2018

The Effects of Recorded Maternal Sound on Preterm Neonates: A Systematic Literature Review

Angela Aloisantoni
University of Central Florida

THE EFFECTS OF RECORDED MATERNAL SOUND ON PRETERM NEONATES: A SYSTEMATIC LITERATURE REVIEW

by

ANGELA ALOISANTONI

A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Nursing
in the College of Nursing
and in the Burnett Honors College
at the University of Central Florida
Orlando, Florida

Spring Term, 2018

Thesis Chair: Mrs. Donna Breit, MSN, RN

ABSTRACT

A fetus hears and responds to maternal sounds as early as 26 weeks' gestation. When born prematurely, a neonate may face health challenges due to overall organ immaturity and hospitalization in the Neonatal Intensive Care Unit, where developmentally important maternal sounds are replaced with routine hospital noise. A potential intervention that can provide meaningful auditory stimulation these neonates lack is implementation of maternal sound interventions. These interventions replicate the intrauterine auditory environment by playing recorded maternal speech and heart sounds in the incubator. A literature review was completed to identify effects on neurodevelopmental, nutritional, and physiological measurements this intervention may have on premature neonates. A review of the literature was conducted using the databases CINAHL Plus with Full Text, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, MEDLINE, and PsycINFO. Search terms utilized were: *Voice*/*Sound*; *preterm*/*prematur**; *neonat**/*infant*/newborn*; and *matern**/*mother**. Results were refined using limiters of peer-reviewed, publication date of 2012-2017, and English language. Twelve articles met the criteria for review. The maternal sounds intervention was found to correlate with improved neurodevelopment in the first months of life, especially relating to auditory and language areas of the brain. Nutritional outcomes were positive, but studies were inconsistent with findings. The physiological measurements were positively affected, with strong evidence of a calming effect, and lowering of the heart rate. Results indicated recorded maternal sound interventions were associated with positive health outcomes in premature neonates. Further research with larger sample sizes and uniform study designs are needed to validate the findings.

DEDICATION

I would like to dedicate this research to all of the families that are affected by premature birth. The challenges you and your baby face are unmeasurable, but the strength and courage you show is inspiring.

This piece is also for the nurses that dedicate their profession to helping and advocating for their patients. You are the ones that make a difference in someone's life every single day you step into the hospital.

ACKNOWLEDGEMENT

I would like to thank my thesis chair, Mrs. Donna Breit for the endless help and encouragement throughout my research journey.

I would also like to thank Dr. Susan Quelly and Dr. Harriet Miller for serving on my committee and giving me wonderful guidance for my research.

To Nathanael Mercado, my amazing fiancé that went through the crazy journey called nursing school with me. You were always there when I needed support and encouragement, and I couldn't have done this without you. You will make an incredible Emergency Department nurse.

To my parents, thank you for always being there to help me get through nursing school Thank you for forgiving me for never seeing you during those tough weeks of work and clinical.

To the best friends I made in nursing school, Molly and Jade. Even though we won't be together every day once we graduate, I know that I have made friends for life.

TABLE OF CONTENTS

INTRODUCTION

While in utero, a fetus can hear and respond to maternal sounds as early as 26 weeks' gestation (McMahon, Wintermark, & Lahav, 2012). The fetus is stimulated by a constant acoustic of the mother's heartbeat, voice, breathing, borborygmi, and movements. When born prematurely, the infant may not experience the normal amount of exposure to these important sounds due to the complex health care required for survival. These infants are generally hospitalized in the Neonatal Intensive Care Unit (NICU), where the soothing sounds of their mothers are replaced with the sounds of a hospital setting.

An intervention that can provide the meaningful auditory stimulation that these preterm neonates lack is needed. A potential solution that may fill this gap is the implementation of maternal sound interventions. These interventions use sounds such as recordings of a mother's speech, singing, heartbeat, or other biological sounds and play them in the incubator to replicate the auditory environment of intrauterine life.

