

Effects of Musical Storytelling on Pain Responses During Heel Lance for Blood Glucose Testing in Premature Infants: A Quasi-Experimental Study

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Abstract: Heel lance for blood glucose monitoring is a routine procedure for preterm infants in neonatal intensive care units. However, it is associated with acute pain that may adversely impact growth and neurodevelopment. This quasi-experimental, cross-over study—conducted at a tertiary hospital in Bangkok—aimed to evaluate the effects of musical storytelling on pain responses during heel lance procedures. Thirty-four preterm infants (gestational age: 34–36⁺⁶ weeks) were purposively recruited and randomly assigned to receive either the experimental condition (musical storytelling plus usual care) or the control condition (usual care only) first. Following the initial intervention, participants crossed over to the alternate condition. Pain responses were measured using the Neonatal Infant Pain Scale, heart rate, respiratory rate, and arterial oxygen saturation at three intervals: baseline, during the procedure, and post-procedure. Data were analyzed using two-way repeated measures ANOVA.

The results demonstrated that infants who received musical storytelling had significantly lower pain scores during the procedure and at 1-, 5-, and 10-minute post-heel-lance compared with the control group. Furthermore, those in the intervention group exhibited lower heart and respiratory rates, along with significantly higher arterial oxygen saturation levels at the 1-, 5-, and 10-minute intervals. These findings suggest that musical storytelling is a beneficial and feasible non-pharmacological intervention for mitigating procedural pain. Integrating this practice into routine neonatal care can empower nurses to provide evidence-based pain management in the neonatal intensive care units. However, future research with larger, more diverse cohorts is necessary to compare various auditory stimuli and determine the optimal timing and duration for the intervention.

Keywords: Blood glucose testing, Heel lance, Music, Nurses, Pain responses, Premature infants, Storytelling

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Introduction

Preterm birth remains a critical global public health challenge, as these infants frequently require admission to the neonatal intensive care unit (NICU) to ensure survival. During their stay, preterm neonates are exposed to repeated painful procedures from the earliest stages of life. On average, they undergo 7.5–17.3 painful procedures daily, with the heel

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lance being among the most common interventions in neonatal care.¹ Infants may undergo heel lance procedures 1 to 22 times per day, accounting for

approximately 61–87% of invasive procedures during hospitalisation.²

Importantly, preterm infants demonstrate heightened behavioral and physiological sensitivity to pain, characterized by specific facial expressions, crying, and body movements, as well as increased heart rates (HR) and respiratory rates (RR) and decreased arterial oxygen saturation (SpO₂).³ Critically, repeated exposure to pain is associated with adverse long-term outcomes in brain development and behavior, including neurodevelopmental impairment, altered brain structure, and behavioral dysregulation, which may ultimately affect physical growth and developmental outcomes.^{4,5}

Pain management in preterm infants includes both pharmacological and non-pharmacological approaches. Although pharmacological agents such as opioids and anesthetics are effective, their use is associated with significant risks, including respiratory depression and potential neurodevelopmental effects.⁴ Consequently, non-pharmacological interventions have gained increasing attention, particularly those that can be independently implemented by nurses, such as non-nutritive sucking, oral sucrose administration, and auditory stimulation.⁶

Emerging evidence suggests that auditory interventions, including music, maternal voice, and white noise, can reduce pain and stabilize physiological responses in preterm infants.^{7,8} These effects are thought to be mediated through activation of the limbic system and the release of endogenous analgesic substances such as endorphins.⁹ However, most previous studies have primarily focused on acoustic properties of sound, such as frequency and rhythm, rather than affective auditory components, including emotional tone and prosody. These elements may play a crucial role in neurobehavioral regulation in preterm infants but remain underexplored.¹⁰

Therefore, the integration of musical storytelling may represent a novel multidimensional auditory intervention that combines structured rhythmic input

with emotionally meaningful vocal characteristics. Although preterm infants are not yet capable of semantic language processing, they can perceive and respond to auditory patterns, rhythm, and prosodic features even before birth.¹¹ This combined auditory stimulation may enhance familiarity and emotional regulation more effectively than music alone. However, to date, no studies have specifically investigated this approach for pain management during heel lance procedures in preterm infants, particularly within the Thai context.

