30±0.47 and the control group 1.95±0.94 (*P*=0.009). Use of sleeping medication scores were 0.20±0.70 in NICU workers and 0.40±0.88 in the control group (*P*=0.431). Daytime dysfunction scores were 1.70±0.66 for NICU workers and 1.20±0.89 for the control group, showing a statistically significant difference (*P*=0.050). Lastly, the total PSQI scores averaged 7.80±2.78 in NICU workers and 8.70±3.79 in the control group (*P*=0.397).

Reaction Time (RT)

As displayed in Table 2, the average reaction times were 0.49±0.23 for NICU workers and 0.41±0.15 for the control group (*P*=0.397), with no statistically significant difference (*P*=0.214).

General Health Questionnaire (GHQ)

The average scores for somatic symptoms were 0.95±0.83 in NICU workers and 0.85±0.88 in the control group (*P*=0.712). For anxiety and insomnia, NICU workers scored 1.25±0.85 compared to 1.20±0.62 in the control group (*P*=0.833) (Table 3). Social dysfunction scores were 1.20±0.41 for NICU workers and 0.90±0.45 for the control group, with a statistically significant difference (*P*=0.033). Scores for severe depression were 0.45±0.61 in NICU workers and 0.20±0.41 in the control group (*P*=0.134). The total GHQ scores were 1.15±0.59 in NICU workers and 0.85±0.59 in the control group (*P*=0.114).

Table 1: Demographic and occupational characteristics of the participants (N=40). All participants were female nurses.

	NICU Group N=20 (50%)	Controls N=20 (50%)	Significance
Age (year)	27.00 (5.80)	30.55 (5.58)	N.S.
Occupational exposure to blue light-emitting sources	100%	0%	N/A
Shift Work Including Night Shifts	100%	100%	N/A

N.S.: Not statistically significant

Table 2: Reaction Time and the Pittsburg Sleep Quality Index (PSQI) Mean (±SD).

PSQI component	NICU Nurses N=20 Mean±SD	Matched Control Group N=20 (Mean±SD)	Significance (*P* value)
Visual Reaction Time	(0.488±0.232)	0.409±0.153	NS *P*=0.214
Subjective Sleep Quality	1.45±0.69	1.60±0.68	NS *P*=0.490
Sleep Latency	2.15±1.04	2.7±1.26	NS *P*=0.141
Sleep Duration	0.45±0.60	0.60±0.99	NS *P*=0.569
Habitual Sleep Efficiency	0.30±0.66	0.20±0.62	NS *P*=0.622
Sleep Disturbances	1.30±0.47	1.95±0.94	***P*=0.009**
Use of Sleeping Medication	0.20±0.70	0.40±0.88	NS *P*=0.431
Daytime Dysfunction	1.70±0.66	1.20±0.89	***P*=0.050**
Total PSQI	7.80±2.78	8.70±3.78	NS *P*=0.397

NS: Not Significant, PSQI: Pittsburgh Sleep Quality Index, NICU: Neonatal Intensive Care Unit

Table 3: General Health Questionnaire (GHQ) Mean (±SD).

GHQ Component	Intervention Group (N=20) Mean±SD	Control Group (N=20) Mean±SD	Significance (*P* value)
Somatic Symptoms	0.95±0.83	0.85±0.88	NS *P*=0.712
Anxiety And Insomnia	1.25±0.85	1.20±0.62	NS *P*=0.833
Social Dysfunction	1.20±0.41	0.90±0.45	***P*=0.033**
Severe Depression	0.45±0.61	0.20±0.41	NS *P*=0.134
Total GHQ Score	1.15±0.59	0.85±0.59	NS *P*=0.114

NS: Not Significant, GHQ: General Health Questionnaire

Discussion

To the best of our knowledge, this is the first study to demonstrate the adverse effects of exposure to blue light from phototherapy devices on sleep disturbances and daytime dysfunction in NICU workers. These findings are supported by previous studies showing that reducing ambient blue light can enhance cognitive performance, alertness, and sleep quality in night shift workers [15]. Moreover, our findings align with studies indicating a link between widespread use of light-emitting devices before bedtime and increased prevalence of insomnia [16]. Our results also agree with studies showing that even evening exposure to low-intensity blue light from LEDs, which typically has no effect on sleep, can induce drowsiness and decreased energy metabolism the following morning [17].

On a broader scale, our findings are consistent with research by Pham et al. in Italy, which found that using electronic devices (EDs) near bedtime for over 30 minutes was significantly associated with poorer sleep quality, even after accounting for depression, exercise, and the consumption of caffeine and alcohol later in the day [18]. In another study in Morocco, Jniene et al. used an electronic questionnaire to investigate sleep quality in 294 medical and pharmacy students, finding that 97.3% of the students used digital screens (smart devices emitting blue light) at bedtime before sleep. Poor sleep quality (PSQI>5) was reported in 35.3% of the students, with 65.7% reporting

sleep disturbances after using digital screens at night [19]. In Saudi Arabia, a cross-sectional study involving 1925 students showed that high mobile screen time (≥8 hours/24 hours) and using digital screens for over 30 minutes before sleeping in the dark were associated with poor sleep quality [20].