Recorded maternal sound interventions have been found to be implemented safely and feasibly in the NICU (Panagiotidis & Lahav, 2010). Additionally, the implementation of this intervention did not interfere with routine care for these medically fragile neonates (Zimmerman, McMahon, Doheny, Levine, & Lahav, 2012). Despite this evidence, most NICU's do not utilize this intervention, and there are no recognized guidelines or recommendations for implementing this potentially beneficial practice in the NICU setting.

BACKGROUND

Prematurity is defined as a gestational age of less than 37 weeks (March of Dimes, 2016). Prematurity is also categorized as late preterm being born between 34-36 weeks, moderately preterm at between 32 -34 weeks, very preterm at <32 weeks and extremely preterm born at or before 25 weeks' gestation (Mayo Clinic, 2014). Generally, the more premature a neonate is born, the more health challenges they face.

The reason for these health issues arise from the overall immaturity of the body systems. Preterm birth can accelerate the maturation of the respiratory, cardiovascular, gastrointestinal and renal system, but it cannot facilitate the maturation of neurodevelopment. (Graven & Browne, 2008). Part of this neurodevelopment involves auditory brain development. This auditory development is directly linked with early sensory experiences during a sensitive period of neonatal life when neural circuitry is generated (McMahon, Wintermark & Lahav, 2012). Although all components of the auditory system are formed and functioning by 20 weeks' gestation, the auditory system requires stimulation for development between 28 to 40 weeks' gestation (Graven & Browne, 2008). These early sensory stimulation experiences start in utero, while the fetus receives an array of low frequency maternal sounds delivered through the amniotic fluid via bone conduction. Once born, the auditory stimulus continues but includes more high frequency background noise and is delivered via air conduction.

The main intrauterine auditory stimulus that the fetus receives is the mother's voice. This is important because early recognition and discrimination of maternal voice is crucial for the process of attachment (Graven & Browne, 2008). Strong infant-parent attachment is important because it is a major predictor of healthy social and emotional outcomes for the child later in life

(Benoit, 2004). It is also noted that newborns prefer the sound of their mother's voice, with evidence of heart rate changes and orienting movements selectively towards the sound of their mother's voice (McMahon et al., 2012). Although the fetus responds to both the mothers' and fathers' voices, there is a displayed preference for the mother's voice after birth (Lee & Kilsilevsky, 2014). This evidence suggests that sound interventions involving maternal sounds will have the most impact on preterm neonates.

Maternal sound interventions can be implemented in a variety of ways. The sound can be delivered via playing a recording or live from the mother in person. Although there are no studies that compare live versus recorded maternal sounds in neonates, there is evidence that fetuses have a different response to live versus recorded maternal voice. Live maternal voice caused a cardiac deceleration as opposed to an acceleration for recorded maternal voice in utero (Krueger, Cave & Garvan, 2015). This research suggests the mode of delivery of the sound may affect the outcome.

Unfortunately, the mother of the preterm infant cannot always be present to provide live maternal voice stimulation. The mother may be unable to be at bedside in the NICU during the neonate's hospitalization due to herself being a patient on the postpartum unit, the need to return to work, or the responsibility of raising other children among others. This leaves the preterm infant with no or limited maternal sound exposure while hospitalized. A possible solution is the use of technology to record maternal sounds and play them in the incubators during the mother's absence. The focus of this literature review will be on recorded exposure for this reason. If the sound is recorded, it can be administered by air conduction or bone conduction. Bone conduction is the delivery of sound via vibration of the cranial bones. Administration via bone conduction more closely resembles the fetal environment, so the effects on the preterm neonate may be different (Picciolini et al., 2014).

One of the main potential outcomes that maternal sound can alter is neurodevelopment. Children with a history of prematurity have more difficulties with language development than term born children (Noort-Van der Spek, Franken, & Weisglas-Kuperus, 2012). One study found that 32%-48% of children born before 30 weeks' gestation had impaired or delayed language development (Soleimani, Zaheri & Abdi, 2014). These language difficulties are hypothesized to be caused by a lack of exposure to maternal speech while in utero and in the NICU (McMahon et al., 2012). When maternal sound interventions incorporate speech, they may possibly have the effect of mitigating the language difficulties associated with prematurity.

