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Effect of multisensory interventions on relieving procedural pain in newborns during neonatal screening

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Abstract
Introduction: Procedural pain in newborns is a serious clinical problem with potential long-term consequences. Multisensory non-pharmacological interventions are currently regarded as an effective and safe alternative to pharmacological pain relief.
Objective: This study aimed to identify the most effective multisensory interventions during neonatal screening and assess the effect of selected perinatal factors on the intensity of the pain response.
Methods: A prospective observational study was conducted on 76 full-term newborns. The assessment of pain was conducted using the Neonatal Infant Pain Scale (NIPS) and the Neonatal Facial Coding System (NFCS) behavioral scales. The subjects of the study were divided into four groups according to the type of intervention received (breastfeeding, breastfeeding and voice, voice and touch, no intervention).
Results: The breastfeeding group exhibited the lowest pain scores. The combination of sensory stimuli demonstrably reduced pain intensity more effectively than methods that did not include breastfeeding ($p < 0.001$). Hypotrophy was identified as a risk factor for higher pain levels ($p < 0.05$). Heart rate proved to be a reliable physiological indicator of pain, whereas oxygen saturation had lower information value.
Conclusion: The results clearly confirm the set goal, which was to determine the most effective multisensory intervention in neonatal screening and to evaluate the influence of perinatal factors. At the same time, the results lead to the recommendation to introduce breastfeeding, or a combination of breastfeeding and verbal stimulation, as a standard part of care during capillary blood collection, with an emphasis on systematic education of healthcare personnel and the active involvement of parents in pain prevention.

Keywords: Breastfeeding; Full-term newborn; Multisensory intervention; Neonatal screening; Procedural pain

Introduction

According to the definition established by the International Association for the Study of Pain (IASP), pain is defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage (Raja et al., 2020). Although pain is a universal human experience, the perception of pain in newborns was greatly underestimated for a long time. Even in the latter half of the 20th century, there was a prevalent view that the immature nervous system of newborns was not yet capable of adequately processing pain. This led to the frequent failure to administer analgesia during painful procedures in newborns (Anand and Hickey, 1987).

However, research conducted in recent decades has clearly demonstrated that premature infants not only perceive pain, but also that repeated or intense procedural pain can lead to long-term changes in their neurodevelopment, hormonal regulation, and pain perception in later life (Grunau, 2013; Vinall and Grunau, 2014). This finding has prompted a shift in clinical practice in neonatal departments, where emphasis is now placed on objective pain assessment combining behavioral manifestations (e.g., facial expressions, crying, motor activity) with changes in vital signs (e.g., heart rate, oxygen saturation) (Cong et al., 2013).

Given the limited possibilities for the use of pharmacological analgesia in the neonatal period, non-pharmacological strategies such as breastfeeding, non-nutritive sucking, skin-to-skin contact, soothing, or sucrose administration are being prioritized. Recent studies have shown that multisensory interventions – i.e., a combination of several stimuli – can have a synergistic effect and are more effective than isolated methods (Pillai Riddell et al., 2015).

Despite the growing number of studies, however, there is no clear consensus on the optimal combination of these interventions, especially for commonly performed painful procedures. Additionally, there is a paucity of research investigating whether and how selected perinatal factors (e.g., mode of delivery, birth weight, previous exposure to pain, GBS colonization, or amniotic fluid characteristics) modify neonatal reactivity to painful stimuli.

The heel prick test is one of the most common standardized painful procedures performed as part of neonatal screening in the early neonatal period. Essential for the early detection of

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serious congenital diseases, this procedure is performed on all live-born infants and represents a valid model for studying the efficacy of non-pharmacological, particularly multisensory, interventions in a real clinical context.

The aim of this study was to identify the most efficacious multisensory interventions during neonatal screening and to assess whether selected perinatal factors which can potentially modify neonatal pain sensitivity (e.g., mode of delivery, birth weight, previous exposure to pain, GBS colonization, or type of amniotic fluid) affect pain intensity.

