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Original Article

The effectiveness of white noise therapy on sleep quality and physiological stability among premature infants in the neonatal intensive care unit

Kharisma Putri Sonya[1], Ira Rahmawati[1], Wardatus Sholihah[1], Uwiek Hentartie[2], Achmad Syarofi Al-Furqon[3]

[1]Department of Pediatric Nursing, Faculty of Nursing, Universitas Jember, Indonesia
[2]Perinatology Nurse, Neonatal Intensive Care Unit (NICU), RSUD dr. R. Soedarsono, Indonesia
[3]Universitas Annuqayah, Indonesia

Abstract:
Premature infants admitted to the neonatal intensive care unit (NICU) are exposed to clinical noise, light, invasive procedures, respiratory support, and repeated handling that may disturb sleep and physiological organization. Sleep protection is a core element of neuroprotective developmental care because it supports brain maturation, energy conservation, autonomic regulation, and recovery. White noise is a simple auditory-based non-pharmacological intervention that may mask sudden environmental sounds and provide a steady stimulus resembling the intrauterine acoustic environment. This case study described the observed effects of white noise therapy on quiet sleep duration and physiological stability among premature infants with respiratory distress syndrome in the NICU at RSD dr. Soebandi Jember. A descriptive case study was conducted with two premature infants diagnosed with respiratory distress syndrome. White noise was administered once daily for 30 minutes at approximately 45-50 dB after routine clinical stabilization. Quiet sleep duration was assessed using the state organization component of the Neonatal Behavioral Assessment Scale, while heart rate, respiratory rate, and oxygen saturation were obtained from bedside monitors before and after intervention. Quiet sleep duration increased from 10 to 30 minutes in Case 1 and from 5 to 20 minutes in Case 2. Heart rate decreased from 120 to 108 beats/minute in Case 1 and from 130 to 121 beats/minute in Case 2. Respiratory rate decreased from 52 to 50 breaths/minute in Case 1 and from 59 to 50 breaths/minute in Case 2, while oxygen saturation remained stable at 100% in both cases. White noise therapy was associated with longer quiet sleep duration and more stable physiological parameters. This intervention may be considered as an adjunctive, low-risk developmental care strategy when delivered within safe sound limits and under continuous clinical monitoring.

Keywords:
NICU, physiological stability, premature infant, sleep quality, white noise

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Corresponding Author:
Kharisma Putri Sonya
kharismaputrisonya.1@gmail.com

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INTRODUCTION

Premature infants are infants born before 37 completed weeks of gestation, and prematurity remains a major contributor to neonatal morbidity, prolonged hospitalization, and risk of developmental vulnerability (World Health Organization, 2023). Immaturity of the respiratory, neurological, gastrointestinal, thermoregulatory, and autonomic systems makes preterm infants highly dependent on intensive monitoring and supportive technology during the earliest postnatal period. Infants diagnosed with respiratory distress syndrome (RDS) are particularly vulnerable because surfactant deficiency, unstable respiratory mechanics, and the need for continuous positive airway pressure or mechanical ventilation can increase physiological workload. Local neonatal evidence from Health and Technology Journal also emphasizes the clinical importance of gestational age in neonatal respiratory compromise and asphyxia risk, reinforcing that preterm birth is not only a demographic descriptor but also a predictor of intensive care needs (Andansari et al., 2023).

The neonatal intensive care unit (NICU) is intended to maintain survival and physiological stability, yet the same environment may expose infants to potentially stressful stimuli. Monitor alarms, ventilator sounds, infusion pumps, conversations, lighting, suctioning, diaper changes, and scheduled procedures may fragment infant sleep and contribute to fluctuations in heart rate, respiratory rate, oxygen saturation, and behavioral state. The American Academy of Pediatrics has long identified excessive noise as a hazard for fetuses and newborns and recommends controlling environmental sound exposure (American Academy of Pediatrics, 1997). A more recent pediatric policy statement also cautions that infants and children require protection from excessive noise because immature auditory systems may be vulnerable to harm when exposure is prolonged or intense (Balk et al., 2023). Current evidence syntheses note that NICU sound often exceeds the recommended 45 dB threshold and that high-quality trials evaluating noise reduction remain limited, meaning bedside nurses must combine available evidence with careful safety monitoring (Sibrecht et al., 2024).

