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The Effect of A White Noise on Sleep Quality Among Critically Ill Patients in Indonesia: A Randomized Controlled Trial

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A B S T R A C T

Introduction: Sleep disturbance is a frequent problem among critically ill patients and may adversely affect recovery. White noise has been proposed as a non-pharmacological approach to reduce environmental disruption and improve sleep; however, evidence from Indonesian intensive care units (ICUs) is currently lacking. **Objectives:** This study aimed to evaluate the effect of white noise exposure on sleep quality among critically ill patients treated in ICUs in Indonesia. **Methods:** A randomized controlled trial was performed in the ICUs of three public hospitals in West Java, Indonesia, involving adult ICU patients. The intervention group received white noise twice daily for three days, while controls received standard care. Sleep quality was measured using the RCSQ and analyzed with repeated-measures ANOVA, Cohen's d, and GEE models. **Results:** Final analyses included 25 participants in the intervention group and 25 in the control group. Sleep quality in the intervention group showed a significant improvement at the third measurement point, with a moderate effect size (d = 0.42). No significant changes were observed in the control group. GEE analysis demonstrated a significantly greater improvement in sleep quality in the intervention group compared with the control group after three days ($\beta = 6.43$, $p < 0.001$). **Conclusions:** White noise intervention was associated with improved sleep quality among critically ill ICU patients. These findings support the incorporation of acoustic management strategies into ICU care to enhance patient comfort and recovery.

ARTICLE INFO

Article History:

Received: November 01st , 2025
Revised: December 03th , 2025
Accepted: December 24th , 2025
First Available Online: December 26th, 2025
Published: December 26th, 2025

Keywords:
White Noise, Sleep Quality, Critically Ill Patients, Intensive Care Unit, Randomized Controlled Trial, Indonesia

1. INTRODUCTION

Sleep represents a fundamental biological need and is closely associated with physical well-being as well as recovery from illness. When individuals are admitted to an intensive care unit (ICU), particularly in critical conditions, they are required to adapt to a highly unfamiliar and demanding environment. This setting is often perceived as disorienting and overwhelming, while patients' perceptions, interactions, and sensory experiences may become limited. ICU patients are continuously exposed to multiple environmental stimuli that can interfere with normal sleep–wake regulation. Common sources of sleep disturbance include routine nursing and medical procedures, family visits, and frequent alarm signals. Persistent exposure to alarms may place patients in a sustained state of alertness. Experimental work by Ryherd and colleagues, using a simulated ICU environment, demonstrated alterations in sleep architecture alongside elevated biochemical indicators of physiological stress (Devlin et al., 2018; Miranda-Ackerman et al., 2020).

Objective sleep assessments using polysomnography in critically ill populations reveal marked disruptions in normal sleep structure. Light sleep (stage N1) is typically brief, often lasting fewer than ten minutes, while stage N2 predominates with a duration of approximately 30–60 minutes, despite offering limited restorative value. In addition, both slow-wave sleep and rapid eye movement (REM) sleep are substantially reduced. Sleep problems may persist well beyond ICU discharge, with insomnia reported for several months following hospitalization (Barr et al., 2013; Simini, 1999).

Inadequate sleep has detrimental effects on autonomic balance and vascular regulation, both of which play a crucial role in tissue healing and physiological recovery among critically ill patients. Insufficient or fragmented sleep may also impair immune responses, thereby increasing vulnerability to infectious complications. Disturbances in sleep are associated with an imbalance between sympathetic and parasympathetic nervous system activity, which can manifest as unstable blood pressure, tachycardia, heightened metabolic demand, reduced oxygenation, and impaired erythropoiesis. Given that outcomes in intensive care are strongly influenced by patients' underlying conditions and the treatments they receive, disrupted sleep represents a significant clinical issue. Moreover, patients with preexisting sleep problems may experience compounded negative effects when exposed to the intensive care environment, potentially prolonging recovery and diminishing overall comfort and well-being during hospitalization (Danielis et al., 2020; Rotondi et al., 2002).