Materials and methods

This prospective observational study used a quantitative approach and was conducted in the neonatal department of a regional hospital in the Czech Republic from March to December 2024. The ethical aspects of the study were thoroughly assessed and approved by the Ethics Committee of the Faculty of Medicine of the University of Ostrava and the Ethics Committee of the medical facility. All legal guardians of newborns provided written informed consent for their child's inclusion in the study.

The study population comprised full-term newborns between 48 and 72 hours of age who were scheduled to undergo routine neonatal screening, which involved the collection of a heel prick blood sample. The selection was deliberately based on predefined criteria, including gestational age of 37–42 weeks, stable clinical condition, and informed consent provided by the mother. Preterm newborns were excluded from the study. The analysis included a total of 76 newborns, which were divided into four groups based on the non-pharmacological intervention used: (1) breastfeeding, (2) breastfeeding combined with verbal soothing by the mother, (3) verbal soothing combined with touch by a legal guardian, and (4) a control group with no intervention. The division into groups was not randomized; it was based on the current preferences and choices of the mothers, which allowed their decisions to be respected.

Capillary blood sampling was performed exclusively by a qualified pediatric nurse or midwife with clinical experience in the neonatal department. The majority of samples were obtained directly in the mother's room; however, if the health condition of the newborn or mother precluded this, the sample was taken in another suitable area (but always in the presence of a legal guardian). The standard collection procedure involved a single puncture with an automatic lancet suitable for newborns.

The procedure was recorded on video which covered three phases: (1) the resting phase – two minutes before the blood collection; (2) the collection phase – from the first contact of the lancet with the skin until the completion of the blood collection; and (3) the recovery phase –two minutes after the procedure ended. This time frame enabled the identification of the response to procedural pain and its differentiation from general discomfort. The video recordings did not contain any identifying information, and all data underwent anonymization post-recording and was stored securely in accordance with personal data protection requirements (GDPR).

Pain was evaluated using two validated behavioral tools: the Neonatal Infant Pain Scale (NIPS), which includes six behavioral indicators with a total score ranging from 0 to 7 points, and a shortened version of the Neonatal Facial Coding System (NFCS), which assesses five facial expressions of pain with a total score ranging from 0 to 5. Both scales are internationally recognized and widely used to assess procedural pain in full-term newborns. Selected vital signs were also monitored, namely heart rate and peripheral blood oxygen saturation (SpO_2), which were measured using a pulse oximeter. The records were evaluated by two independent assessors with clinical experience in pediatrics and midwifery. The midwife was selected based on her daily work with newborns and knowledge of their behavioral expressions. All evaluators underwent initial training on the proper use of both scales. Prior to the actual evaluation, the degree of concordance among the evaluators was verified. In instances of discordance, a third independent assessor was consulted to determine the ultimate score.

The data were analyzed using Microsoft Excel and STATISTICA software. The normality of the data distribution was verified using the Shapiro–Wilk test. The Mann–Whitney *U* test was utilized to compare differences between two groups, while the Kruskal–Wallis test was employed when comparing more than two groups. The statistical significance of relationships between categorical variables was determined using the chi-square test and Fisher's exact test. The statistical significance was set at $p < 0.05$.

Results

The present study included a total of 76 full-term newborns, aged 48 to 72 hours, who underwent capillary blood collection from the heel as part of routine neonatal screening. The study evaluated the effects of four types of non-pharmacological interventions on pain manifestations during this procedure, employing behavioral scales and physiological indicators. Of the total number, 39 were male (51.3%) and 37 were female (48.7%). The mean birth weight was 3,304.7 g (SD = 428.5 g), with a range from 2,340 g to 4,200 g. All newborns were clinically stable.

With respect to the method of delivery, 53 newborns (69.7%) were born spontaneously, while 23 newborns (30.3%) were delivered surgically (cesarean section, vacuum extraction, or forceps). In 21 newborns (27.6%), other previous painful stimuli, such as vitamin K administration or blood sampling, were recorded. Postnatal adaptation disorders occurred in 16 children (21.1%), most commonly in the form of transient respiratory distress. Turbid amniotic fluid was observed with 16 newborns (21.1%), and positive colonization with *Streptococcus agalactiae* (GBS) was confirmed in 15 mothers (19.7%).