Literature Review and Conceptual Framework

This study was guided by the gate control theory proposed by Melzack and Wall, which conceptualizes pain as a multistage process involving transduction, transmission, modulation, and perception.¹² During heel lance procedures, noxious stimuli are detected by nociceptors and converted into electrical signals through transduction. These signals are subsequently transmitted via small-diameter nerve fibers, including A-delta and C fibers, to the dorsal horn of the spinal cord, where the substantia gelatinosa regulates signal transmission to higher centers.¹² Heel lance procedures are considered acute painful stimuli in preterm infants. Pain signals from these procedures are primarily transmitted through small myelinated A-delta fibers, which mediate rapid, well-localized acute pain, whereas unmyelinated C fibers are more commonly associated with slow, diffuse, and prolonged pain.¹² Increased activity of these fibers inhibits inhibitory interneurons, resulting in gate opening and facilitation of nociceptive transmission. In contrast, activation of large-diameter myelinated fibers, including A-alpha and particularly A-beta fibers, enhances inhibitory signaling within the substantia gelatinosa, leading to gate closure and suppression of pain signals.¹²

Furthermore, during modulation, descending inhibitory pathways originating from supraspinal structures, such as the periaqueductal gray and the rostroventral medulla, play a critical role in pain regulation. These pathways promote inhibitory interneuron activity at the dorsal horn and facilitate the release of endogenous opioids, including endorphins and enkephalins, which suppress nociceptive transmission.⁹ Consequently, pain perception is determined by the balance between excitatory and inhibitory inputs. It is reflected in behavioral and physiological responses, including changes in facial expression, crying, HR, RR, and SpO₂.

Preterm infants have physiologically immature sensory and autonomic regulatory systems, which increase their vulnerability to painful stimuli during hospitalization.¹³ Although nociceptive pathways are sufficiently developed to transmit pain, inhibitory pathways remain functionally immature, resulting in increased nociceptive signaling and reduced self-regulatory capacity.¹³ Consequently, repeated painful experiences during hospitalization may disrupt neurodevelopmental organization and physiological stability.

Musical storytelling is conceptualized as a multidimensional auditory stimulus that integrates structured rhythmic elements with emotionally meaningful vocal prosody. This intervention may modulate pain through several mechanisms, including attentional distraction, sensory competition at the dorsal horn level, and activation of descending inhibitory pathways. Moreover, auditory characteristics such as slow tempo, repetitive rhythm, and soothing vocal tones resembling maternal sounds may reduce physiological arousal and promote autonomic stability.^{14,15} Importantly, emotionally salient auditory input may further contribute to gate closure by engaging limbic and cortical systems that activate descending inhibitory pathways, thereby enhancing endogenous opioid release and strengthening inhibitory control at the dorsal horn. Therefore, musical storytelling may attenuate nociceptive

transmission while supporting physiological stability in preterm infants.

Although pharmacological interventions are effective, their use in preterm infants is limited by potential adverse effects, including respiratory depression, hypotension, and prolonged ventilator dependence.⁴ Therefore, non-pharmacological interventions, which can be independently implemented by nurses, have gained increasing attention.¹⁶ Among these, auditory interventions such as music, white noise, maternal voice, and lullabies have been shown to reduce pain and stabilize physiological responses.^{7,8,16}

Slow and rhythmic music or lullabies have been shown to reduce pain and stabilize physiological responses in preterm infants.^{7,8} These effects are thought to occur through activation of the limbic system and the release of endogenous analgesic substances, such as endorphins and enkephalins.⁹ Previous studies have demonstrated that auditory interventions, including music therapy, maternal voice exposure, and soothing vocal stimulation, may reduce behavioral pain responses during painful procedures. A reduction in pain and stress responses has also been associated with improved physiological stability, including decreased HR and RR, as well as increased SpO₂.^{14,16}

However, existing auditory interventions predominantly focus on acoustic features, such as rhythm, tempo, and frequency, while the affective dimension of sound, particularly emotional prosody embedded in human voice, remains underexplored. Moreover, some approaches, such as maternal voice recordings, may be limited by practical constraints, including maternal availability in the immediate postpartum period.¹⁷ Importantly, current evidence lacks integration between structured musical elements and emotionally meaningful vocal input, despite their potential synergistic effects on sensory and emotional regulation.