In India, a cross-sectional observational study of 450 medical undergraduate students revealed that those who used screens for more than 2 hours had significantly prolonged sleep latency, reduced sleep duration, sleep inefficiency, and daytime sleep disturbances [21]. Furthermore, there are reports suggesting that blue-enriched light in the workspace has the potential to improve subjective sleepiness in night shift workers [22, 23]. Some studies have even introduced amber lenses that block blue light as a safe, affordable, and easily implementable therapeutic intervention for sleep problems [16]. Therefore, we recommend that NICU nurses who use active phototherapy units consider wearing blue light-blocking glasses at work.

Conclusion

This study is the first to examine the adverse health effects of occupational exposure to nocturnal blue light from phototherapy devices in NICU nurses. Given the reported efficacy of blue-blocking amber lenses as a safe and easily implemented intervention for sleep problems, we encourage nurses using active phototherapy units to consider wearing blue light-blocking glasses at work.

Acknowledgment

This study was supported by Shiraz University of Medical Sciences.

Authors' Contribution

SMJ. Mortazavi conceived the main idea. Z. Zahadatpour and SMJ. Mortazavi designed the study. All authors including SM. Razavinejad, A. Eslaminejad, H. Vafapour and SAR. Mortazavi were actively involved in the different stages of the study. SAR. Mortazavi drafted the manuscript. All authors have read and approved the final manuscript.

Ethical Approval

The study was approved by the SUMS ethics committee (Permit Number: IR.SUMS.REC.1399.807).

Informed Consent

The participants signed a consent form and were given a copy of their signed form.

Funding

This project was funded by the SUMS student research committee (Project No. 21364).

Conflict of Interest

SMJ. Mortazavi, as the Editorial Board Member, was not involved in the peer-review and decision-making processes for this manuscript.

References

1. Stevens RG, Brainard GC, Blask DE, Lockley SW, Motta ME. Adverse health effects of nighttime lighting: comments on American Medical Association policy statement. *Am J Prev Med.* 2013;**45**(3):343-6. doi: 10.1016/j.amepre.2013.04.011. PubMed PMID: 23953362.
2. Stevens RG. Light-at-night, circadian disruption and breast cancer: assessment of existing evidence. *Int J Epidemiol.* 2009;**38**(4):963-70. doi: 10.1093/ije/dyp178. PubMed PMID: 19380369. PubMed PMCID: PMC2734067.
3. Grønli J, Byrkjedal IK, Bjorvatn B, Nødtvedt Ø, Hamre B, Pallesen S. Reading from an iPad or from a book in bed: the impact on human sleep. A randomized controlled crossover trial. *Sleep Med.* 2016;**21**:86-92. doi: 10.1016/j.sleep.2016.02.006. PubMed PMID: 27448477.
4. Taheri M, Darabyan M, Izadbakhsh E, Nouri F, Haghani M, Mortazavi SAR, et al. Exposure to Visible Light Emitted from Smartphones and Tablets Increases the Proliferation of Staphylococcus aureus: Can this be Linked to Acne? *J Biomed Phys Eng.* 2017;**7**(2):163-8. PubMed PMID: 28580338. PubMed PMCID: PMC5447253.
5. Tosini G, Ferguson I, Tsubota K. Effects of blue

light on the circadian system and eye physiology. *Mol Vis.* 2016;**22**:61-72. PubMed PMID: 26900325. PubMed PMCID: PMC4734149.