Sleep is not a passive state in premature infants. It is a developmental process that supports synaptogenesis, growth hormone regulation, energy conservation, cardiorespiratory organization, and sensory processing. Premature infants frequently demonstrate immature and unstable sleep-wake organization, and sleep-related problems may persist beyond discharge. Huang et al. (2014) found that sleep and breathing problems are common among infants born prematurely at six months postnatal age, demonstrating that sleep disruption in early life deserves clinical attention rather than being treated as a minor comfort issue. Developmental care frameworks position protected sleep as a core nursing responsibility. Coughlin et al. (2009) included protected sleep, pain and stress management, developmental activities of daily living, family-centered care, and the healing environment as core measures of developmentally supportive care. Similarly, the Neonatal Integrative Developmental Care Model identifies safeguarding sleep, minimizing stress and pain, and optimizing the healing environment as interdependent measures for neuroprotective care (Altimier & Phillips, 2016).

Non-pharmacological interventions are increasingly prioritized in neonatal nursing because they may improve comfort while avoiding unnecessary medication exposure. Evidence-based sleep protection strategies in premature infants include clustering care, reducing light and noise, supportive positioning, skin-to-skin care, parental involvement, pain prevention, and developmentally

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appropriate sensory stimulation (Gu et al., 2024). Related neonatal and infant care literature also supports the role of safe tactile and caregiver-based interventions in promoting regulation and mother-infant interaction, including maternal-infant massage for hospitalized preterm infants (McCarty et al., 2023). Another study emphasizes the importance of respiratory health, family-based childcare, and patient safety in both clinical and community contexts. Kurniyawan et al. (2023) discussed parental roles in meeting children's nutritional and respiratory health needs, while Kurniyawan et al. (2024) reviewed clean and healthy living behaviors to prevent acute respiratory infections. Although these studies were not NICU-based white noise trials, they strengthen the broader nursing rationale that respiratory stability, caregiver education, and preventive care are central to child health outcomes.

White noise is a continuous sound containing a broad spectrum of frequencies at relatively steady intensity. In neonatal practice, white noise is theorized to mask sudden environmental sounds, reduce startle responses, and provide a more predictable auditory background. A randomized trial by Liao et al. (2021) compared mothers' voices and white noise for premature infants in the NICU and evaluated physiological reactions and sleep-wake patterns. A meta-analysis by Zhang et al. (2024) concluded that white noise had favorable effects on pain, weight gain, heart rate, respiratory rate, and oxygen saturation among preterm infants in NICU randomized trials. Düken and Yayan (2024) further reported that massage therapy and the application of white noise improved sleep duration and sleep efficiency in premature infants. Other studies have examined white noise for sucking success and comfort during breastfeeding (Tanriverdi & Kuzlu Ayyildiz, 2023), physiological parameters during peripheral intravenous catheter insertion (Rahimi et al., 2025), heel-lancing stress responses (Kirbas et al., 2024), vaccination pain (Kucukoglu et al., 2016), and procedural pain-related cortical responses (Ren et al., 2022).

Despite this growing evidence, white noise should not be treated as automatically beneficial in every circumstance. The intervention must be delivered within safe sound levels, for an appropriate duration, and with monitoring for clinical instability. A comprehensive review of white noise in maternal and neonatal care highlighted potential benefits for sleep, stress, and pain outcomes, while cautioning that prolonged or high-intensity exposure may pose risks to hearing and neurodevelopment (Oz & Demirci, 2025). Therefore, more local clinical descriptions are needed to demonstrate how white noise can be applied in real-world NICU settings, especially among premature infants with RDS who receive respiratory support. This study aimed to describe the observed effects of white noise therapy on quiet sleep duration and physiological stability among two premature infants treated in the NICU at RSD dr. Soebandi Jember. The study was designed as a descriptive case study, so the findings are interpreted as clinically informative observations rather than definitive causal evidence.

METHOD

This study used a descriptive case study design to describe premature infants' responses to white noise therapy in a real NICU setting. A case study approach was selected because the intervention was implemented as a focused nursing intervention in a small number of clinically vulnerable infants, and the purpose was to document changes in quiet sleep duration and

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physiological parameters before and after exposure rather than to test statistical effectiveness. The study was conducted in the NICU of RSD dr. Soebandi Jember from June 4 to June 6, 2026. The reporting of the method was strengthened to make the intervention reproducible for journal production while maintaining the original design and data structure.

The participants were two premature infants diagnosed with respiratory distress syndrome. Case 1 was a female infant born at 33 weeks of gestation with a birth weight of 1,940 grams, and she received continuous positive airway pressure. Case 2 was a male infant born at 28-29 weeks of gestation with a birth weight of 1,240 grams, who received mechanical ventilation. Inclusion criteria were premature birth before 37 weeks of gestation, admission to the NICU, diagnosis of respiratory distress syndrome, use of respiratory support, and clinical permission from the responsible health team to receive non-pharmacological auditory stimulation. Infants were not observed during acute clinical deterioration, active resuscitation, invasive procedures, or periods requiring urgent changes in respiratory support. These restrictions were applied because premature infants may be sensitive to environmental stimuli and because sound management in the NICU should prioritize safety, stable oxygenation, and prevention of excessive noise exposure (American Academy of Pediatrics, 1997; Balk et al., 2023; Sibrecht et al., 2024).

