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REVIEW ARTICLE

Prematurity: can music have a role in neonatal intensive care unit?

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Abstract

Prematurity is a challenge for preterm infants (PTI) and their parents. Due to their overall immaturity, PTI have inadequate responses towards stress and an increased risk for impaired neurodevelopment. The unfavorable acoustic environment at Neonatal Intensive Care Unit (NICU) causes physiological instability, disrupts sleep cycles, and hampers important auditory experiences. The use of music as therapy in this population has been under research for decades with promising results so far. This narrative review aimed to summarize the effects of music on PTI and their parents at NICU, analyzing studies that were further classified as using music therapy (MT) or musical stimulation (MS), according to the intervention described. This review emphasizes the potential benefits of music as a complementary therapy at NICU, with a positive impact on many clinical aspects, such as vital signs, sleep quality, neurodevelopment, and growth, and an important influence on parent-infant bonding. Moreover, this review highlights MT for the consistency of positive results and the importance of an individualized approach. Future studies should investigate the effects of MT and MS interventions on NICU PTI based on their characteristics, trying to understand what suits each situation best, and aiming to establish some formal recommendations.

Keywords: Music therapy. Premature infants. Neonatal intensive care unit. Newborn.

Prematuridade: pode a música ter um papel na unidade de cuidados intensivos neonatais?

Resumo

A prematuridade constitui um desafio para os recém-nascidos prematuros e para os pais. Devido à sua imaturidade, estes recém-nascidos apresentam respostas inadequadas ao stress e um maior risco de patologias do neurodesenvolvimento. O ambiente acústico hostil na Unidade de Cuidados Intensivos Neonatais provoca instabilidade fisiológica, perturba os ciclos de sono e impede experiências auditivas importantes. O uso da música como terapia nesta população tem sido estudado há décadas e com resultados promissores até ao momento. Esta revisão narrativa teve como objetivo sumariar os efeitos da música em recém-nascidos prematuros e nos pais durante a permanência na Unidade de Cuidados Intensivos Neonatais, analisando estudos cuja abordagem foi, posteriormente, classificada como musicoterapia ou estimulação musical, de acordo com a intervenção descrita. Esta revisão enfatiza os potenciais benefícios da música enquanto terapia complementar nestas unidades, com impacto positivo em vários parâmetros clínicos, como sinais vitais, qualidade do sono, neurodesenvolvimento e crescimento, e uma influência importante na relação entre os pais e o recém-nascido prematuro. Ademais, esta revisão sublinha a consistência dos resultados positivos em relação à musicoterapia e a importância de uma abordagem individuali-

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zada. Investigações futuras devem avaliar os efeitos da musicoterapia e da estimulação musical nos recém-nascidos prematuros durante o internamento na Unidade de Cuidados Intensivos Neonatais com base nas suas características, tentando compreender o que melhor se aplica em cada caso, e com o objetivo de estabelecer algumas recomendações formais.

Palavras-chave: Música. Musicoterapia. Prematuros. Unidade de cuidados intensivos neonatais. Recém-nascido.

Key points

What is known:

- Medical advances have improved the survival rate of preterm infants, resulting in a growing population with prematurity-related problems.
- Previous studies stated that music is a powerful complementary therapy at Neonatal Intensive Care Unit, with multiple benefits in several clinical aspects.
- The heterogeneity of previous studies has made it impossible to establish formal recommendations on the use of music so far.

What is added:

- Summary of the reported effects of music as complementary therapy for preterm infants and parents at Neonatal Intensive Care Unit.
- Highlight of music therapy as a more effective and consistent method, when compared to other approaches involving music in this population.
- Recommendations for further publications concerning the heterogeneity found in previous studies in order to establish clinical guidelines.

Introduction

Over the last decades, advances in obstetric and neonatal care have led to an increase in overall survival among PTI. However, these improvements brought other challenges. The population of ex-preterm infants increased, and pediatricians are facingproblems related to prematurity more often, such as neurodevelopmental morbidities[1]. Thereby, interest concerning neurodevelopment long-term impairment in PTI has been growing and, consequently, related neurodevelopment follow-up and early intervention have become important concerns[2].