Efficacy of multisensory interventions

The newborns were divided into four groups based on the type of non-pharmacological intervention applied during blood collection:

1. Breastfeeding ($n = 22$)
2. Breastfeeding and verbal soothing ($n = 21$)
3. Verbal soothing and touch ($n = 15$)
4. No intervention (control group; $n = 18$)

The lowest pain levels were observed in newborns in the breastfeeding group. The mean pain score according to the NIPS scale was 1.34 ± 1.23 (median = 2; IQR = 2.00), and according to the NFCS scale it was also 1.34 ± 1.45 (median = 2; IQR = 2.00). Next was the group that received a combination of breastfeeding and verbal soothing, with the following outcomes: NIPS: 1.77 ± 1.69; NFCS: 1.77 ± 1.69 (median = 2; IQR = 3.00).

In contrast, the highest pain scores were documented in the group that received a combination of verbal soothing and touch (NIPS: 4.33 ± 2.22, median = 5, IQR = 2.75; and NFCS: 3.89 ± 1.64, median = 5, IQR = 2.00). The control group exhibited moderate pain scores (NIPS: 2.57 ± 1.90; NFCS: 2.57 ± 1.62; median = 3).

The Kruskal–Wallis test confirmed statistically significant differences between the groups for both scales (NIPS and NFCS, $p < 0.001$), thereby confirming the effect of interventions on reducing procedural pain.

Pain intensity according to the NIPS and NFCS scales

On the NIPS scale, pain was categorized as follows:

- 0–2 points (no or mild pain): 42 newborns (55.3%)
- 3–6 points (moderate pain): 30 newborns (39.5%)
- 7 points (severe pain): 4 newborns (5.3%)

On the NFCS scale, the scores were distributed as follows:

- 0–2 facial expressions of pain: 42 newborns (55.3%)
- 3–4 expressions: 30 newborns (39.5%)
- 5 expressions (maximum): 4 newborns (5.3%)

The distribution of results on both scales was found to be highly analogous, thereby substantiating the notion of consistency between behavioral assessment methods.

Unlike the NIPS scale, for which pain categorization is commonly reported in the literature (0–2 = no/mild pain; 3–6 = moderate pain; 7 = severe pain), the NFCS scale does not have an official, clinically validated classification system based on pain intensity. For this reason, a descriptive analysis of the number of pain-related facial expressions without categorization into levels was performed for the NFCS scale.

Occurrence of pain by type of intervention

A NIPS and NFCS score ≥1 was considered to indicate the occurrence of pain. The breastfeeding group exhibited the lowest frequency of pain (NIPS: 38% with no pain; NFCS: 48% with no pain). The highest incidence of pain was observed in the verbal soothing and touch group (89% on both scales).

The statistical significance of pain incidence was confirmed only for the NFCS scale (Fisher's exact test: $p = 0.034$); the difference was not statistically significant for the NIPS scale ($p = 0.186$).

Effect of birth weight

The newborns in the study were divided into three categories according to their birth weight percentile: hypotrophy ($n = 10$), eutrophy ($n = 61$), and hypertrophy ($n = 5$). Hypotrophic newborns had the highest pain scores (NIPS: 3.90; NFCS: 3.70), followed by eutrophic newborns (NIPS: 2.05; NFCS: 1.95) and hypertrophic newborns (NIPS and NFCS: 2.00). These differences were statistically significant for both the NIPS ($p = 0.011$) and the NFCS ($p = 0.013$), which suggests that low birth weight may be a risk factor for higher pain levels.

Effect of other factors

Delivery method: Surgically delivered infants ($n = 23$) exhibited higher average pain scores (NIPS: 2.74; NFCS: 2.48) compared to those delivered spontaneously ($n = 53$) (NIPS: 2.09; NFCS: 2.06). However, the difference was not statistically significant (NIPS: $p = 0.272$; NFCS: $p = 0.350$).