Musical storytelling, which combines rhythmic musical structure with emotionally expressive vocal

prosody, may provide a multidimensional auditory stimulus that enhances both sensory and emotional processing. Auditory characteristics such as slow tempo, repetitive rhythm, and soothing vocal tones resembling intrauterine sounds may reduce physiological arousal and promote autonomic stability.^{14,15,18} Furthermore, emotionally salient auditory input may activate limbic and cortical systems, facilitating endogenous opioid release and attenuating pain perception.⁹ However, to date, no studies have specifically investigated the use of musical storytelling for pain relief during heel lance procedures in preterm infants.

Aims and Hypothesis

Despite these theoretical advantages, no prior studies have specifically examined the effects of musical storytelling on pain responses during heel lance procedures in preterm infants, particularly within the Thai context. Therefore, this study aimed to investigate the effects of musical storytelling on behavioral and physiological pain responses, including pain scores, HR, RR, and SpO₂, in preterm infants undergoing heel lance procedures, to develop an effective, safe, and clinically applicable pain management strategy. The hypothesis is: Preterm infants receiving musical storytelling had lower pain scores, lower HR and RR, and higher SpO₂ during heel lance procedures and at 1-, 5-, and 10-minute post-procedure than those who did not receive it.

Methods

Design: This was a quasi-experimental study with a single-group, two-sequence crossover design and pretest-posttest intervention measurements. Each preterm infant received both conditions: musical storytelling and usual care. The report followed the Transparent Reporting of Evaluation with Non-randomized Designs (TREND) checklist as a guideline.

Sample and Setting: The participants in this study were preterm infants with a gestational age of 34–36⁺⁶ weeks and a postnatal age of no more than one week who were admitted to the NICU of a tertiary care hospital in Bangkok. Purposive sampling was employed to recruit the participants according to the following inclusion criteria: 1) infants who required at least two heel lance blood glucose tests, with a minimum interval of 3 hours, performed before feeding, and who had undergone no more than one heel lance before enrollment; 2) normal bilateral otoacoustic emissions (OAE) screening results, assessed at birth and repeated at ≥ 48 hours of age; and 3) stable vital signs before the intervention, assessed 3 minutes before initiation, including HR of 100–160 beats per minute, RR of 40–60 breaths per minute, and SpO₂ $\geq 90\%$. Exclusion criteria were 1) presence of chromosomal abnormalities, congenital anomalies, or congenital infections; 2) neurological abnormalities affecting behavioral pain responses, such as seizures or intraventricular hemorrhage; 3) requirement for oxygen therapy or mechanical ventilation; and 4) administration of sedatives, analgesics, or cardiotonic drugs within 48 hours before the heel lance procedure.

The sample size was calculated using G*Power version 3.1.9.4, with a significance level (α) of 0.05 and a statistical power ($1 - \beta$) of 0.80. The effect size was based on a previous similar study,¹⁷ which examined the effects of maternal voice on pain and mother–infant bonding in preterm infants. Based on data from that study, the effect size was calculated using Glass's formula,¹⁹ yielding 1.03. However, for a more conservative and appropriate estimate, a large effect size ($f = 0.40$), based on Cohen,²⁰ was used in the sample size calculation. Using a repeated-measures ANOVA with one factor, the required total sample size was 32 participants.

To account for potential attrition, the sample size was increased by 5%, based on a similar previous study,¹⁷ which reported an attrition rate of approximately

4.69%. Therefore, the final sample size for this study was 34 participants, with 17 infants assigned to receive musical storytelling first and 17 infants assigned to receive usual care first.

Participants were selected through purposive sampling based on the inclusion and exclusion criteria. Preterm infants were randomly assigned, using simple randomization without replacement, to one of two intervention sequences. Number 1 represented infants who received musical storytelling and usual care first, whereas number 2 represented infants who received usual care first. A total of 34 preterm infants were assigned equally to the two sequences. Each infant underwent two heel lance procedures separated by a washout period of at least 3 hours.

Ethical Considerations: Ethical approval was obtained from the Institutional Review Board of the Faculty of Medicine Ramathibodi Hospital, Mahidol University (COA No. MURA2024/913, approved December 9, 2024; renewed through December 8, 2026), and from the Institutional Review Board of the Faculty of Medicine Vajira Hospital, Navamindradhiraj University (COA No. 002/2568, approved January 6, 2025; renewed through January 5, 2027).

The hospital administration granted permission to conduct the study. Eligible preterm infants were identified through medical record review, and their parents were approached by the primary investigator (PI). The study purpose, procedures, potential benefits, and the right to accept or decline participation were clearly explained. Written informed consent was obtained from parents prior to participation. All data were kept confidential and reported only in aggregate form, with no identifiable information disclosed.