Prematurity — or preterm birth — is defined as the birth of an infant born alive before 37 weeks of pregnancy have been completed, and it is divided into extremely preterm (< 28 weeks of gestation), very preterm (28-32 weeks of gestation), and moderate to late preterm (32-37 weeks of gestation)[3]. PTI are at an increased risk of neurological deficits and they are conditioned by the functional and structural modifications their brains undergo between 24 and 40 weeks of gestation, a highly important period for neurodevelopment that is disrupted by premature birth[4,5]. The risk of major disability increases with decreasing gestational age (GA); the extremely and very preterm groups are at higher risk than the moderate to late preterm one[6]. Besides GA, other predictors of poor neurological outcome include birth weight, male gender, and structural changes of the brain[7].

Regarding hearing, PTI miss out on an important opportunity for auditory experiences in the womb[8]. The intrauterine environment is characterized by the presence of constant, periodic sounds such as the mother's voice and heartbeat[9]. These familiar pleasant sounds are suddenly replaced by loud, unpredictable noises and alarms coming from medical equipment in the NICU environment[10]. There is strong evidence that this negatively affects auditory and language development on the long term[11,12].

In addition to prenatal and natal risk factors, PTI sometimes face other challenges during NICU hospitalization such as mechanical ventilation, bronchopulmonary dysplasia, brain injury, infection, and treatments, such as postnatal corticosteroids and inotropes, which have been associated with poor neurodevelopmental outcomes (Fig. 1)[13-22]. Furthermore, exposure to noise and bright lights, frequent handling for clinical assessment, or routine care and painful invasive life-saving procedures can cause overstimulation of PTI[23,24]. This can be perceived as an aggression and lead to physiological responses such as apnea, bradycardia, decreased peripheral oxygen saturation (SpO_2), and increased stress hormone levels[13]. The normal architecture of sleep can be disrupted, resulting in shorter REM periods. This influences the metabolic, immune, and cardiovascular systems and compromises weight gain. During this period, ensuring quality sleep is also crucial for neural plasticity and brain development[25].

The postnatal period for PTI can also be stressful and challenging for parents. Premature birth, feeling unready and unable to attend to their child's needs without the help of a primary care professional can be rather traumatizing. Parents often cope with their concerns about their children's health condition while dealing with feelings of insecurity, fear, guilt, and stress alone[26-29].

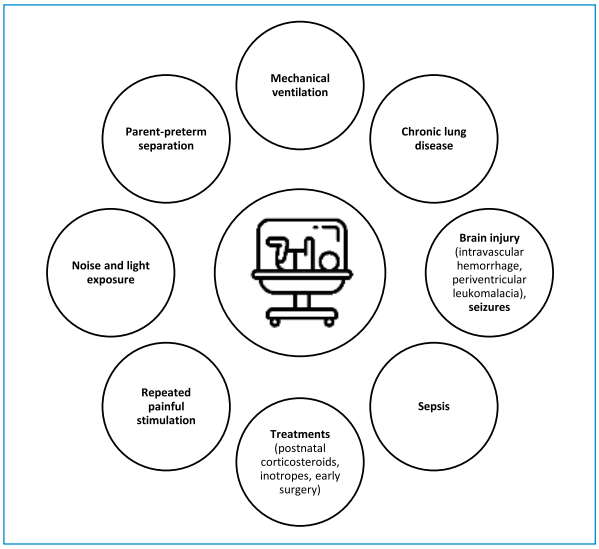

Figure 1. Risk factors for poor neurodevelopmental outcomes in premature infants

Mothers of PTI are at a higher risk of developing anxiety disorders and postpartum depression, and some studies suggest that 20% of parents still show signs of stress one year after their stay in the NICU[30,31]. Conversely, maternal deprivation can also be stressful for the infant[32,33]. Prematurity and prolonged NICU stays act as barriers to the natural mother-child bonding process[34]. These biological and other socio-economic factors, that are present from the prenatal period and throughout life, are also known to impact brain development and should not be neglected[32-34].