Previous painful stimuli: Newborns who had previously been exposed to painful stimuli ($n = 21$) had higher pain scores (NIPS: 2.59; NFCS: 2.34) compared to those who had not been subjected to such exposure (NIPS: 2.11; NFCS: 2.09), though the difference was not statistically significant (NIPS: $p = 0.258$; NFCS: $p = 0.547$).

Postnatal adaptation: Infants with impaired postnatal adaptation ($n = 16$) had lower pain scores (NIPS: 1.81; NFCS: 1.63) than children without complications (NIPS: 2.42; NFCS: 2.33). However, this difference was not statistically significant.

Factors associated with infection risk

Amniotic fluid type: Infants born with cloudy amniotic fluid ($n = 16$) had lower pain scores (NIPS and NFCS: 1.69) than those born with clear fluid (NIPS: 2.45; NFCS: 2.32), though the difference was not statistically significant.

GBS: Infants of mothers with positive GBS colonization ($n = 15$) exhibited marginally lower pain scores (NIPS: 1.93; NFCS: 1.73) compared to infants of mothers with negative results (NIPS: 2.35; NFCS: 2.27). This difference, however, was not statistically significant.

Neither of these perinatal factors associated with an elevated risk of infection had a significant effect on pain perception during screening.

Physiological responses to pain

In addition to behavioral manifestations, changes in heart rate (HR) and oxygen saturation (SpO_2) were monitored as physiological indicators of pain. The analysis was conducted with respect to the presence of pain, which was defined as a score of ≥1 on both the NFCS and NIPS scales.

NFCS scale: Newborns exhibiting signs of pain according to the NFCS scale (NFCS ≥ 1; $n = 50$) had a significantly higher increase in heart rate by an average of 15.6 beats/min. (SD = 12.99), compared to children without pain (NFCS = 0; $n = 26$), where the increase was only of 7.1 beats/min. (SD = 14.68). The difference was statistically significant ($p = 0.012$).

The mean decrease in SpO_2 saturation was –1.82% (SD = 3.61) in children experiencing pain, while in children without pain, the decrease was only –0.23% (SD = 1.53). However, this difference did not reach statistical significance ($p = 0.056$), which may be related to rapid homeostatic compensation in full-term newborns.

NIPS scale: A similar trend was observed in the analysis according to the NIPS scale. Newborns with a NIPS score ≥ 1 ($n = 55$) had an average increase in HR of 14.4 beats/min. (SD = 13.26), while children with a NIPS score of 0 ($n = 21$) had an average increase of only 8.1 beats/min. (SD = 15.45). The difference indicates a tendency toward higher activation of the autonomic nervous system in children with behavioral manifestations of pain, albeit with a lower degree of significance than in the NFCS scale.

Decrease in SpO_2 saturation was also more pronounced in the group of newborns experiencing pain according to NIPS (–1.64%; SD = 3.50) than in the no-pain group (–0.33%; SD = 1.62). However, the observed difference did not attain statistical significance in this instance either.

A limitation of the present study is the relatively modest sample size, particularly in terms of the representativeness of the results and the statistical significance of some of the differences observed. The aim of the analysis is to present the first preliminary results of the study as soon as possible, which, even within this limited scope, allow for the formulation of some conclusions and recommendations. The collection of data for the study is ongoing, and the publication of subsequent findings is planned as definitive results.

Discussion

Procedural pain in newborns is a prevalent and recurring phenomenon, as even full-term infants undergo several invasive procedures in the first days after birth, such as capillary blood sampling, vitamin K administration, or venous blood sampling in indicated cases. According to epidemiological studies, more than 90% of newborns experience at least one painful procedure during hospitalization. Given the evidence of the short- and long-term effects of pain on neurodevelopment, behavioral reactivity, and stress response in newborns, it is essential to seek effective and safe pain management strategies (Williams and Lascelles, 2020). The results of the present study confirm that breastfeeding is the most effective method of pain relief for full-term newborns during neonatal screening. Procedural pain in newborns has been a frequent subject of professional interest in recent years because of its immediate behavioral manifestations and possible long-term consequences of repeated painful stimulation at an early age. Whether applied alone or in combination with verbal soothing, breastfeeding led to a statistically significant reduction in pain scores. Breastfeeding is a complex, multisensory intervention that stimulates the oral, olfactory, tactile, and emotional receptors of the newborn. In our cohort of newborns, the analgesic efficacy of breastfeeding was demonstrated based on assessments using the NIPS and NFCS scales.