Research Instruments: These consisted of two data-collection instruments and the intervention program instruments. The instruments for data collection were:

A Demographic and Clinical Data Record Form used to collect information on date, time, participant number, group assignment, ward, sex, mode of

delivery, Apgar scores at 1 and 5 minutes, gestational age at birth and at study entry, birth weight and current weight, diagnosis, and the site and timing of the heel lance procedure. This Form was reviewed for content validity by three experts in neonatology and neonatal nursing. The content validity index (CVI) was 1.00, indicating excellent content validity.

A Physiological and Pain Response Record Form was used to assess four indicators: pain score, HR, RR, and SpO₂. Measurements were obtained at baseline (3 minutes before heel lance), during the procedure, and at 1 (t1), 5 (t5), and 10 (t10) minutes post-procedure. The instrument was reviewed by the same three experts above, yielding a CVI of 1.00.

The Neonatal Infant Pain Scale (NIPS), developed by Lawrence et al.,²¹ was used to assess pain and evaluate six behavioral indicators: facial expression, cry, breathing patterns, arm movements, leg movements, and state of arousal. Scores range from 0 to 7, with higher scores indicating greater pain. The NIPS has established validity ($r = 0.53-0.84$), high inter-rater reliability ($r = 0.92-0.97$), and strong internal consistency (Cronbach's $\alpha = 0.87-0.95$).²¹ In this study, inter-rater reliability was assessed by the PI and a research assistant (RA) using ten preterm infants undergoing procedures. The inter-rater reliability was 0.90, indicating acceptable reliability.²²

The intervention program: musical storytelling

A recorded musical storytelling audio titled "*Mommy Loves You*," created by Santiphap Korcharoenwat under the "Raise a good child by reading" project and supported by the Thai Media Fund,²³ was used as the intervention. The story conveys maternal affection through narration accompanied by lullaby-like music characterized by repetitive rhythmic patterns, slower pitch and tempo, and soothing sounds. The musical storytelling audio was played starting 3 minutes before the heel lance and continued for 10 minutes after the procedure (total duration: 13 minutes).

According to the American Academy of Pediatrics, safe sound levels should not exceed 60

dB, and noise levels in the neonatal intensive care unit should ideally remain below 45 dB.²⁴ However, previous studies have reported that typical ambient noise levels in neonatal intensive care units range from 55 to 75 dB due to equipment and alarms.^{24,25} Therefore, based on prior literature indicating that therapeutic sound levels for preterm infants are commonly set at 50–55 dB, the sound level in this study was maintained within a safe range of 45–50 dB.

A battery-operated portable speaker, disinfected with 70% alcohol before and after each use, was placed inside the incubator approximately 30 centimeters above the infant's ears to ensure equal sound distribution to both ears. Sound intensity was continuously monitored using a sound level meter to ensure safety throughout the intervention. The intervention was administered within the first seven days after birth. Content validity of the musical storytelling audio was evaluated by three experts in music therapy, neonatology, and neonatal nursing. The CVI was 1.00, indicating excellent content validity.

Control condition (usual care)

Usual care was provided for preterm infants undergoing heel lance procedures. Infants were placed supine with shoulder support and wore only a diaper, without clothing or swaddling. Hygiene care was provided as needed, and a clean, dry diaper was applied. A sham speaker and sound level meter were positioned inside the incubator in the same manner as in the experimental condition; however, no audio was played. This procedure was used to maintain blinding of the RA who performed the heel lance procedure.

Data Collection: This study was conducted from February to November 2025. Only preterm infants with stable vital signs were included. Before each session, infants were positioned supine, fitted with monitoring devices on the right hand, and left undisturbed for at least 30 minutes. Environmental noise was minimized, and standardized equipment, including vital sign monitors, a video recording

system, a sound level meter, and a portable speaker, was prepared by the PI.

The first RA wore headphones playing music while performing the heel lance procedure to mask external sounds and prevent identification of the infant's assignment to the experimental or control condition. She performed the heel lance using a standardized protocol in both the experimental and control conditions. The medial aspect of the heel was selected (the left heel for the first procedure and the right heel for the second). The skin was cleansed with 70% alcohol and allowed to dry for 15 seconds. A lancing device (Accu-Chek), set at approximately 0.9 mm, was used to perform the puncture perpendicular to the skin while avoiding the central heel area. The first drop of blood was wiped away, and a blood sample was collected for glucose testing. Gentle pressure was applied using dry cotton, and the puncture site was covered with an adhesive dressing.