Another outcome that maternal sound interventions can alter is nutrition. Preterm neonates are more likely to have feeding difficulties than term born newborns, often due to immature suck-swallow-breath coordination and dysfunctional sucking skills (Dodrill, 2011). Premature infants struggle with weight and are often categorized as Low Birth Weight (LBW) at <2,500g, Very Low Birth Weight (VLBW) at <1,500g and Extremely Low Birth Weight (ELBW) at <1,000g at birth (Glass et al., 2015). Additionally, prematurity is associated with difficulty establishing a tolerance to oral feedings in the weeks following birth (Dodrill, 2011). Music therapy has shown to have a beneficial effect on feeding behaviors on premature infants (Loewy, Stewart, Dassler, Telsy, & Homel, 2013). Therefore, it is possible that maternal sound interventions can improve nutritional outcomes in preterm infants as well.

Maternal sound interventions may also improve physiological stability of preterm neonates. Physiological outcomes include heart rate, respiratory rate, oxygen saturation, temperature, skin color, and more. As stated previously, fetuses and term neonates react to maternal voice by demonstrating heart rate changes (Krueger et al., 2015; McMahon et al., 2012). In addition to heart rate, respiratory rate has also been shown to demonstrate changes with exposure to sound. Neonates instinctively use breathing sounds to develop respiratory regulation (Loewy et al., 2013). This may suggest that maternal sound interventions that utilize voice and breathing sounds may impact heart rate and respiratory rate.

SIGNIFICANCE

It is estimated that 15 million babies are born prematurely each year, and that prematurity is the number one cause of death in children less than five years old (World Health Organization, 2016). A majority of these preterm births occur in under developed countries that have limited prenatal care, but developed countries are affected as well. In 2016 the United States had a preterm birth rate of 9.6% per live births (March of Dimes, 2016). The United States is also included in the top 10 list of countries worldwide with highest number of preterm births at 517,400 (World Health Organization, 2016).

This is important because premature birth can cause many health challenges for the neonate. Out of the neonates who survive, many face breathing problems, developmental delay, feeding difficulties, vision problems, hearing impairment, and cerebral palsy, as well as lifelong emotional and financial difficulties for the families (Centers for Disease Control and Prevention, 2016). Considering the prevalence and negative effects of prematurity, interventions that can improve outcomes and lessen the harsh transition to extrauterine life should be investigated. Maternal sounds are a low cost, easily accessible intervention that may benefit premature neonates.

Another reason for the significance of this topic is the increased awareness of the effects of sound on preterm infants in the NICU. There is a plethora of research involving noise levels in the NICU, mostly concerning noise levels that are too high. Loud NICU environments can cause preterm infants to have potentially dangerous fluctuations in heart rate, respirations, and blood pressure, as well as put the neonates at an increased risk for abnormal brain development, speech and language issues, and hearing loss (Brown, 2009). This has led many NICU's to implement noise reducing interventions. One such intervention is the switch from multi-bed shared rooms to single patient rooms.

Although there are benefits to single patient NICU rooms, one potential pitfall to this design is sensorial deprivation. While being secluded the neonate may miss out on important sensorial experiences, which are necessary for auditory brain development. Neonates hospitalized in single room NICU's were found to have decreased brain maturation and lower language and motor skills at 2 years of age (Pineda et al., 2014). This is important because utilization of recorded maternal sound interventions played in incubators may mitigate the sensorial deprivation of single bed NICU's.

PURPOSE

The purpose of this literature review is to analyze the associations between exposure to recorded maternal sounds in premature neonates and health outcomes. An analysis on these findings will guide a decision as to the efficacy of this intervention. Determining the different types of recorded maternal sound exposure associated with various health outcomes in premature newborns will guide recommendations for future practice and research.

METHODS

A thorough review of the literature was conducted using the databases CINAHL Plus with Full Text, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, MEDLINE, and PsycINFO. The search terms utilized were *Voice* OR *Sound* and *Preterm* OR *prematur** and *neonat** OR *infant* OR *newborn* and *matern** OR *mother**. Results were refined with the limiters of scholarly (peer reviewed) journals, publication date of 2012 to 2017, and English language.