Numerous studies concur that breastfeeding constitutes a highly efficacious method of pain relief. Soltani et al. (2018) found that breastfeeding resulted in lower pain scores than 25% dextrose, kangaroo care, or EMLA cream, which had the lowest analgesic effect among the methods studied. These results lend support to the hypothesis that breastfeeding provides complex multisensory stimulation through sucking, thermal comfort, taste, and smell, and that this combination is key to effective analgesia. In a similar vein, Kumar et al. (2020) demonstrated that both sucrose and breastfeeding led to a significant reduction in pain, while distilled water or rocking had no effect. Napiórkowska-Orkisz et al. (2022) found no significant differences between breastfeeding, glucose, and non-nutritive sucking. However, all of these interventions led to lower pain scores compared to standard care.

Breastfeeding is widely recognized as an effective non-pharmacological intervention with proven analgesic effects in newborns (Carbajal et al., 2003; Gray et al., 2002; Witt et al., 2016). Its mechanism of action is multifactorial, involving physiological and psychological aspects that synergistically modulate pain perception.

It is hypothesized that mechanical stimulation of the oral mucosa (e.g., during breastfeeding or non-nutritive sucking) can activate endogenous opioid pathways and contribute to reduced pain perception (Witt et al., 2016). Similarly, oral glucose administration and non-nutritive sucking (e.g., pacifier sucking) have been repeatedly shown to be effective in alleviating pain during minor invasive procedures in newborns. These methods are thought to share common analgesic mechanisms, likely involving activation of endogenous opioid pathways (Stevens et al., 2013).

In addition to its neurochemical effects, breastfeeding involves multisensory stimulation. Key elements of this stimulation include skin-to-skin contact, which has been shown to reduce pain and stress. This is evidenced by a decrease in stress hormones, such as cortisol, and an increase in beta-endorphins and oxytocin (Cong et al., 2012). Breast milk provides olfactory and gustatory sensations, and the breastfeeding environment includes auditory stimuli from the mother's voice and heartbeat.

A study by Carbajal et al. (2003) demonstrated that breastfeeding significantly reduces behavioral manifestations of pain (e.g., crying and facial expressions) in full-term newborns during venipuncture. Gray et al. (2002) also demonstrated a reduction in the heart rate of newborns during breastfeeding while undergoing a painful procedure. These results support the hypothesis that breastfeeding is an effective non-pharmacological intervention for the management of procedural pain.

From a clinical practice perspective, breastfeeding is an undemanding, cost-free, and easily implementable method. However, it is crucial that healthcare personnel have sufficient competence to educate mothers and support breastfeeding, including in the context of procedural pain. For infants who cannot breastfeed, it is important to consider other alternative multisensory interventions.

This necessity is substantiated by the findings of studies that have confirmed the importance of multisensory approaches. For instance, a study by Yilmaz and Inal (2020) broadened the perspective on combined methods by examining the effects of swaddling, holding, and breastfeeding. The lowest pain levels were recorded in newborns who were swaddled, held in the arms and breastfed at the same time. This combination underscores the importance of simultaneous use of multisensory modalities which potentiate each other. Although our study did not include swaddling, combining breastfeeding with the mother's voice produced better results than vocal stimulation and touch, which is fully consistent with the conclusions of the aforementioned study and thus supports recommendations for clinical practice.