At a time when there is an extended knowledge of this subject and advanced medical care that allow PTI with lower GA to survive and thrive, the role of complementary therapies that can improve clinical outcomes and reduce the risk of developing health issues or deficits is becoming increasingly important.

MT is an emerging intervention that has been studied for decades. The World Federation of Music Therapy defines MT as the "professional use of music and its elements as an intervention in medical, educational, and everyday environments with individuals, groups, families, or communities who seek to optimize their quality of life and improve their physical, social, communicative, emotional, intellectual, and spiritual health and wellbeing"[35]. There are several reasons why music is an intuitive therapy to implement during this period. Firstly, auditory development begins quite early, during the third trimester of pregnancy[36]. Infants' hearing structures and neural pathways are fully formed and functional by 28 weeks of gestation[37]. Moreover, research shows that there is already an ability to understand and remember auditory stimuli such as the mother's voice as early as 32 weeks of gestation[38]. Secondly, the communication between the infant and the mother has, on its own, an intrinsic "musicality", prosody, a spontaneous characteristic of speech[39]. Finally, music can neutralize the overstimulation of the NICU and create a soothing environment that benefits the infants and nurtures the parent-infant relationship[40].

However, this definition narrows the spectrum of interventions that can be considered MT, since many of those already described in the literature are not conducted by a qualified therapist. The presence of a trained professional enables the session to be carefully adapted to the infant's specific needs and provides a personalized approach[41]. There is increasing evidence recommending the use of qualified therapists. With this in mind, and for the purposes of this study, we will define MS as all interventions that are not planned or executed by a music therapist.

In this narrative review, we aim to collect and summarize evidence on the application of music on PTI and their parents in the NICU between 2000 and 2022. Our intention is to explore the different approaches and highlight their advantages and disadvantages. Ultimately, we hope to determine whether music should be incorporated into NICU's clinical practice.

Methods

This narrative review is based on a thorough literature search of the Medical Subject Headings (MeSH) terms in PubMed/Medline, on National Library of Medicine (NIH), Cumulated Index to Nursing and Allied Health Literature (CINAHL) and Embase databases, between June 2022 and December 2022. The MeSH terms *Music* OR *Music Therapy* AND *Preterm Infants* AND *Neonatal Intensive Care Unit* were used in this research. These terms were also combined with secondary terms in order to refine the results, such as *Vital Signs* OR *Blood Pressure* OR *Heart Rate* OR *Respiratory Rate* OR *Body Temperature* OR *Sleep* OR *Growth* OR *Development* OR *Developmental Disabilities* OR *Behavior Problems* OR *Feeding Problems* OR *Pain Management* OR *Parent-child Relations* OR *Mother-child Relations* OR *Maternal-fetal Relations*. This research included publications from 2000 to 2024.

It should be noted that only articles written in English were retrieved in this study. Furthermore, systematic and narrative reviews, observational studies, medical books, and other relevant sources were included,

followed by the exclusion of incomplete papers. The abstracts of the identified articles were assessed for relevance, along with screening of their references for further relevant publications. Studies regarding multimodal approaches, in which the role of music or music therapy could not be isolated from other interventions, were excluded.

Finally, the included studies were further classified into the categories of MT, when involving the intervention of a music therapist and an individualized approach; or MS, when planned by other health professionals or researchers, in a standardized way.

Discussion

Physiological parameters

The NICU acoustic environment triggers negative physiological responses in PTI that can result in an adverse clinical state, including apnea, bradycardia, and decreased SpO_2[42,43]. In these stress-related states, there is a relative dominance of the sympathetic over the parasympathetic nervous system[44]. Music restores the balance between the sympathetic and parasympathetic nervous systems[44-46].