A variety of strategies have been explored to reduce environmental disturbances in ICUs. Interventions such as eye masks and earplugs have shown beneficial effects; however, these approaches primarily block sensory input rather than addressing the environmental sources of light and noise. Their effectiveness is also limited by poor patient compliance, as discomfort, anxiety, and feelings of sensory isolation may reduce acceptance (Delaney et al., 2015; Demoule et al., 2017; Matthews, 2011). White noise, defined as a continuous sound with uniform energy distributed across a wide frequency spectrum ranging from 20 to 20,000 Hz, has been proposed as an alternative approach. It is commonly generated using natural sound patterns such as rainfall, wind, or ocean waves (Boot, 2012; Rowley-Conwy, 2018).

DOI: https://doi.org/10.17509/jpki.v11i2.93926
e-ISSN 2477-3743 | p-ISSN 2541-0024

Previous studies have increasingly highlighted the potential role of white noise as a supportive intervention for improving sleep in critical care environments. A systematic review conducted by Jun and colleagues synthesized evidence from non-pharmacological sleep interventions and found that approaches incorporating white noise were associated with favorable sleep outcomes among critically ill adult patients. The review emphasized that masking disruptive environmental sounds may help stabilize sleep–wake patterns in intensive care units, where noise exposure is unavoidable.

Further empirical support is provided by a randomized controlled trial carried out in India, which specifically examined the use of a white noise application among ICU patients. In that study, participants exposed to white noise over a three-day period demonstrated a significant improvement in perceived sleep quality when compared with patients receiving routine care alone. These findings suggest that white noise may mitigate the negative effects of environmental noise in ICUs. Collectively, available evidence supports the feasibility and effectiveness of white noise as a non-pharmacological strategy to enhance sleep quality in critically ill populations, warranting further investigation across diverse healthcare settings (Falcó-Pegueroles & Rodríguez-Martín, 2018; Murphy et al., 2011). Despite these encouraging findings, no empirical studies have examined the effects of white noise on sleep among critically ill patients in Indonesian ICUs. Given the documented advantages of white noise and the growing body of supporting clinical evidence, this study was designed to investigate its effect on sleep quality among critically ill patients in Indonesia using a randomized controlled trial approach (Castillo et al., 2016; Moser et al., 2003).

2. METHODS

Study Design

This research employed a randomized controlled trial design conducted in the intensive care units (ICUs) of three government-owned hospitals in West Java, Indonesia. Ethical approval was granted by the Institutional Review Board of the Faculty of Nursing, Universitas Indonesia (reference number: KET-29/UN2.F12.D1.2.1/PPM.00.02/2023). Written informed consent was obtained from all participants before enrollment and data collection.

Sample

Eligible participants were adults aged 18 years or older who demonstrated stable postoperative hemodynamic status and normal hepatic, renal, and pulmonary function. Individuals with a history of diabetes mellitus, neurological or psychiatric disorders were excluded. Additional exclusion criteria included severe sleep disturbances, postoperative complications such as renal failure, thoracic aortic dissection, delirium, coma, unconsciousness, and conditions requiring continuous sedation or analgesia, including cardiac valve replacement and congenital heart disease. Throughout the study period, nursing staff were instructed to maintain routine clinical practices without implementing specific noise-reduction strategies.

DOI: https://doi.org/10.17509/jpki.v11i2.93926
e-ISSN 2477-3743 | p-ISSN 2541-0024

Sample size estimation was based on findings from a preliminary pilot study, which indicated an expected standard deviation of 27. A non-pharmacological intervention was projected to yield a 28-point difference in mean sleep quality scores between groups. Assuming an effect size of 0.8 and a significance threshold of 0.05, a minimum of 20 participants per group was required. To account for an anticipated attrition rate of 10%, 25 participants were recruited for each study arm (Induja et al., 2022; Richards, 1987; Sundstrom et al., 1994).

Randomization and Blinding

Random assignment was performed using a computer-generated sequence with block randomization and a block size of six to ensure balanced allocation between groups. Equal allocation ratios were applied. Sequential screening numbers were assigned to participants according to the generated random sequence. A total of 50 participants were organized into blocks, each comprising six individuals.

A research assistant, who was not informed about the study objectives, managed the randomization process. Group assignments were sealed in opaque envelopes to maintain concealment. This assistant was responsible for configuring identical music players to deliver either white noise at 50 dB for the intervention group or silence (0 dB) for the sham condition. The assistant maintained a consistent and neutral approach and did not use ear protection. Blinding was maintained for the investigator, clinicians, participants, and outcome assessors throughout the trial.