The effect of olfactory (smell) and gustatory (taste) stimulation by breast milk on pain relief was the subject of studies by Lin et al. (2022) and Lan et al. (2021). The findings of these studies demonstrated that the olfactory and gustatory qualities of breast milk can effectively mitigate painful responses in newborns. The efficacy of this analgesic effect was found to be amplified when combined with other sensory stimuli, such as the mother's voice or touch. While the present study did not evaluate these specific modalities separately, its results suggest that a combination of multiple stimuli (e.g., breastfeeding with verbal stimulation) is more effective than their isolated use, which is consistent with the conclusions of the aforementioned studies.

While complex multisensory interventions, such as breastfeeding, have been demonstrated to be highly effective in alleviating pain, the analgesic effect of isolated touch or voice tends to be less pronounced. Our study corroborated this trend, which is consistent with the findings of Lan et al. (2021). Their research indicated a degree of effectiveness in gentle hugging and voice stimulation employing the scent of breast milk, but the effect was found to be milder in comparison to methods involving oral stimulation. These findings suggest that sucking, and thus the activation of oral mechanoreceptors and taste stimuli, plays a fundamental and potentially dominant role in the neurophysiological suppression of pain in newborns. Oral stimulation triggers the release of endogenous opioids and activates the parasympathetic nervous system, leading to a deeper state of calm and analgesia.

While oral stimulation frequently predominates, physical stabilization of the newborn and support for its positional security constitute an additional significant, and at times even more potent, non-pharmacological strategy. A notable example is the study by Avcin and Küçükoğlu (2021), which compared the effectiveness of breastfeeding, kangaroo care, and

facilitated tucking. Surprisingly, the authors found that facilitated tucking resulted in the lowest pain intensity and shortest crying duration, surpassing both breastfeeding and kangaroo care. This finding underscores the fact that stable and secure body positioning, which minimizes unwanted movement and provides a sense of containment, can have a powerful analgesic and calming effect. This is particularly important in procedures where movement of the infant is undesirable or in newborns for whom breastfeeding is not possible. Integrating these findings into clinical practice enables the optimization of pain management strategies, taking into account individual needs and the context of the situation.

In addition to behavioral pain assessment, physiological parameters have also proven to be a valuable supplement, particularly heart rate. In the present study, changes in heart rate closely correlated with facial expressions of pain assessed by the NIPS and NFCS scales, confirming its validity as a supporting indicator of pain intensity. Across studies, heart rate has been shown to be the most sensitive and consistent vital sign in response to pain and its relief. For example, olfactory and gustatory stimuli from breast milk (Lin et al., 2022), facilitated tucking (Subedi et al., 2024), mother's hug (Roshanray et al., 2020), and skin-to-skin contact (Liu et al., 2015) resulted in a significant reduction in heart rate after a painful stimulus. Quantitative data from Napiórkowska-Orkisz et al. (2022) also show that although the differences between interventions were not statistically significant, all methods studied (non-nutritive sucking, breastfeeding, and glucose) led to a reduction in the difference between resting and maximum heart rate, with lower heart rate variability correlating with less pain intensity. In contrast, oxygen saturation, although often following a similar trend, has lower explanatory power, probably due to the newborn organism's rapid compensatory capacity. Significant differences were noted in interventions involving breast milk (Lin et al., 2022), skin-to-skin contact (Liu et al., 2015), and tucking (Subedi et al., 2024). Other techniques, such as mother's hug or massage (Roshanray et al., 2020), did not show any changes in oxygen saturation. These findings support a comprehensive approach to pain monitoring that combines behavioral and physiological indicators to reflect individual newborn responses to various non-pharmacological interventions.

One of the key aspects of our study was to assess the impact of specific perinatal factors on the pain response of newborns. Our analysis demonstrated that hypotrophy, defined as a condition in which a child is born with a significantly lower birth weight relative to its gestational age, is a substantial factor influencing the intensity of the pain response. Specifically, newborns who fell into the hypotrophic category (i.e., with a weight below the 10th percentile) exhibited significantly higher average scores on standardized pain assessment scales (NIPS and NFCS) compared to children with normal birth weight (eutrophic). The findings of this study indicate that lower birth weight may diminish a newborn's innate capacity to effectively cope with procedural stress and pain. It is therefore crucial to provide these children with effective analgesia because they often have a reduced ability to adapt to stressful stimuli. Multisensory approaches should be applied systematically and prioritized in this group.