However, there are conflicting results regarding the effect of music on physiological parameters. A comparison of the white noise and lullabies groups with a control group revealed positive effects on heart rate (HR), respiratory rate (RR), and SpO2, according to Dora et al[47]. As for Namjoo et al., none of these registered a significant difference, despite the use of live and recorded music. This may be due to the heterogeneity between these studies.[48] They adopt different approaches (MT *versus* MS), differ in the number, frequency and duration of music sessions, and vary in their inclusion criteria for participants (GA, birthweight, clinical state, etc.)[49-51].

Nevertheless, considering the studies included, MT produced positive results more consistently regarding physiological outcomes. Lowey et al. investigated the effect of Gato-box and Ocean Disc on vital signs, under the principles of the First Sounds Rhythm-Breath-Lullaby (RBL) model[52]. The RBL model is based on the notion of entrainment, whereby infants synchronize their physiological rhythms in response to external stimuli, and focuses on entraining PTI's vital rhythms through music, enabling self-regulation[52]. The Gato-box and the Ocean Disc are two instruments designed for use in music therapy sessions. The Ocean Disc is a metallic instrument that simulates the maternal heartbeat—the "whoosh"-like sound of the placenta — and it is played to mirror the infants' breathing patterns. The Gato-box, in turn, is a wooden box played to entrain the infant's heartbeat[52,53]. The music therapist plays these instruments in accordance with the PTI's vital signs and the infants respond by adapting to the stimulus. When subjected to this therapy, PTI showed stable HR and increased SpO_2, demonstrating that the approach achieved its goal of enhancing the infants' self-regulation and physiological stability[52]. Later, Lowey corroborated these same results by using the lullaby 'Twinkle' and 'songs of kin'[53]. 'Songs of kin' consist of lullabies selected by parents that reflect their familial and cultural heritage resulting in more personalized interventions[53]. Varisco et al. reported less HR variability in PTI that were sung to by parents, indicating stability and illustrating a balance between the parasympathetic and sympathetic nervous systems. These findings were confirmed by systematic reviews that emphasized the importance of having a music therapist involved[49,51]. Costa et al. underlined that it could also be interesting to evaluate the long-term physiological effects in future studies[49].

MS studies and studies involving infants suffering from clinical conditions that affect their stability, such as brain injury, have demonstrated more limited outcomes, reporting minimal or no significant improvement in parameters like HR, SpO_2, and RR[55-57].

Pain management

PTI hospitalized at NICU are frequently submitted to painful procedures that can affect their physiological parameters and behavioral states. Their neurological immaturity makes them susceptible to long-term effects of pain, which highlights the importance of pain management during this period[58].

Mozart's music has shown to be safe and effective in controlling pain during heel-lance procedures[58]. Bergomi et al. theorized that this effect may be due to the repetition of melodic lines exclusively found in Mozart's music when compared to that of other composers. The periodicity of the melody mimics physiological body functions and is, therefore, enjoyed by the brain[58]. Similar results were found in later publications, which confirmed a positive effect of music on pain management[59]. Groups listening to music or white noise scored significantly lower on pain scales than control groups. It is thought that this analgesic effect results from the release of endorphins, which antagonizes sympathetic system responses during pain[59].

As for studies onthe impact of MT interventions on pain, Costa et al. identified positive effects on PTI

undergoing retinopathy examinations[49]. Only one study failed to identify positive effects on pain scores[51].

Growth, feeding, and hospitalization time

Weight gain is a positive sign of growth, especially on PTI, and is usually associated with a shorter hospitalization. Healthy term infants are able to perform coordinated sucking, swallowing and breathing movements that allow for oral feeding with minimal repercussions on HR or respiratory outcomes. In addition, due to their organized behavioral states, feeding-related signs are more easily read by caregivers[60]. However, when it comes to PTI, neurological immaturity produces uncoordinated sucking movements and altered behavioral states, resulting in cardiorespiratory impairment. The energy expended on nutritive sucking decreases SpO_2 and consumes calories, which results in weight loss[60].