Pain and physiological responses were assessed. Pain was evaluated using the NIPS, while HR, RR, and SpO₂ were continuously monitored. Measurements were recorded at baseline (3 minutes before the procedure), during the heel lance procedure, and at 1-, 5-, and 10-minute post-procedure. Video recordings were obtained from 3 minutes before to 10 minutes after the procedure. Pain responses were independently assessed by the PI and a second RA, both of whom were blinded to group allocation. All video recordings were independently evaluated one week after the completion of data collection to enhance inter-rater reliability and minimize potential bias.

Data Analysis: Data collected from the participants were analyzed using the Statistical Package for the Social Sciences (SPSS) Statistics version 21. Statistical significance was set at $p < 0.05$. Descriptive statistics were used to summarize the general characteristics of preterm infants, including sex, gestational age, birth weight, current age, and diagnosis. Frequencies, percentages, means, standard deviations, and ranges were calculated. Differences in mean pain

scores, HR, RR, and SpO₂ across measurement time points were analyzed using repeated measures ANOVA.

Results

A total of 34 preterm infants participated in this study. Most infants were born at 36–36⁺⁶ weeks

of gestation and were female. All infants were assessed on the first day after birth. More than half had birth and current weights greater than 2,500 grams. The most common diagnosis was transient tachypnea of the newborn (TTNB). The detailed demographic and clinical characteristics of the participants are shown in **Table 1**.

Table 1. General characteristics of infants (N = 34)

Variables	N	Percentage	Min–Max	Mean	SD
Sex					
Male	13	38.20			
Female	21	61.80			
Gestational age (weeks)			34 ⁺¹ –36 ⁺⁶		
34–34 ⁺⁶	3	8.80			
35–35 ⁺⁶	7	20.60			
36–36 ⁺⁶	24	70.60			
Postnatal age (days)					
1	34	100.00			
Apgar score					
1 minute				8.50	0.66
5 minutes				9.62	0.49
Birth weight (grams)			1,960–3,170	2,515	343.98
1,500–2,499	16	47.10			
≥ 2,500	18	52.90			
Current weight (grams)			1,910–3,140	2,503	343.52
1,500–2,499	16	47.10			
≥ 2,500	18	52.90			
Diagnosis					
Maternal GDM (insulin control)	5	14.71			
Maternal GDM (diet control)	3	8.82			
Transient tachypnea of the newborn: TTNB	26	76.47			

Pain scores

As shown in **Table 2**, before the heel lance procedure for blood glucose testing, there was no significant difference in mean pain scores between preterm infants who received musical storytelling and those who received usual care. During the heel lance procedure, infants in the musical storytelling group

had significantly lower mean pain scores than those in the usual care group. Following the procedure, infants who received musical storytelling continued to demonstrate significantly lower mean pain scores than those who received usual care at 1, 5, and 10 minutes.

Table 2. Comparison of mean pain scores in infants between groups across time during heel lance procedures using repeated measures ANOVA (N = 34)

Time points	Musical storytelling group (n = 34)		Usual care group (n = 34)		F ^a	p-value
	Mean	SD	Mean	SD		
Before heel lance	0.09	0.29	0.06	0.24	0.21	0.648
During heel lance	3.21	1.37	4.85	1.21	27.72	< 0.001
After heel lance 1 minute	1.76	1.08	2.79	1.74	8.64	0.005
After heel lance 5 minutes	0.56	0.71	1.68	1.43	16.72	< 0.001
After heel lance 10 minutes	0.03	0.17	0.76	1.52	7.87	0.007

Note. ^a F values were adjusted using the Greenhouse–Geisser correction due to violation of the sphericity assumption.

F values indicate differences between groups at each time point.

Heart rate

As shown in **Table 3**, before the heel lance procedure for blood glucose testing, there was no significant difference in mean HR between preterm infants who received musical storytelling and those who received usual care. During the procedure, no significant

difference in mean HR was observed between the two groups. Following the procedure, infants who received musical storytelling demonstrated significantly lower mean HR than those who received usual care at 1, 5, and 10 minutes.