Study Intervention

Before the intervention commenced, all participants were fully conscious, positioned comfortably in bed, and exposed to an ICU environment with minimized background noise. Ambient and operational noise levels remained below 50 dB. The intervention consisted of exposure to a white noise application twice daily over three consecutive days. Different sound profiles were employed across the intervention period: a steady air-conditioning sound on day one, ocean wave sounds on day two, and continuous rainfall on day three, corresponding respectively to white, pink, and brown noise. The intervention was delivered using JBL C10SI earbuds, selected for their noise isolation and cancellation properties.

Participants in the control group underwent a sham intervention involving a device set at 0 dB, while routine ICU environmental noise was left unchanged to reflect real-world conditions. Both groups remained in the same clinical setting, with the only difference being the auditory intervention. The research assistant's role was limited to monitoring and documenting adverse events and did not include patient care or data analysis responsibilities.

Instruments

Demographic and clinical characteristics were obtained from medical records and included age, sex, length of ICU stay (hours), duration of hospitalization (days), and body mass index.

DOI: https://doi.org/10.17509/jpki.v11i2
e-ISSN 2477-3743 | p-ISSN 2541-0024

Illness severity was assessed using the Acute Physiology and Chronic Health Evaluation (APACHE) II score, calculated within the first 24 hours following ICU admission.

Sleep Quality Assessment

Sleep quality was evaluated using the Richards–Campbell Sleep Questionnaire (RCSQ), a self-report instrument measuring five domains: depth of sleep, time to fall asleep, frequency of awakenings, ease of returning to sleep, and overall sleep perception. Each domain is scored on a 0–100 scale, with higher scores indicating better sleep. The overall sleep quality score was calculated as the mean of the five domain scores. In this study, internal consistency reliability was high, with a Cronbach's alpha of 0.88.

Data Collection Procedure

Two trained research assistants conducted data collection under the supervision of the project coordinator. Patient screening took place during weekday daytime hours in collaboration with the assigned nursing staff. Eligible patients were invited to participate and provided written consent prior to completing baseline and post-intervention questionnaires. Daily sleep diaries were collected each morning. Data entry was completed using tablet devices by either the participants or the research assistants. All data were exported to Microsoft® Excel 2016 and securely stored on a protected server.

Data Analysis

Descriptive statistics, including means, standard deviations, and frequencies, were computed for all variables. Group differences in categorical variables were examined using chi-square tests, while independent t-tests were applied for continuous variables. Changes in sleep quality scores between pre- and post-intervention measurements were analyzed using analysis of variance (ANOVA). Effect size was calculated using Cohen's d. To assess the longitudinal impact of the intervention, a Generalized Estimating Equation (GEE) model was employed, focusing on estimating population-averaged effects across time points. Statistical analyses were performed using SPSS version 23 (SPSS Inc., Chicago, IL, USA).

3. RESULTS

A total of 60 eligible patients were initially enrolled in the study. During the intervention phase, several participants from the intervention arm did not complete the protocol. Specifically, three individuals were withdrawn due to serious clinical complications, five declined the use of earplugs and eye masks, and two refused exposure to the audio intervention. Consequently, the final analysis included 50 participants, comprising 25 patients in the intervention group and 25 in the control group.

DOI: https://doi.org/10.17509/jpki.v11i2.93926
e-ISSN 2477-3743 | p-ISSN 2541-0024

Table 1. Comparison of sleep quality scores in the intervention and control groups across time points using ANOVA

Group	T0 (Mean ± SD)	T1 (Mean ± SD)	T2 (Mean ± SD)	T3 (Mean ± SD)	F	p-value	Cohen's d
Intervention group	68.5 ± 16.61	73.42 ± 5.71	78.52 ± 7.23	83.7 ± 14.7	9.78	0.001	0.42
Control group	66.5 ± 8.43	65.1 ± 11.2	64.4 ± 15.3	68.1 ± 7.45	1.13	0.231	0.03

Note: RCSQ total score measured at baseline (T0), day 1 (T1), day 2 (T2), and day 3 (T3).

Table 2. Effect of the intervention on sleep quality based on repeated-measures analysis using the GEE approach

Variables	Within group (Ref: Baseline)	Between group (Ref: Control)	Interaction (Group × Time)
	β	p	β
Sleep quality	3.34	0.32	6.43

Note: IG = intervention group; CG = control group; β = regression coefficient. Estimates were obtained using GEE models including a Group × Time interaction term; p-values adjusted accordingly.