Articles were only included if they specifically addressed the patient population of premature neonates hospitalized in the NICU. Additionally, articles were included if they measured the effects of the intervention of recorded maternal sounds on physiological, nutritional, or developmental parameters. Studies were excluded if they utilized other interventions in combination with maternal sound exposure, or if they used non-maternal sounds. Additionally, studies were excluded if they exclusively measured the effects on the mother and not the neonate.

RESULTS

Thorough examination of selected databases revealed eighteen potentially relevant studies, in which twelve articles met all inclusion and exclusion criteria and were included in this review. Articles examined found numerous positive effects associated with exposure to recorded maternal sounds in hospitalized preterm neonates. Additionally, all studies reviewed found no negative outcomes associated with this intervention.

Outcomes affected by this intervention were categorized into three domains that include neurodevelopmental effects, nutritional effects, and physiological effects. Three articles were found to analyze neurodevelopmental effects, five articles analyzed nutritional effects and five articles analyzed physiological effects. Studies that measured several effects may have overlapped domains and were included in both sections.

Delivery of the sound intervention varied between each study. The studies reviewed reported sound levels in decibels (dB), with increasing dB meaning increase in volume. The American Academy of Pediatrics recommends noise levels greater than 45 dB be avoided in the NICU setting to offset negative effects of noise exposure in the preterm neonate (1997). However, not a single study included in this review followed these recommendations. The average normal conversation is 60 dB, and this is the sound level that was utilized for most studies. The loudest study used a volume of up to 75 dB (Nöcker-Ribaupierre et al., 2015), while the study that came closest to the American Academy of Pediatrics recommendations used a sound level of <50 dB (Sajjadian et al., 2017). Two articles did not specify the sound level at which the intervention was delivered (Chorna et al., 2014; Zimmerman et al., 2012).

All studies used maternal sounds, but the exact sound content varied per study. Five out of the twelve studies used maternal speech alone, including the variations of singing, humming, and talking (Butler et al., 2014; Chorna et al., 2014; Piccolini et al., 2014; Nocker-Ribaupierre et al., 2015; Sajjadian et al., 2017). The remaining six studies used a combination of maternal speech and heart beat played simultaneously as the neonate would hear while intrauterine (Gomes Da Silva et al., 2017; Doheny et al., 2012; Hamm et al., 2015; Rand & Lahav, 2014; Webb et al., 2015; Zimmerman et al., 2013; Zimmerman et al., 2012). Four studies attenuated the sounds using a low pass filter with a cutoff of 400hz; which indicates that the sound was muffled and turned lower frequency to mimic the womb like acoustic experience (Doheny et al., 2012; Rand & Lahav, 2014; Webb et al., 2015; Zimmerman et al., 2013). Eleven studies used air conduction to deliver the sound, while one study used bone conduction; which was the first study of its kind to analyze this method of exposure.

Neurodevelopmental Effects

Prematurity is a well-known risk factor for acquiring neurodevelopmental impairments. It has been shown decreased gestational age increases the probability and severity of cognitive, language, sensory, learning, visual-perceptual, and attention deficits (Allen, 2008). Three studies investigated maternal sounds as a possible developmental care intervention. As defined by Picciolini (2014), developmental care interventions are any intervention utilized to improve neurodevelopmental outcomes. Each of these studies measured the neurodevelopmental effects associated with maternal sound interventions, focusing on auditory and language development.

One study (n=71) using bone conduction found that auditory orientation in the intervention group was better than that of the control group (p=.01). This same study also found that the intervention group had significantly better general movements and visual orientation at age adjusted term than the control group (Picciolini et al., 2014). This study also found a significantly better Neurofunctional Assessment (NFA) score in the intervention group at three months corrected age when compared to the control group (p=<.01); however, the NFA showed no significant difference at six months corrected age.