Table 3. Comparison of mean heart rate in infants between groups across time during heel lance procedures using repeated measures ANOVA (N = 34)

Time points	Musical storytelling group (n = 34)		Usual care group (n = 34)		F ^a	p-value
	Mean	SD	Mean	SD		
Before heel lance	126.62	9.58	129.44	9.78	1.15	0.23
During heel lance	135.24	7.30	137.53	11.47	0.97	0.33
After heel lance 1 minute	130.06	8.52	136.26	10.07	7.52	0.008
After heel lance 5 minutes	125.62	6.04	132.03	10.30	9.80	0.003
After heel lance 10 minutes	122.12	5.69	129.00	1.57	13.82	< 0.001

Note. ^a F values were adjusted using the Greenhouse–Geisser correction due to violation of the sphericity assumption.

F values indicate differences between groups at each time point.

Respiratory rate

As shown in **Table 4**, before and during the heel lance procedure for blood glucose testing, there were no significant differences in mean RR between preterm infants who received musical storytelling and those who received usual care.

However, following the procedure, infants who received musical storytelling had significantly lower mean RR than those who received usual care at 1 and 5 minutes. In addition, at 10 minutes post-procedure, the mean RR remained significantly lower in the musical storytelling group compared to the usual care group.

Table 4. Comparison of mean respiratory rate in infants between groups across time during heel lance procedures using repeated measures ANOVA (N = 34)

Time points	Musical storytelling group (n = 34)		Usual care group (n = 34)		F ^a	p-value
	Mean	SD	Mean	SD		
Before heel lance	47.24	2.56	47.53	2.51	0.23	0.634
During heel lance	48.24	2.78	48.94	2.88	1.06	0.307
After heel lance 1 minute	48.71	2.99	50.53	3.46	5.41	0.023
After heel lance 5 minutes	47.82	3.01	49.65	3.09	6.07	0.016
After heel lance 10 minutes	47.12	2.61	48.59	2.85	4.91	0.030

Note. ^a F values were adjusted using the Greenhouse–Geisser correction due to violation of the sphericity assumption.

F values indicate differences between groups at each time point.

Oxygen saturation

As shown in **Table 5**, before and during the heel lance procedure for blood glucose testing, there was no significant difference in mean SpO₂ between preterm infants who received musical storytelling

and those who received usual care. However, following the procedure, infants who received musical storytelling had significantly higher mean SpO₂ levels than those who received usual care at 1, 5, and 10 minutes.

Table 5. Comparison of mean arterial oxygen saturation in infants between groups across time during heel lance procedures using repeated measures ANOVA (N = 34)

Time points	Musical storytelling group (n = 34)		Usual care group (n = 34)		F ^a	p-value
	Mean	SD	Mean	SD		
Before heel lance	99.03	1.09	98.47	1.42	3.32	0.073
During heel lance	97.41	1.21	96.85	1.71	2.43	0.124
After heel lance 1 minute	98.35	1.39	97.56	1.64	4.65	0.035
After heel lance 5 minutes	98.85	1.42	97.76	1.67	8.39	0.005
After heel lance 10 minutes	99.24	1.13	98.06	1.43	14.12	< 0.001

Note. ^a F values were adjusted using the Greenhouse–Geisser correction due to violation of the sphericity assumption.

F values indicate differences between groups at each time point.

Discussion

This study evaluated the effects of musical storytelling on pain responses during heel lance procedures among 34 premature infants. Our findings suggest that musical storytelling can reduce pain during heel lance and enhance physiological stability in preterm infants.

These findings can be explained by the gate control theory of pain, which posits that pain transmission is modulated at the spinal level through a “gating” mechanism influenced by non-nociceptive sensory input.¹² Auditory stimulation through musical storytelling may activate large-diameter sensory fibers and multisensory pathways, thereby inhibiting nociceptive signal transmission. In this study,

the rhythmic and soothing qualities of music, combined with emotionally expressive narration, likely facilitated parasympathetic activation, reduced stress responses, and enhanced descending inhibitory pathways, thereby decreasing pain perception.