Participants in the intervention group had a mean age of 51.25 ± 14.15 years, and men accounted for 60% of the sample. The mean APACHE II score recorded at admission was 20.45 ± 2.56, while the average body mass index was 21.32 ± 3.76. Patients in this group spent an average of 52.3 ± 15.33 hours in the ICU and remained hospitalized for a mean duration of 12.3 ± 6.54 days. In the control group, the mean age was 52.69 ± 12.44 years, with males representing 52% of participants. The mean APACHE II score at admission was 21.54 ± 3.14, and the average body mass index was 22.71 ± 4.06. ICU stay averaged 53.6 ± 13.52 hours, while the mean length of hospital stay was 10.5 ± 6.23 days. Statistical analyses demonstrated no significant baseline differences between groups with respect to age, sex, ICU length of stay, total hospitalization days, or body mass index ($p > 0.05$).

At the initial assessment, sleep quality scores did not differ significantly between the intervention and control groups. Repeated-measures ANOVA revealed a significant improvement in sleep quality at the third follow-up measurement (T3) within the intervention group, accompanied by a moderate effect size (Cohen's $d = 0.42$). In contrast, no meaningful change in sleep quality was observed among participants assigned to the control group after three consecutive days (Table 1).

Further analysis indicated a statistically significant interaction between time and treatment group with respect to sleep quality outcomes. Patients in the intervention group experienced a significantly greater improvement in sleep quality following three days of exposure compared with those in the control group ($\beta = 6.43$, $p < 0.001$), as demonstrated by the Generalized Estimating Equation (GEE) model (Table 2).

4. DISCUSSION

This research serves as an initial exploration of the effects of white noise exposure on sleep quality among critically ill patients receiving care in intensive care units in Indonesia. The results

DOI: https://doi.org/10.17509/jpki.v11i2
e-ISSN 2477-3743 | p-ISSN 2541-0024

are consistent with findings from a randomized controlled study conducted in India in 2022, which reported that technology-based noise management interventions were associated with improved sleep outcomes in ICU populations. Previous investigations have also evaluated the use of white noise in neonatal intensive care settings, particularly among preterm infants, and have demonstrated beneficial effects. In pediatric populations, white noise has similarly been shown to alleviate discomfort in children experiencing illness-related distress (Castillo et al., 2016; Moser et al., 2003).

From a scientific perspective, white noise is defined as a sound signal with equal energy distributed across the full range of frequencies audible to humans, approximately 20 to 20,000 Hz. In clinical and environmental contexts, it commonly takes the form of natural ambient sounds, such as rainfall, ocean waves, wind through trees, or nocturnal animal calls (Akpinar et al., 2022; Jun et al., 2021; Polat et al., 2022). These stable and low-intensity auditory patterns are thought to generate a calming effect and facilitate improved sleep. Due to its constant power spectral density, white noise has been utilized as an adjunctive intervention in the management of certain neurological conditions, particularly to support sleep regulation. Consequently, integrating white noise into nursing care for critically ill patients may contribute to better clinical outcomes and support recovery processes (Prajapat et al., 2021; Ryherd et al., 2008).

To date, reports of adverse effects related to white noise exposure remain limited. Nonetheless, excessive or prolonged exposure at high intensity levels may pose potential risks, including disruption of auditory pathway development and noise-induced hearing impairment. Among the existing literature, only one study explicitly reported the absence of negative outcomes following white noise exposure (Hong et al., 2021; Hubbard et al., 2010; Riedy et al., 2021). Given the relatively small number of available studies, firm conclusions regarding the safety and efficacy of white noise in critically ill populations cannot yet be drawn. As the use of white noise devices becomes more widespread in critical care environments, future investigations should systematically assess potential adverse effects and provide more detailed interpretations of both benefits and risks (Prajapat et al., 2021; Tingle, 2010).