6. Shang YM, Wang GS, Sliney D, Yang CH, Lee LL. White light-emitting diodes (LEDs) at domestic lighting levels and retinal injury in a rat model. *Environ Health Perspect.* 2014;**122**(3):269-76. doi: 10.1289/ehp.1307294. PubMed PMID: 24362357. PubMed PMCID: PMC3948037.
7. Mortazavi SMJ, Mortazavi SAR, Habibzadeh P, Mortazavi G. Is it Blue Light or Increased Electromagnetic Fields which Affects the Circadian Rhythm in People who Use Smartphones at Night. *Iran J Public Health.* 2016;**45**(3):405-6. PubMed PMID: 27141511. PubMed PMCID: PMC4851763.
8. Arjmandi N, Mortazavi G, Zarei S, Faraz M, Mortazavi SAR. Can Light Emitted from Smartphone Screens and Taking Selfies Cause Premature Aging and Wrinkles? *J Biomed Phys Eng.* 2018;**8**(4):447-52. doi: 10.31661/jbpe.v0i0.599. PubMed PMID: 30568934. PubMed PMCID: PMC6280109.
9. CDC. What are Jaundice and Kernicterus? Centers for Disease Control and Prevention (CDC); 2020.
10. Ebbesen F, Vandborg PK, Madsen PH, Trydal T, Jakobsen LH, Vreman HJ. Effect of phototherapy with turquoise vs. blue LED light of equal irradiance in jaundiced neonates. *Pediatr Res.* 2016;**79**(2):308-12. doi: 10.1038/pr.2015.209. PubMed PMID: 26484622.
11. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 1989;**28**(2):193-213. doi: 10.1016/0165-1781(89)90047-4. PubMed PMID: 2748771.
12. Chiu N-Y, Hsu W-Y. Sleep Disturbances in Methadone Maintenance Treatment (MMT) Patients. Chapter 62. Neuropathology of Drug Addictions and Substance Misuse. San Diego: Academic Press; 2016. p. 608-15.
13. Mortazavi SM, Rouintan MS, Taeb S, Dehghan N, Ghaffarpanah AA, Sadeghi Z, Ghafouri F. Human short-term exposure to electromagnetic fields emitted by mobile phones decreases computer-assisted visual reaction time. *Acta Neurol Belg.* 2012;**112**(2):171-5. doi: 10.1007/s13760-012-0044-y. PubMed PMID: 22426673.
14. Mortazavi SMJ, Taeb S, Dehghan N. Alterations of visual reaction time and short term memory in military radar personnel. *Iran J Public Health.* 2013;**42**(4):428-35. PubMed PMID: 23785684. PubMed PMCID: PMC3684731.
15. Kazemi R, Alighanbari N, Zamanian Z. The effects of screen light filtering software on cognitive performance and sleep among night workers. *Health Promot Perspect.* 2019;**9**(3):233-40. doi: 10.15171/hpp.2019.32. PubMed PMID: 31508344. PubMed PMCID: PMC6717920.
16. Shechter A, Kim EW, St-Onge MP, Westwood AJ. Blocking nocturnal blue light for insomnia: A randomized controlled trial. *J Psychiatr Res.* 2018;**96**:196-202. doi: 10.1016/j.jpsychires.2017.10.015. PubMed PMID: 29101797. PubMed PMCID: PMC5703049.
17. Kayaba M, Iwayama K, Ogata H, Seya Y, Kiyono K, Satoh M, Tokuyama K. The effect of nocturnal blue light exposure from light-emitting diodes on wakefulness and energy metabolism the following morning. *Environ Health Prev Med.* 2014;**19**(5):354-61. doi: 10.1007/s12199-014-0402-x. PubMed PMID: 25092557. PubMed PMCID: PMC4166587.
18. Pham HT, Chuang HL, Kuo CP, Yeh TP, Liao WC. Electronic Device Use before Bedtime and Sleep Quality among University Students. *Healthcare (Basel).* 2021;**9**(9):1091. doi: 10.3390/healthcare9091091. PubMed PMID: 34574865. PubMed PMCID: PMC8466496.
19. Jniene A, Errguig L, El Hangouche AJ, Rkain H, Aboudrar S, El Ftouh M, Dakka T. Perception of Sleep Disturbances due to Bedtime Use of Blue Light-Emitting Devices and Its Impact on Habits and Sleep Quality among Young Medical Students. *Biomed Res Int.* 2019;**2019**:7012350. doi: 10.1155/2019/7012350. PubMed PMID: 31950050. PubMed PMCID: PMC6944959.
20. Rafique N, Al-Asoom LI, Alsunni AA, Saudagar FN, Almulhim L, Alkaltham G. Effects of Mobile Use on Subjective Sleep Quality. *Nat Sci Sleep.* 2020;**12**:357-64. doi: 10.2147/NSS.S253375. PubMed PMID: 32607035. PubMed PMCID: PMC7320888.
21. Krishnan B, Sanjeev RK, Latti RG. Quality of Sleep Among Bedtime Smartphone Users. *Int J Prev Med.* 2020;**11**:114. doi: 10.4103/ijpvm.IJPVM_266_19. PubMed PMID: 33088442. PubMed PMCID: PMC7554597.
22. Sletten TL, Ftouni S, Nicholas CL, Magee M, Grunstein RR, Ferguson S, et al. Randomised controlled trial of the efficacy of a blue-enriched light intervention to improve alertness and performance in night shift workers. *Occup Environ Med.* 2017;**74**(11):792-801. doi: 10.1136/oemed-2016-103818. PubMed PMID: 28630378.
23. Sunde E, Pedersen T, Mrdalj J, Thun E, Grønli J, Harris A, et al. Blue-Enriched White Light Improves Performance but Not Subjective Alertness and Circadian Adaptation During Three Consecutive Simulated Night Shifts. *Front Psychol.* 2020;**11**:2172. doi: 10.3389/fpsyg.2020.02172. PubMed PMID: 33013558. PubMed PMCID: PMC7462016.