White noise was delivered for 30 minutes using a continuous audio file placed at a safe distance from the infant's bed or incubator. The sound intensity was maintained at approximately 45-50 dB, consistent with commonly cited NICU noise safety thresholds and the need to avoid high-intensity exposure. The intervention was administered only after routine care was completed and the infant was clinically stable, as determined by the attending nurse. During the intervention, unnecessary handling was minimized, lighting was kept consistent with usual NICU practice, and bedside alarms and respiratory support remained active. The nurse continuously observed the infant to identify signs of intolerance, including desaturation, apnea, increased work of breathing, excessive agitation, or an unstable heart rate. If any clinically significant deterioration occurred, the intervention would be discontinued, and routine clinical management would take priority.

The primary outcome was quiet sleep duration before and after white noise therapy. Sleep quality was operationally defined as the duration of quiet sleep observed through the state organization component of the Neonatal Behavioral Assessment Scale, focusing on behavioral indicators such as closed eyes, reduced motor activity, regular breathing pattern, and absence of crying or marked agitation. The observation period before intervention was used to establish baseline sleep duration, while the post-intervention period was used to document subsequent quiet sleep duration. Because this was a descriptive case study, the outcome was expressed in minutes and summarized as within-case change.

Physiological stability was measured using bedside monitor parameters: heart rate (beats per minute), respiratory rate (breaths per minute), and oxygen saturation (%). Baseline values were documented immediately before white noise therapy, and post-intervention values were documented after the 30-minute exposure. These parameters were selected because they are routinely monitored in the NICU and are clinically relevant indicators of autonomic and respiratory regulation in premature infants. The use of technology-based monitoring was consistent with the broader patient safety rationale that clinical technologies can support early risk recognition when integrated into nursing assessment (Adhitama et al., 2023).

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Data were analyzed descriptively by comparing each infant's pre- and post-intervention values. No inferential statistical test was performed because the sample consisted of 2 cases and the design lacked randomization or a control group. Results were interpreted cautiously in relation to existing evidence on sleep protection, developmental care, and white noise interventions in neonatal populations (Gu et al., 2024; Zhang et al., 2024). Ethical principles were maintained through parental informed consent, confidentiality of participant information, and respect for routine NICU clinical decisions. The intervention was non-invasive and did not replace standard medical or nursing care.

RESULT

This study involved two premature infants with respiratory distress syndrome who received white noise therapy during NICU hospitalization. The results are presented descriptively according to participant characteristics, changes in quiet sleep duration, and changes in physiological parameters before and after the intervention.

Table 1. Characteristics of Participants

Characteristics	Case 1	Case 2
Sex	Female	Male
Gestational age	33 weeks	28-29 weeks
Birth weight	1,940 g	1,240 g
Diagnosis	Respiratory distress syndrome (RDS)	Respiratory distress syndrome (RDS)
Respiratory support	Continuous positive airway pressure (CPAP)	Mechanical ventilator

Case 1 was a moderately premature infant with low birth weight who received CPAP support, while Case 2 was an extremely premature infant with very low birth weight who received mechanical ventilation. These differences should be considered when interpreting the magnitude of the response, as respiratory support, gestational age, and baseline condition may influence sleep organization and physiological stability.

Table 2. Quiet Sleep Duration Before and After White Noise Therapy

Case	Before (minutes)	After (minutes)	Difference (minutes)
Case 1	10	30	+20
Case 2	5	20	+15

Both infants demonstrated increased quiet sleep duration after the intervention. Case 1 showed a 20-minute increase, from 10 minutes before white noise therapy to 30 minutes after therapy. Case 2 showed a 15-minute increase, from 5 minutes before therapy to 20 minutes after therapy. The pattern suggests improved sleep continuity during the observation period, although the case study design does not permit causal inference.

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Table 3. Physiological Stability Before and After White Noise Therapy

Parameter	Case 1 Before	Case 1 After	Case 2 Before	Case 2 After
Heart rate (beats/minute)	120	108	130	121
Respiratory rate (breaths/minute)	52	50	59	50
Oxygen saturation (%)	100	100	100	100

Heart rate and respiratory rate decreased in both cases after white noise therapy, while oxygen saturation remained stable at 100%. Case 1 showed a reduction in heart rate from 120 to 108 beats/minute and respiratory rate from 52 to 50 breaths/minute. Case 2 showed a reduction in heart rate from 130 to 121 beats/minute and respiratory rate from 59 to 50 breaths/minute. No decline in oxygen saturation was observed during the documented observation period.