Several limitations of the present study should be acknowledged. First, sleep quality was evaluated solely through subjective self-report measures, without incorporating objective assessments such as polysomnography, which is considered the gold standard for sleep analysis . However, routine use of polysomnography in ICU settings is often impractical due to its high cost and operational complexity (Chapple et al., 2021; Liao et al., 2021; Ren et al., 2022). Second, sleep assessment was confined to a 12-hour nighttime period during the initial days of ICU admission rather than capturing continuous 24-hour sleep–wake patterns. Critically ill patients frequently experience circadian rhythm disruption, resulting in fragmented sleep occurring throughout both day and night. Ideally, future studies should monitor sleep architecture and circadian rhythms over extended, consecutive 24-hour intervals. Additionally, the study population represented a specific subgroup of ICU patients, which may limit the generalizability of the findings. Finally, the relatively small sample size reduced the statistical power of the analyses. Further research

DOI: https://doi.org/10.17509/jpki.v11i2.93926
e-ISSN 2477-3743 | p-ISSN 2541-0024

involving larger and more diverse samples is needed to validate these findings and strengthen the evidence base.

Clinical Implications

The findings of this study have important implications for nursing practice and environmental management in intensive care units. White noise represents a simple, low-cost, and non-pharmacological intervention that can be integrated into routine ICU care to support sleep among critically ill patients. Given the high prevalence of sleep disturbance in ICUs and the potential adverse consequences for physiological recovery, incorporating white noise as part of standard nursing interventions may help reduce environmental stressors without increasing medication use. Nurses play a central role in implementing and monitoring such interventions, including adjusting sound levels, selecting appropriate masking sounds, and assessing individual patient responses. Moreover, the use of white noise may complement existing strategies aimed at creating a more healing ICU environment, such as optimizing lighting, minimizing unnecessary alarms, and clustering care activities. From a broader perspective, integrating acoustic management interventions like white noise into ICU design and care protocols may enhance patient comfort, improve sleep quality, and potentially contribute to better clinical outcomes. However, careful consideration of sound intensity and duration is necessary to ensure patient safety and prevent unintended auditory effects.

Study Limitations

Several limitations should be considered when interpreting the findings of this study. First, sleep quality was assessed using a subjective self-report instrument, which may be influenced by patients' perceptions, recall bias, or clinical condition. Objective measurements such as polysomnography were not employed, although they are regarded as the gold standard for sleep assessment; their use in ICU settings is limited by high cost, technical complexity, and potential interference with patient care. Second, sleep evaluation was restricted to nighttime periods rather than continuous 24-hour monitoring. Given that critically ill patients often experience disrupted circadian rhythms with fragmented sleep throughout the day and night, this approach may not fully capture overall sleep patterns. Third, the study was conducted in a limited number of hospitals and involved a relatively small sample size, which may reduce statistical power and limit generalizability. Additionally, the sample consisted of a specific subgroup of ICU patients, and the findings may not be applicable to all critically ill populations. Finally, potential long-term effects and adverse outcomes related to prolonged white noise exposure were not assessed, highlighting the need for extended follow-up in future research.

5. CONCLUSIONS

This study provides preliminary evidence that the application of white noise may improve sleep quality among critically ill patients treated in intensive care units in Indonesia. Exposure to

DOI: https://doi.org/10.17509/jpki.v11i2
e-ISSN 2477-3743 | p-ISSN 2541-0024

structured white noise over three consecutive days was associated with a significant enhancement in perceived sleep quality compared with standard care. These findings suggest that white noise may serve as a feasible and non-pharmacological supportive intervention within the ICU setting. Although the results are promising, they should be interpreted with caution due to the study's methodological limitations, including its reliance on subjective sleep assessment and a relatively small sample size. Future studies employing objective sleep measurements, longer observation periods, and larger, more diverse patient populations are needed to confirm the effectiveness and safety of white noise interventions. Integrating white noise into comprehensive environmental management strategies may contribute to improved patient comfort and recovery in critical care environments.

6. ACKNOWLEDGMENTS

We express our gratitude to all the individuals who participated in the study for their participation. The funding for this study was provided by PUTI Pascasarjana Universitas Indonesia.

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DOI: https://doi.org/10.17509/jpki.v11i2
e-ISSN 2477-3743 | p-ISSN 2541-0024

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DOI: https://doi.org/10.17509/jpki.v11i2.93926
e-ISSN 2477-3743 | p-ISSN 2541-0024

DOI: https://doi.org/10.17509/jpki.v11i2
e-ISSN 2477-3743 | p-ISSN 2541-0024