Our findings are consistent with growing evidence supporting the effectiveness of auditory stimulation in managing procedural pain in preterm infants. Recent systematic reviews and meta-analyses have consistently demonstrated that auditory interventions, including music, lullabies, maternal voice, and white noise, may reduce pain responses and improve physiological stability during painful procedures in preterm infants.²⁶⁻²⁹ Similarly, previous studies support our finding that auditory interventions, including Mozart music,³⁰ classical music and lullabies,¹⁴ and maternal voice³¹ could reduce pain and improve selected physiological parameters, including HR, RR, and SpO₂, during or after painful procedures in preterm infants.³²⁻³⁵ Lullabies, in particular, have been reported to be more effective than classical music in reducing pain in preterm infants.³⁶

Collectively, these findings suggest that auditory stimulation may support autonomic regulation and reduce stress- and pain-related responses in preterm infants, particularly when the auditory stimuli are slow, rhythmic, maternal-like, and soothing.^{28,32,37} Musical storytelling, which combines rhythmic music with gentle narration, may therefore serve as a multidimensional auditory intervention that promotes sensory regulation, attentional distraction, relaxation, and behavioral calmness during painful procedures. Although preterm infants may not fully comprehend linguistic content, they are responsive to rhythm, prosody, and continuous auditory patterns, which may enhance familiarity, soothe distress, and facilitate recovery following painful experiences.^{14,38,39}

However, although significant differences in physiological parameters were observed during the post-procedural period, no significant between-group

differences were identified during certain phases of the procedure, particularly during heel lance. This finding is consistent with previous evidence indicating that changes in HR, RR, and SpO₂ during acute painful stimulation may remain inconsistent despite reductions in behavioral pain scores.^{28,29} One possible explanation is that acute nociceptive input during heel lance strongly stimulates the sympathetic nervous system, resulting in immediate increases in HR and RR instability, thereby disrupting physiological homeostasis. These acute autonomic responses may temporarily override the modulatory effects of auditory stimulation during direct exposure to pain, particularly in preterm infants with an immature autonomic nervous system. Consequently, no significant differences in HR or RR were observed between conditions during the procedure. However, once the painful stimulus subsides, the calming and regulatory effects of the musical narrative may become more evident through facilitation of parasympathetic recovery, reduction of sympathetic arousal, and stabilization of autonomic function. This may explain why significant improvements in physiological parameters were observed at the post-procedural recovery period rather than during the acute painful phase itself. Previous studies have likewise reported that physiological parameters tend to show greater variability and less consistency than behavioral indicators during painful procedures in preterm infants.²⁷⁻²⁸ Additionally, variations in gestational age, neurological maturity, clinical status, characteristics of auditory stimuli, and exposure duration may contribute to inconsistencies in physiological outcomes across studies.

Nevertheless, the sustained improvement in physiological stability observed at the post-procedural period in this study may indicate that musical storytelling supports recovery and autonomic re-regulation following painful stimulation. Overall, the findings of this study support musical storytelling as a promising non-pharmacological intervention for

procedural pain management in preterm infants, with beneficial effects on both behavioral pain responses and physiological stability following heel lance. Given that this intervention is non-invasive, low-cost, and easily implemented, musical storytelling may be feasibly integrated into routine neonatal intensive care practice.

Limitations

A limitation of this study is that the sample was restricted to late-preterm infants with a gestational age of 34–36⁺⁶ weeks. As physiological and neurological maturation may differ across gestational age groups, the findings of this study may not be generalized to extremely preterm, very preterm, or full-term infants.

Conclusions and Implications for Nursing Practice

The findings of this study indicate that musical storytelling may facilitate recovery of physiological stability following heel lance in preterm infants. Nurses can apply this intervention to reduce pain responses in preterm infants during painful procedures after further testing of our findings. In addition, incorporating maternal or family voices into the intervention may support family-centered care in the NICU. Further research is warranted with larger sample sizes and more diverse gestational age groups among preterm infants. Comparative studies examining different types of auditory stimuli, as well as the optimal duration and timing of the intervention, are recommended. In addition, if a one-group design is used, a double change-over design is recommended to ensure that the intervention effect can be distinguished from time-related effects. Future studies should also explore the long-term effects on behavioral outcomes and neurodevelopment to strengthen the evidence base and support the development of evidence-based nursing practice.

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Author Contributions

Conceptualization, Method and design: PS, LS, AP

Data collection and analysis: PS

Research supervision: LS, AP

Data interpretation, Drafting and reviewing the manuscript: PS, LS, AP

Editing and revising the manuscript: PS, LS, AP

Final approval of the manuscript: PS, LS, AP

All authors have read and agreed to the published version of the manuscript.

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The authors disclose no potential conflicts of interest associated with this research.

Declaration of AI used for Scientific Writing

We used AI to improve English clarity and help in the literature review.