DISCUSSION

The findings of this case study showed that both premature infants experienced longer quiet sleep duration after 30 minutes of white noise therapy. Case 1 increased from 10 to 30 minutes, and Case 2 increased from 5 to 20 minutes. These changes are clinically relevant because sleep in premature infants is closely linked to energy conservation, behavioral organization, oxygen demand, and neurodevelopmental protection. The findings are consistent with evidence summaries stating that protection of sleep should be integrated into NICU developmental care and should involve control of environmental stimuli, clustering of nursing procedures, positioning, and sensory regulation (Coughlin et al., 2009; Gu et al., 2024). The observation also aligns with the Neonatal Integrative Developmental Care Model, which places safeguarding sleep and minimizing stress within a broader neuroprotective framework (Altimier & Phillips, 2016).

The likely mechanism of benefit is auditory masking and reduction of sudden environmental stimulation. NICU noise is often unpredictable; alarms, staff conversation, equipment, and procedures may occur intermittently and may trigger arousal in infants with immature sensory regulation. White noise provides a continuous auditory background that may reduce the infant's responsiveness to abrupt noise changes. This interpretation is consistent with the meta-analysis by Zhang et al. (2024), which found favorable effects of white noise on several outcomes in preterm infants, and with the randomized trial by Düken and Yayan (2024), which reported improved sleep duration and efficiency after white noise and massage interventions. Similarly, Liao et al. (2021) showed that auditory interventions, including maternal voice and white noise, may influence premature infants' sleep-wake patterns and physiological reactions.

The decrease in heart rate after white noise therapy in both cases may indicate reduced sympathetic arousal or improved comfort. Case 1 showed a decrease from 120 to 108 beats/minute, while Case 2 decreased from 130 to 121 beats/minute. Although these values remained within clinically interpretable ranges for premature infants under NICU monitoring, the direction of change supports the interpretation that the intervention did not increase physiological stress during the observation period. Rahimi et al. (2025) similarly evaluated the use of white noise during peripheral intravenous catheter insertion and reported its usefulness as a safe nursing intervention to support physiological parameters. Kirbas et al. (2024) also found that white noise and kangaroo mother care helped reduce stress-related responses during heel lancing. Procedural pain studies by Kucukoglu

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et al. (2016) and Ren et al. (2022) further support the role of white noise as a non-pharmacological comfort measure in neonatal care.

Respiratory rate also decreased in both infants, from 52 to 50 breaths/minute in Case 1 and from 59 to 50 breaths/minute in Case 2. In preterm infants with RDS, respiratory patterns are influenced by lung immaturity, respiratory support mode, handling, sleep state, and autonomic stability. A modest reduction in respiratory rate after white noise may reflect a calmer behavioral state rather than a direct respiratory treatment effect. This distinction is important because white noise cannot replace CPAP, mechanical ventilation, surfactant therapy, thermoregulation, nutritional support, or standard RDS management. Rather, it may be positioned as an adjunctive developmental care intervention that supports comfort and sleep. The study by Dağ and Yayan (2024) on facilitated tucking and white noise among newborns receiving nasal CPAP is especially relevant because it connects auditory intervention with respiratory support contexts.

Oxygen saturation remained stable at 100% in both cases before and after the intervention. Stability of oxygen saturation is important because it suggests that the intervention did not compromise oxygenation during the observed period. However, stable saturation should not be overinterpreted as proof of effectiveness. Bedside oxygen saturation is influenced by respiratory support, oxygen settings, probe accuracy, perfusion, infant position, and clinical condition. Nonetheless, the absence of desaturation during white noise exposure supports the practical feasibility of short-duration use when infants are stable and monitored. Studies examining white noise in procedural and neonatal care settings have reported either maintenance or improvement of oxygen saturation when sound levels are controlled (Kirbas et al., 2024; Rahimi et al., 2025; Zhang et al., 2024).

The findings also support the concept that sleep quality and physiological stability should be interpreted together. A premature infant may appear asleep but still demonstrate unstable cardiorespiratory parameters, and conversely, stable monitors do not necessarily indicate restorative sleep. Combining behavioral observation with heart rate, respiratory rate, and oxygen saturation provides a more clinically meaningful picture. Technology-assisted monitoring can strengthen bedside decision-making, but it must remain integrated with nursing judgment. This point aligns with patient safety, as evidenced by the systematic review by Putra Adhitama et al. (2023), which emphasized the role of technology in hospital safety systems. In NICU practice, monitors provide continuous data, but nurses interpret trends, contextualize changes, and decide whether to continue stimulation.