Non-nutritive sucking promotes sucking behaviors and has substantially encourages full oral feeding, reducing the length of hospital stay[61]. Based on these principles, Standley et al. developed the Pacifier Activated Lullaby (PAL), an equipment that stimulates continuous sucking behaviors by activating a selection of lullabies, making the presentation of music contingent on sucking behavior[62,63]. They verified that PAL reduced the length of gavage feeding, especially in infants > 34 weeks of gestation, when they are thought to be neurologically ready for nipple feeding[60]. This is, however, contradicted by following studies suggesting that infants prior to 30 weeks of gestation benefit most from PAL[64]. PAL also improved the subsequent nipple-feeding rates on PTI — and infants seemed to improve with practice[62]. The sucking rate was twice as high in the group using PAL, which not only confirms the hypothesis of discrimination between the on and off conditions, but also shows that infants seek this stimulus[63]. Therefore, music acts as a powerful reinforcement of non-nutritive sucking behaviors.

A pilot study found that Mozart's music meaningfully reduced resting energy expenditure[65]. Although the mechanisms involved are not entirely clear yet and resting energy expenditure is only one component of total energy expenditure, these findings might suggest that music can increase metabolic efficiency and improve weight gain[65].

Although most studies included in this category had MS approaches, MT seems to be equally effective. While the results did not reach statistical significance, maternal lullaby singing was associated with an increased tendency toward weight gain and reduced length of stay compared to the control group, which is promising[55]. Positive results were achieved with Gato-box therapy, which stimulated sucking behaviors[52]. These results are consistent with the analysis of systematic reviews and suggest that music can be an effective tool for improving sucking ability, stimulating nipple feeding, increasing weight gain, and, consequently, reducing the length of NICU stays[51,66].

Neurodevelopment and behavioral state

PTI are at an increased risk of developing structural and functional network alterations, which translates into deficits in neurological outcomes[2].

Lordier et al. used resting-state functional magnetic resonance imaging to investigate the influence of Mozart's music on a previously defined neuronal pathway of interest, thought to be affected by premature birth[2]. This circuitry of interest included the salience network, which is involved in complex brain functions such as communication and the integration of sensory, emotional, and cognitive information[67]. Compared to the control group, the music group displayed significantly higher functional connectivity in connections involving the auditory, sensorimotor and medial superior frontal networks. This suggests that listening to music during a NICU stay enhances sensory perception and improves the ability to detect and respond to salient stimuli. The researchers also found that there was an increased activity in the primary auditory cortex in infants listening to previously heard music, which corroborates the development of familiarity processing and suggests that they are already able to identify and remember auditory stimuli[2].

Recent publications are in line with these findings. Ren et al. demonstrated that PTI are not only capable of processing different musical features such as timbre, tone, and rhythm, but also that each feature stimulates different functional areas[68]. Timbre and tone activate the prefrontal cortex, which is involved in high-order cognitive functions such as working memory and planning. Rhythm, conversely, is associated with improved function in the auditory cortex, Broca's area, and premotor cortex — important areas for future processing of language and cognition. Finally, timbre alone was proven to stimulate the primary somatosensory cortex, the superior frontal gyrus, and the postcentral gyrus, suggesting that music can encourage motor behaviors. Although these changes were observed, long-term musical interventions are recommended to achieve permanent effects on cerebral functional connectivity[68].

Another study found that after three weeks of MS, participants exhibited marked improvements in their activity and displayed more limb movements[69]. To assess the infants' motor performance, the Test of Infant Motor Performance (TIMP) and Infant Neurological International Battery (INFANIB) scales were used[69]. TIMP is a standardized test that was developed to identify neuromotor disturbances and to assess the efficacy of physical and occupational therapies. Among other parameters, it evaluates the motor response during different movements and postures, as well as the infant's attention to visual and auditory stimuli. INFANIB is another tool used for the assessment of neuromotor development. It evaluates posture, extremity and axial tone, primitive reflexes, and postural reactions[69]. The infants' higher scores as well as their tendency to turn their heads toward the source of music during the intervention suggest that music exposure may improve their state of alertness and create a habituation response to this kind of stimulation, inducing them to explore their surroundings[69].