In a second study (n=24) neonates in the experimental group were found to have significantly earlier achievement of two-word sentences than the control group (p=.008) (Nocker-Ribaupierre et al., 2015). This same study also found that developmental tests (Griffith's Developmental Quotient) done at post-term age of five months were significantly (p=.007) better in the intervention group than the control group; however, there were no differences in developmental test scores between the two groups at twenty months and 4 years eight months. This study also found that at six years of age the children in the intervention group had significantly (p=<.05) better speech understanding than those in the in the control group (Nocker-Ribaupierre et al., 2015).

The final study examining neurodevelopmental effects found that neonates exposed to maternal voice interventions had larger auditory cortexes bilaterally on cranial ultrasounds when compared to the control group (Webb et al., 2015). These results provide evidence that the auditory regions of the brain have experience dependent plasticity before reaching term, and the auditory regions are more responsive to maternal sounds than to routine NICU noise (Webb et al., 2015). This means that brain development in premature neonates is dependent on maternal sound exposure.

Several themes were uncovered during analysis of these articles. Piccolini et al. (2014) speculated that early achievement of adequate neurobehavioral skills and autonomic maturation may result in improved performance in other neurodevelopmental domains at later ages. This theory is supported by the finding of Nocker-Ribaupierre et al. (2015) that at six years old there was better speech understanding in the intervention group than the control group. The findings of Webb et al. (2015) also support the results of the other studies on improved language development, with increased auditory brain plasticity possibly being the cause of all language related effects of maternal voice interventions.

Nutritional Effects

Nutritional parameters in premature neonates are often compromised due to immaturity of the suck swallow breath reflex and illnesses that impair the ability to feed (Medline Plus, 2017). This being an important measurement in neonatal outcomes, several studies in this review analyzed the effects that maternal sound have on nutrition in premature neonates. Results were categorized by topic including sucking, feeding, and weight gain.

Sucking

Several studies analyzed characteristics of sucking as an outcome associated with exposure to recorded maternal sounds. One study (n=24) that used a yoked control design found that exposure to maternal voice did not cause any change in the rate of sucking on a pacifier attached to a transducer (Butler et al., 2014). However, this same study found that rate of sucking differed between exposure to highly modulated maternal speech versus maternal speech with low modulation. Speech modulation is determined by fluctuations in pitch frequency, with highly modulated speech taking on an infant-directed speech quality, versus low modulation which sounds flat and has adult-directed speech qualities. Neonates exposed to speech that was highly modulated had a significantly (p=.03) greater rate of sucking than neonates exposed to maternal speech with low modulation (Butler et al., 2014). Another study (n=94) used a pacifier that utilized positive reinforcement to deliver maternal voice when a suck was detected (Chorna et al., 2013). This study found that the intervention group had an increase in suck pressure of 15 mmHg between the first and fifth day of exposure (Chorna et al., 2014). However, in the study by Piccolini et al. (2014) it was found there were no changes in the time until spontaneous suckling associated with maternal sound interventions was observed.

Feeding

The study (n=94) by Chorna et al. (2014) found that infants in the intervention group had an increased oral feeding rate, volume of oral intake during twenty-four hours after the intervention, and number of oral feeding per day. This study also found that the intervention group achieved full oral feedings seven days earlier than the control (Chorna et al., 2014). This study raised concerns over the nature of the positive reinforcement design possibly causing later feeding related issues attributed to infants not feeding unless they heard their mother's voices. However, this was contradicted by the follow up study (n=72) that found no increase in feeding related diagnoses or delay in the development of feeding milestones in the first year of life after the study (Hamm et al., 2015). A study (n=32) by Zimmerman et al. (2013) used attenuated recordings of biological maternal sounds to test nutritional outcomes on very low-birth-weight neonates. The study found no difference in days spent nothing by mouth, days until full enteral feeds, total fluid intake or total caloric intake (Zimmerman, et al., 2013). The study by Picciolini et al., (2014) found no change in the time it took to achieve independent feeding.

Weight Gain

The study (n=32) by Zimmerman et al. (2013) found neonates in the intervention group had significantly ($p<0.001$) increased weight gain velocity when compared to controls. Another study (n=40) found increased daily weight gain in neonates exposed to recorded maternal speech and heartbeat (Zimmerman et al., 2012). Two studies did not find any weight gain changes between the intervention and control groups (Picciolini et al, 2014; Nocker-Ribaupierre et al., 2015).