Other monitored factors, such as postnatal adaptation disorders, risk of infection (GBS colonization and cloudy amniotic fluid), repeated painful stimuli, and method of delivery, were not statistically significant in the present sample. With respect to the mode of delivery, our finding that this factor did not have a statistically significant effect on pain experience is consistent with the results of other studies. Similarly, Vu-Ngoc et al. (2020) observed that the mode of delivery did not exert a significant influence on pain intensity in newborns within the confines of their study. Lan et al. (2021) examined the correlation between pain response and various risk and demographic factors, including gender, birth weight, and mode of delivery. The findings of their research demonstrated that none of these factors exhibited a statistically significant impact on the level of pain experienced by newborns during the procedure under observation. Previous painful exposure is also frequently cited as a potential source of variability in response to treatment. The possibility exists that the relatively small sample size or variability in data collection, which may have reduced the statistical power of the analyses, contributed to the lack of statistical significance in our sample. Nevertheless, it is important to continue monitoring these data and to investigate the relationship between perinatal factors and the development of pain awareness in the future.

Conclusion

The results of this study demonstrate the achievement of the set objective, i.e., to determine the most effective multisensory intervention and to evaluate the influence of selected perinatal factors, and they are consistent with previously published scientific findings.

The findings unequivocally substantiate the incorporation of multisensory non-pharmacological interventions as a conventional component of care for full-term newborns during painful procedures, such as neonatal screening. The highest efficacy was demonstrated for breastfeeding – whether applied alone or in combination with verbal stimulation – which emphasizes the importance of early lactation and active maternal involvement. Breastfeeding appears not only to be analgesically effective but also to be an easily accessible and safe intervention with minimal associated costs.

In accordance with the principle of sensory saturation, it has been demonstrated that the combination of multiple sensory stimuli (e.g., sucking, voice, physical contact) is more efficacious than the utilization of them in isolation. These findings have direct implications for clinical practice, not only in terms of improving pain relief strategies, but also in terms of strengthening early emotional bonding, supporting parental competence, and the overall humanization of neonatal care. The study also confirmed that even simple stimuli, such as the mother's voice or skin-to-skin contact, can be utilized in scenarios where breastfeeding is not possible, for example, during separation or due to health restrictions. In such cases, recorded voices, scent cloths, or positioning strategies, which all activate natural self-regulation mechanisms can be used.

From a research perspective, the long-term effect of repeated use of multisensory interventions remains an open question, particularly with regard to neurodevelopment, behavioral adaptation, and stress response in older children. The long-term effects of systematic pain prevention in the neonatal period have not been adequately researched. While some studies have suggested a link between early painful stimulation and neurodevelopmental or behavioral outcomes, larger longitudinal studies comparing different types of non-pharmacological interventions and their impact on child development are lacking. The utilization of objective biomarkers, such as stress hormone levels and functional neuroimaging methods, has emerged as a promising avenue for enhancing our comprehension of the efficacy of diverse approaches.

The data obtained unequivocally substantiate the implementation of standardized recommendations for the prevention and management of pain in full-term newborns. During invasive procedures, it is recommended that breastfeeding, or a combination of breastfeeding and verbal stimulation, be incorporated into the care regimen. We propose the implementation of educational initiatives targeting healthcare personnel, complemented by the active involvement of mothers in the process of pain prevention. A multisensory approach should be systematically implemented in both maternity wards and neonatal units, with an emphasis on the active involvement of parents, staff education, and respect for the psychobiological needs of the child. The present study lends further credence to the notion that it is feasible to administer humane, safe, and effective care for newborns even during routine invasive procedures. It is imperative, therefore, that efforts are made to ensure that pain prevention becomes an integral part of modern neonatal practice.

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Conflict of interest
The authors have no conflict of interest to declare.

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