These results on neurodevelopment seem to be achieved through music, regardless of the type of intervention. A recent pilot study assessing the impact of MT on this topic also showed excellent results. 9 out of 10 infants showed improved general movement scores while being sung to by parents or while hearing MT instruments — the Ocean Disc and the Gato box — being played under the RBL principles[70].

Although there is ample evidence supporting the use of music to achieve results in neurodevelopmental outcomes, it becomes a less obvious choice when it comes to improving the infant's behavioral state. Most studies assess the infant's behavioral state using various scales. The most common one is a 6-point behavioral scale that distinguishes between "quiet sleep" (state 1), "active sleep" (state 2), "drowsiness" (state 3), "quiet alertness" (state 4), "active alertness" (state 5) and "crying" (state 6). Two meta-analyses concluded that there were no immediate or short-term positive effects on behavioral outcomes, which was confirmed by a subsequent clinical trial[50,51,71]. However, we should point out that most of the negative results came from studies in which the intervention consisted of MS. As for MT, it has been proven to be beneficial even when applied for a short period of time (~30 minutes)[46]. The infants' clinical state also seems to be a determining factor in how they respond to therapy, since PTI with severe brain injuries did not benefit from MT[57].

MS had significant impact on infants displaying inconsolable crying (a crying episode lasting longer than five minutes and continuing despite nursing interventions), which was less frequent and five times less prolonged in the intervention group[72].

Sleep

Sleep plays a key role in neurodevelopment, especially during the first year of life. Good nighttime sleep reduces the number of awakenings and, thus, the disturbances they cause[48]. Significant sleep organization occurs during the last trimester of pregnancy, when two distinct sleep states are differentiated: active sleep (AS) and quiet sleep (QS). PTI sleep is characterized by an increase in "indeterminate sleep" and "transitional sleep". These sleep periods, during which behavioral and electroencephalogram features do not entirely match the definition of AS or QS, indicate immaturity[73].

Recorded music has shown positive effects on sleep by increasing the mean duration of nighttime sleep when compared to live intervention and control groups[48]. Although it did not reach statistical significance, a trend toward more mature sleep-wake cycles was reported with MS interventions, suggesting that music might have a small effect on QS[74]. Mature sleep-wake cycles are a sign of neurological integrity, are present in healthy term infants, and are therefore considered a good prognostic sign[75].

Regarding MT interventions, there were positive effects as well. In a study comparing the effects of a default lullaby — 'Twinkle' — with those of 'songs of kin' and control groups, there was a rise in the percentage of sleep time after two weeks of therapy in the lullaby group[53]. On the contrary, the "songs of kin" revealed a significant impact on sleep patterns on infants diagnosed with sepsis[53]. Another study using the RBL principles found a statistically significant increase in overall sleep quality after two weeks of using the Ocean Disc. The group using the Ocean Disc got 95.7% AS time compared to the 71.1% AS time in the control group[52]. This is extremely relevant since REM periods generate spontaneous activity, which is vital for the organization of central nervous system circuits and somatotopic maps[76]. Animal experiments have shown that a lack of REM sleep during the early stages of neurodevelopment can lead to behavioral problems[77]. Given its importance in neuronal restitution, body temperature regulation, and energy conservation, sleep is the most important behavioral state for newborns, especially PTI,

so it is essential to ensure good quality sleep in this population[78-81].