Overall, the nutritional effects of maternal sound interventions were not consistent. Suckling may be increased from infant-directed maternal speech, and pacifiers that deliver maternal sound may teach infants to suck stronger. Feeding results were mixed and should not be considered until more evidence can establish associations. Weight gain results were not consistent and need further investigation.

Physiological Effects

Premature neonates suffer from physiological immaturity of the autonomic nervous system, which can lead to dangerous fluctuations in heart rate and oxygen saturation (Doheny et al., 2012). These cardiorespiratory parameters are affected not only by gestational age and gender, but also by the influence of environmental factors (Gomes Da Silva Leopoldo Portugal et al., 2017).   Studies using maternal sounds change the acoustic environment of the NICU to possibly improve the physiological stability of the preterm infant. Results were divided into cardiac, respiratory and overall physiological stability.

Cardiac

Several studies measured the effect of maternal sounds on heart rate. One study (n=71) using sound delivered via bone conduction found a significantly ($p<.01$) lower heart rate in the intervention group (Picciolini et al., 2014). Another study (n=18) found neonates that received maternal sound interventions had more stable heart rates (p=.000) and lower heart rates after the first week of the intervention period (Gomes Da Silva Leopoldo Portugal et al., 2017). Rand & Lahav (2014) found significantly (p<.0001) lower heart rate during the exposure period compared to matched periods of care without exposure on the same day, including neonates receiving respiratory support and caffeine therapy. Another study (n=35) analyzing heart rate found that the heart rate decreased during and after the intervention when compared to the rate before the intervention (Sajjadian et al., 2017).

Respiratory

Maternal sound interventions were found to have positive effects on the respiratory system. Two studies found increased oxygen saturation in the intervention group when compared to the control (Gomes Da Silva Leopoldo Portugal et al., 2017; Sajjadian et al., 2017). However, Picciolini et al. (2014) found no difference in oxygen saturation between the intervention and control group. This could be due to the fact that Picciolini et al. (2014) used bone conduction rather than air conduction used in the two previous noted studies. The study (n=28) by Zimmerman, et al. (2012) found that neonates in the intervention group were able to breath room air much sooner than in the control group. Another study (n=18) found that neonates had an increased respiratory rate during the intervention (Gomes Da Silva Leopoldo Portugal et al., 2017). These results differed from Sajjadian, et al. (2017) in which the findings were decreased respiratory rate during the intervention.

Overall Physiological Stability

Premature neonates frequently suffer from cardiorespiratory events (CRE's), which are episodes of apnea or bradycardia (Doheny et al., 2012). One study found that neonates greater than or equal to thirty-three weeks post-conceptual age have significantly (p=.03) less episodes of CRE's during maternal sound exposure (Doheny et al., 2012). Picciolini et al. (2014) found neonates in the intervention group had more stable skin color with less mottling during the exposure than the control group.

Maternal sound interventions appear to have an influence on the physiological parameters of premature infants. One theory behind this evidence is that maternal sounds stimulate the infant, which can increase the capacity for self-regulation and allow for less critical events and hypoxia (Picciolini et al., 2014). There is very strong evidence to prove that the intervention can lower the neonates heart rate. There were mixed results regarding oxygen saturation and respiratory rate, so caution in drawing conclusions from these parameters is needed. Although Picciolini, et al. (2014) found no difference in oxygen saturation, the study did find more stable skin color which can be an indication of better oxygenation. Overall, physiological stability appears to be improved with this intervention.

DISCUSSION

Summary of Evidence

Recorded maternal sound interventions were found to positively impact health outcomes in preterm infants. Domains analyzed were neurodevelopmental effects, nutritional effects, and physiological effects. All areas found beneficial outcomes for the neonates, but certain aspects had stronger evidence than others. Neurodevelopment appeared to be improved as measured by developmental tests, with especially strong evidence for enhanced development of speech and language areas of the brain. Developmental tests were increased throughout the first few months of life before becoming the same as the control group at later ages, but increased language skills appeared to carry on into childhood. Nutritional outcomes had inconsistent findings, and no concrete conclusions can be drawn from the current evidence. Maternal sound interventions had positive physiological effects on preterm infants. There is very strong evidence that the intervention demonstrates a soothing effect that lowers the heart rate, and evidence that it can increase the oxygen saturation and lead to less episodes of apnea and bradycardia during exposure time.