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ผลของเสียงเล่านิทานประกอบดนตรีต่อการตอบสนองความปวดจากการเจาะเลือดบริเวณส้นเท้า เพื่อตรวจวัดระดับน้ำตาลในเลือดของทารกเกิดก่อนกำหนด : การศึกษากึ่งทดลอง

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บทคัดย่อ: การเจาะเลือดบริเวณส้นเท้าเพื่อตรวจระดับน้ำตาลในเลือดเป็นหัตถการที่ทำเป็นประจำในทารกเกิดก่อนกำหนดที่เข้ารับการรักษาในหอผู้ป่วยวิกฤตทารกแรกเกิด ซึ่งก่อให้เกิดความปวดเฉียบพลันซึ่งอาจส่งผลกระทบต่ออาการเจริญเติบโตและพัฒนาการทางสมอง งานวิจัยนี้เป็นการศึกษา กึ่งทดลองแบบข้ามสลับในกลุ่มเดียวในโรงพยาบาลระดับตติยภูมิ กรุงเทพมหานคร วัตถุประสงค์ เพื่อศึกษาผลของเสียงเล่านิทานประกอบดนตรีต่อการตอบสนองความปวดจากการเจาะเลือดบริเวณส้นเท้า ทารกเกิดก่อนกำหนดจำนวน 34 ราย (อายุครรภ์ 34–36⁺6 สัปดาห์) คัดเลือกแบบเฉพาะเจาะจงและสุ่มให้ได้รับสถานการณ์ทดลอง (เสียงเล่านิทานประกอบดนตรีร่วมกับการพยาบาลตามปกติ) หรือสถานการณ์ควบคุม (การพยาบาลตามปกติเพียงอย่างเดียว) ก่อนเป็นลำดับแรก ภายหลังได้รับสถานการณ์แรก ทารกจะได้สลับไปรับสถานการณ์ตรงข้าม การตอบสนองความปวดประเมินโดยแบบประเมิน Neonatal Infant Pain Scale อัตราการเต้นของหัวใจ อัตราการหายใจ และความอึดตัวของออกซิเจนในเลือดแดงใน 3 ช่วงเวลา ได้แก่ ก่อน ขณะ และหลังการทำหัตถการ วิเคราะห์ข้อมูลด้วยสถิติ two-way repeated measures ANOVA ผลการวิจัยพบว่า ทารกที่ได้รับฟังเสียงเล่านิทานประกอบดนตรีมีคะแนนความปวดต่ำกว่าอย่างมีนัยสำคัญทางสถิติ ทั้งในช่วงเวลาขณะทำหัตถการ และหลังทำหัตถการ นานที่ 1, 5, และ 10 เมื่อเปรียบเทียบกับกลุ่มควบคุม นอกจากนี้ ทารกกกลุ่มทดลองมีอัตราการเต้นของหัวใจและอัตราการหายใจลดลง ขณะที่ค่าความอึดตัวของออกซิเจนในเลือดแดงสูงขึ้นในช่วงเวลานานที่ 1, 5, และ 10 หลังทำหัตถการ ผลการศึกษานี้บ่งชี้ถึงประโยชน์ที่เป็นไปได้ และสนับสนุนการนำเสียงเล่านิทานประกอบดนตรีไปใช้เป็นมาตรการบรรเทาความปวดแบบไม่ใช้ยา เพื่อช่วยลดความปวดจากหัตถการ การบูรณาการแนวทางปฏิบัตินี้เข้ากับการดูแลทารกแรกเกิดตามปกติ สามารถเสริมศักยภาพให้พยาบาลในการจัดการความปวดตามหลักฐานเชิงประจักษ์ในหอผู้ป่วยทารกแรกเกิดวิกฤตได้ อย่างไรก็ตาม การวิจัยในอนาคต ควรมีการศึกษาด้วยขนาดตัวอย่างที่มากขึ้นและครอบคลุมช่วงอายุครรภ์ที่หลากหลาย รวมถึงการเปรียบเทียบรูปแบบของสิ่งกระตุ้นทางเสียง ระยะเวลาและช่วงเวลาที่เหมาะสมของการจัดกระทำ

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คำสำคัญ: การตรวจวัดระดับน้ำตาลในเลือด การเจาะเลือดบริเวณส้นเท้า เสียงดนตรี พยาบาล การตอบสนองความปวด ทารกเกิดก่อนกำหนด การเล่านิทาน

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