Parent-infant bonding and maternal anxiety

The premature birth of a child can be a stressful and disturbing experience for parents[82]. The reality of an early birth, the NICU environment, and the perception that they cannot properly care for their child make parents feel helpness and guilty[83]. Reports show that mothers of PTI are more likely to develop postpartum depression and anxiety for months or years after being discharged from the NICU[28,30]. These disorders make mothers less sensitive to their child's interaction signals, thus compromising the infants' nutrition, growth, and neurodevelopment, while also hampering their connection[84-86]. Besides that, early separation from the mother affects the oxytocin system, which impacts the long-term prosocial behaviors of infants[87].

Literature is very unanimous on the use of music to prevent maternal anxiety and depression and promote parent-infant bonding. Seeing their babies respond positively - by smiling and opening their eyes while listening to music made parents feel relaxed as well[88,89]. When compared to control groups, mothers on the MT group had a lower incidence of postpartum depression and anxiety[90,91]. Parents' well-being automatically made them more available to sense and entrain their infants' breathing rhythms while experiencing the positive effects of music themselves, therefore allowing for moments of true connection and intimacy to be created[92].

By allowing mothers to relax, music increased breast milk secretion, which is the best nutrition for newborns[93,94]. Beyond its antioxidant properties, breast milk is rich in cholesterol, crucial for myelination. Breastfed PTI are at a 20% lower risk of dying than those who are not breastfed[95]. The act of breast feeding itself is also a propitious moment for mother-infant interaction — improving its efficiency enhances mother-infant bonding[93-95].

Although both MS and MT have positive effects, MT seems to have a significant advantage related to the intervention of a music therapist. Their guidance throughout all sessions gave parents a better understanding of their children by teaching them to recognize different behavioral states and signs of discomfort and how to properly interact with them by using effective soothing strategies and addressing their needs[89]. Furthermore, MT provided empathetic listening to mothers and created a safe space for parents to express themselves, while developing their intrinsic parental skills and sharing special moments with their children. Haslbeck et al. found that most parents strongly recommended music as a complementary therapy in the NICU without being asked about it[92]. Regarding its ability to create a peaceful atmosphere, many parents reported that music continued to accompany them on their daily lives and helped them soothe their baby through the hardest times[89].

However, there are no clear benefits for infants with severe brain injury. Studies involving this population have not reached statistical significance in terms of improving maternal anxiety and promoting bonding[57]. This might be related to the inherent physiological and behavioral instability of these infants and the negative impact this has on parents. Their anxiety about their children's condition makes it difficult for them to sing freely and adapt to their children and to the therapy[57]. MT interventions should be studied and modified to meet the needs of these infants.

A recent project — the LongSTEP study — evaluated long-term effects of MT on PTI and their parents at NICU and/or after discharge across a 12-month period[96]. Although MT reportedly failed on promoting parent-infant bonding in this study, it was still considered a safe and well-accepted approach[97].

On this topic, a descriptive observational study followed families of PTI and questioned parents one and six years after the first MT intervention. Most parents reported that MT made the transition home much easier and allowed them to better soothe and interact with their child. They considered it important for the PTI's development and learning throughout the years while providing a sense of comfort to the parents and the families as a whole[98].

Given the common association between all these factors and improved developmental outcomes, it is reasonable to consider MT not only beneficial for individual families, but also as an indicator of a broader commitment to high-quality neonatal care.

Music therapy versus musical stimulation

Decades of literature support the implementation of MT as a complementary therapy in NICUs due to its positive impact on all aspects of PTI development (Table 1). Although both MT and MS have shown their strengths through the many branches of development, MT consistently produced positive results and offered clear advantages in physiological parameters and parent-infant bonding. MT constitutes an individualized

Table 1. Summary of the reported main benefits of music on PTI and parents during NICU stay.