This evidence is of high relevance to registered nurses, as the implementation of recorded maternal sound interventions is strongly influenced by nursing care. In the studies reviewed, nurses were responsible for scheduling care around the intervention, starting and stopping the recording, and monitoring the neonates during exposure. Nurses have the opportunity to contribute to the reduction of harmful routine NICU noise, and advocate for its replacement with soothing maternal sounds. These results are also relevant to policy makers, such as the American Academy of Pediatrics (AAP). AAP has set guidelines for reducing noise levels in the

NICU but has not proposed a replacement for the decreased auditory stimulation. Using the results found through review of the evidence, future policy on the systematic implementation of maternal sound interventions can be created. This evidence is also of importance to the parents caring for their infant hospitalized in the NICU due to this intervention being family centered and considered beneficial for both mother and infant. It is known that mothers that participate in parental interventions in the NICU have reduced stress levels (Matricardi et al., 2012). Including the mother in this intervention that helps her baby will facilitate feelings that she is participating in the care of her baby even when she can't be there in person.

Limitations

Limitations found in the articles reviewed included small sample sizes, and the exclusion of the sickest infants who could have potentially benefited from this intervention. Most studies excluded infants that suffered from significant brain damage such as intraventricular hemorrhage and neonatal asphyxia, major chromosomal abnormalities, and congenital infections. Limitations that are inherent to systematic reviews such as incomplete retrieval of identified research and the possibility of bias in reporting of results must always be considered.