The local and regional literature added to this manuscript helps contextualize the intervention within Indonesian nursing concerns. Andansari et al. (2023) highlighted the relationship between gestational age and neonatal asphyxia in a NICU context, confirming the need for close monitoring of preterm and respiratory-compromised infants. Kurniyawan et al. (2023), emphasized the importance of parental roles in nutrition and respiratory health, while Kurniyawan et al. (2024), reviewed respiratory infection prevention among families. These sources are not direct white noise trials, but they are relevant because they position respiratory health, family education, prevention, and nursing care as connected determinants of infant and child outcomes. Including these references also strengthens the manuscript's alignment with Indonesian nursing scholarship.

The intervention should still be applied cautiously. The American Academy of Pediatrics (1997) and Balk et al. (2023) warn that excessive noise exposure may harm infants and children. Sibrecht

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et al. (2024) further noted that evidence on NICU sound management remains limited and that sound levels frequently exceed recommended thresholds. White noise is, therefore, not a license to add more noise to an already noisy unit. It should be used only as a controlled auditory stimulus, at low intensity, for a limited duration, and with continuous monitoring. Oz and Demirci (2025) reached a similar conclusion: white noise may support sleep, stress reduction, and pain management, but prolonged or high-intensity use may carry potential risks. These cautions are particularly important for premature infants whose auditory and neurological systems are still developing.

The results are also consistent with broader evidence on sensory stimulation. Akiyama et al. (2020) reported that music and white noise may influence EEG functional connectivity among neonates in the NICU, suggesting that auditory interventions can affect neurophysiological activity rather than merely changing outward behavior. Tanriverdi and Kuzlu Ayyildiz (2023) found that white noise improved sucking success and comfort during breastfeeding among premature infants. Balice-Bourgois et al. (2020) also emphasized non-pharmacological approaches in neonatal procedural pain guidelines, supporting the integration of low-risk comfort measures into routine care. Taken together, current evidence suggests that controlled sensory interventions may help premature infants regulate responses to NICU stressors when they are individualized and safely implemented.

This study has several limitations. First, the sample included only two cases, so the results cannot be generalized to all premature infants. Second, the design lacked a control group or randomization, making it impossible to separate the intervention effect from maturation, clinical stabilization, respiratory support, or timing of routine care. Third, environmental noise levels in the room were not continuously measured, so the exact masking effect of white noise could not be quantified. Fourth, quiet sleep duration was assessed through behavioral observation rather than polysomnography or electroencephalography. Fifth, the intervention was brief and did not assess long-term outcomes, including weight gain, length of stay, neurodevelopment, feeding progression, or parental involvement. Future studies should use randomized controlled designs, larger samples, standardized sound-level measurement, longer follow-up, and stratification by gestational age, respiratory support mode, and baseline clinical condition.

Despite these limitations, the case study provides practical clinical value. It demonstrates that a short, monitored white noise intervention can be incorporated into NICU nursing care without disrupting respiratory support or bedside monitoring. The observed increase in quiet sleep duration and stable oxygenation suggests that white noise may be useful as part of developmental care when applied judiciously. For production-level interpretation, the conclusion should be phrased carefully: white noise was associated with improved sleep duration and stable physiological parameters in two cases, but effectiveness must be confirmed through stronger experimental research. This cautious interpretation protects the scientific integrity of the manuscript while preserving its clinical contribution.

CONCLUSION

White noise therapy administered for 30 minutes at approximately 45-50 dB was associated with longer quiet sleep duration and more stable physiological parameters in two premature infants with respiratory distress syndrome treated in the NICU at RSD dr. Soebandi Jember. Heart rate and

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respiratory rate decreased after the intervention, while oxygen saturation remained stable. These findings suggest that white noise may be considered an adjunctive non-pharmacological nursing intervention in developmental care, provided it is delivered within safe and sound limits and under continuous clinical monitoring. Because this study used a descriptive case study design with two infants, the findings should be interpreted as preliminary clinical observations rather than definitive evidence of effectiveness. Larger controlled studies are recommended.

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to this manuscript.

ETHICAL CONSIDERATIONS

Parental informed consent was obtained before data collection. Participant confidentiality was maintained, and the intervention was implemented without replacing standard medical and nursing care.

DATA AVAILABILITY

The data used in this case study are available from the corresponding author upon reasonable request, provided that participant confidentiality is considered.

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