Clinical variables	Reported effects
Physiological parameters	Stabilizes HR, RR, and SpO_2
Pain management	Reduces pain during painful procedures such as heel-lance procedures and retinopathy examinations Improves overall pain control
Growth, feeding, and hospitalization time	Reduces the length of gavage feeding Stimulates sucking behaviors Improves the rate of nipple feeding Reduces resting energy expenditure Increases weight gain Reduces length of stay at NICU
Neurodevelopment and behavioral state	Enhances sensory perception Improves detection and response to salient stimuli Stimulates future cognitive functions: working memory, planning, language, and cognition Encourages motor behaviors Improves state of alertness and stimulates the exploration of surroundings Decreases both frequency and duration of inconsolable crying
Sleep	Increases the duration of nighttime sleep Increases the overall percentage of sleep time Improves sleep patterns in infants diagnosed with sepsis Increases the overall quality of sleep (increasing AS time)
Parent-infant bonding and maternal anxiety	Decreases the incidence of maternal anxiety and postpartum depression Creates moments of connection and intimacy Increases breast milk secretion Improves parental understanding of the infant's needs and stimulates parent-infant interaction Allows parents to better express themselves

AS: active sleep; HR: heart rate; NICU: neonatal intensive care unit; RR: respiratory rate; SpO_2: peripheral oxygen saturation

approach, tailored to meet each infant´s needs. This makes perfect sense in an era when we are beginning to understand that Medicine is not "one size fits all". The presence of the music therapist is a key feature[49,51,89]. Their role is to plan and guide MT sessions, adapting musical stimuli to the infants' reactions and vitals. They help parents to better understand their children's needs and how to interact with them properly[89]. MT teaches parents how to entrain the infants' physiological rhythms, thus enabling them to connect with their surroundings and to self-regulate. More than just a therapy for PTI, it certainly addresses parent's needs as well by providing empathetic support and allowing them to ease their minds during difficult times. It is, therefore, a family-centered therapy.

Recommendations for future studies and clinical practice

While most studies revealed promising results regarding the effects of music interventions on NICU infants and their parents, the heterogeneity in the quality of the studies and the methodologies used (sample of patients, type and time of intervention, outcome measures) make it difficult to establish formal recommendations in this context. However, music can be regarded as a complementary therapy — an adjunctive therapeutic modality to be incorporated into standard medical care[99] — as part of a patient-centered approach. It provides comfort and emotional support to PTI and their families. It is also low-cost[100], non-invasive, and easy to implement, as it essentially requires the presence of a trained professional and the active participation of the family during the sessions.

Although none of the included studies reported signs of overstimulation in PTI during exposure to music, future studies and clinical practice should follow recommendations on noise level limits. According to the Sociedade Portuguesa de Neonatologia, sound levels > 45 dB should be considered harmful, and transient sounds should never exceed 65 dB[101]. This way, NICU acoustic environment supports physiological stability, sleep quality, and intelligible verbal communication between parents and health care professionals[101].

Future studies should address the effects of music on different GA, birthweights, and underlying diseases, such as brain injury and its sequelae. They should also compare both MS and MT to help understand which intervention suits each situation better and to establish clinical practice guidelines, if possible.

Conclusion

The NICU stay is a challenging time for PTI and their parents. Music has proven to be an effective complementary treatment that improves physiological and neurodevelopmental outcomes while nurturing parent-infant relationships. MT consistently produced more positive results than MS with regard to physiological parameters and parent-infant bonding. Its key feature is the presence of a music therapist who adapts interventions to meet both the infants' and the parents' needs. Future studies should address how both interventions affect different GA, birthweights, and underlying diseases, to determine the best fit for each situation. Music is a valuable asset in the NICU for clinical practice. If there are obstacles to prematurity, music is certainly one way to try and overcome them.

Author contributions

D. Pinto: Conceptualization, bibliographic research, writing (original draft), and writing (review, and editing). I.N. Vicente: Conceptualization, writing (review and editing), and validation. A. Ferraz: Conceptualization, bibliographic research, validation, writing-review and editing.

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Conflicts of interest

None to declare.

Ethical considerations

Protection of humans and animals. The authors declare that no experiments involving humans or animals were conducted for this research.

Confidentiality, informed consent, and ethical approval. The study does not involve patient personal data nor require ethical approval. The SAGER guidelines do not apply.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing of this manuscript.

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