Conclusions

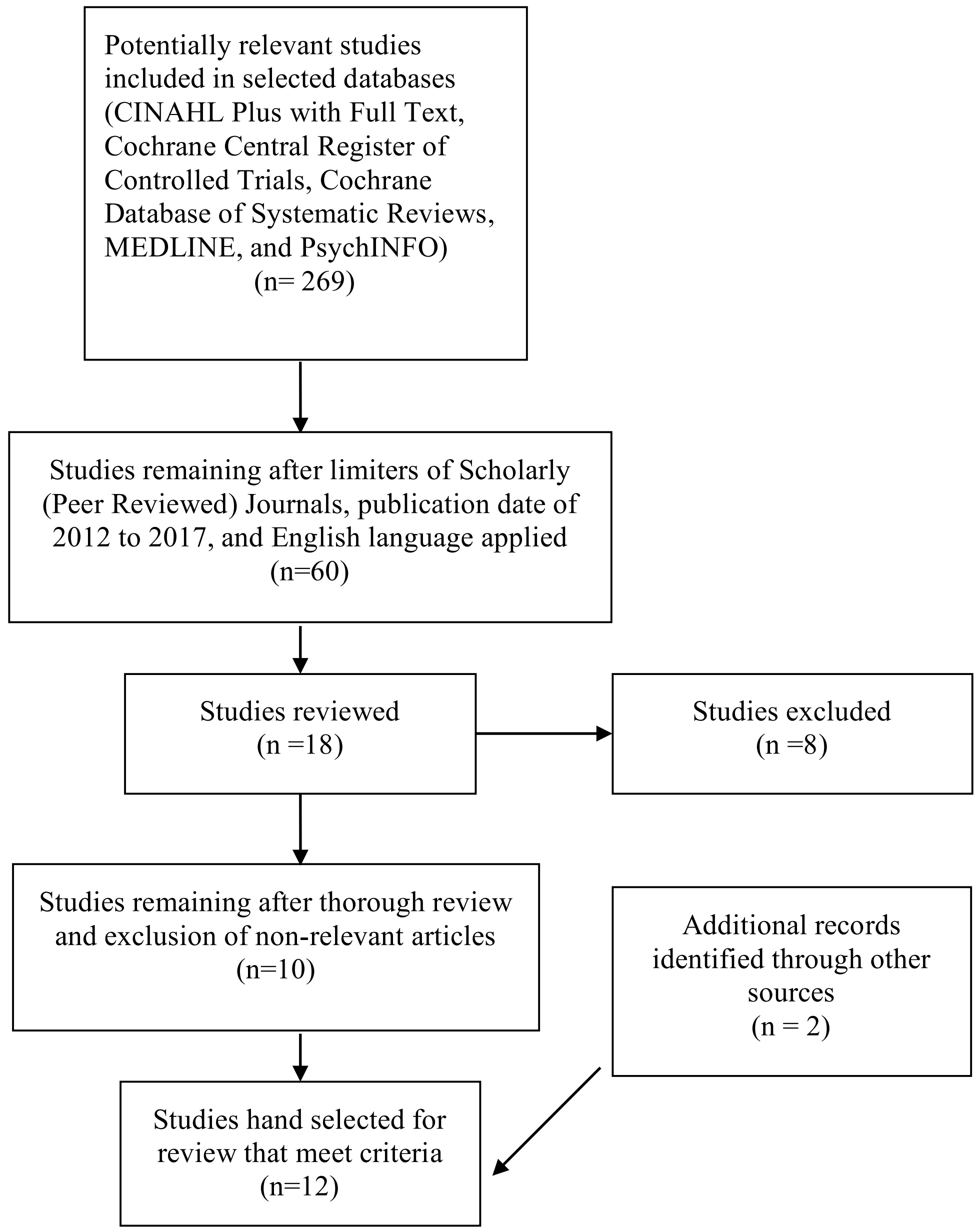
The use of recorded maternal sound interventions for premature infants hospitalized in the NICU are associated with positive health outcomes related to neurodevelopment, and physiological stability. Although numerous benefits and zero adverse effects have been reported in the results of these studies, more research is needed to further define the extent of these benefits. The recommendation of future research with larger sample sizes is warranted due to the high number of studies with small sample sizes. Studies reviewed had large variations in sound levels, sound duration, and content of sound. Since all studies reported positive findings, it is difficult to speculate which exposure paradigm was most beneficial. Future research that includes study designs comparing the same health effects using different exposure types may lead to a recommendation for implementation guidelines. The use of bone conduction for sound delivery was seen in only one study, which was the first of its kind. Additional studies delivering maternal sounds via bone conduction are needed to fully understand the benefits of this type of delivery.

It is important to note that this intervention does not replace maternal presence at the bedside. Mother's should always be encouraged to be present with their infants as much as possible. Maternal sounds should not be played while the mother is visiting her baby, as to not replace her. When the mother is at the bedside, it is appropriate for the nurse to encourage her to speak to or sing to her baby as live maternal sounds have also been demonstrated to be beneficial for preterm infants (Fillipa, Devouche, Arioni, Imberty, & Gratier, 2013). Mothers may also be encouraged to utilize live maternal voice during kangaroo care, which has also been demonstrated to be beneficial (Arnon et al., 2014).

Funding

No funding was provided to support the making of this review of the literature.

APPENDIX: CONSORT DIAGRAM


Potentially relevant studies included in selected databases (CINAHL Plus with Full Text, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, MEDLINE, and PsychINFO) (n= 269)
Studies remaining after limiters of Scholarly (Peer Reviewed) Journals, publication date of 2012 to 2017, and English language applied (n=60)
Studies reviewed (n =18)
Studies excluded (n =8)
Studies remaining after thorough review and exclusion of non-relevant articles (n=10)
Additional records identified through other sources (n = 2)
Studies hand selected for review that meet criteria (n=12)

APPENDIX: TABLE OF EVIDENCE

Authors(s) and Year	Study Design	Purpose	Sample Size and Demographics	Method of Exposure	Key Findings and Limitations
Butler, S. C., et al. (2014)	Randomized controlled design study	Tested if infants will suck to hear their mother’s voice. Used a pacifier attached with a pressure transducer to measure sucking. Each suck was rewarded with the mother’s voice; goal of reaching high amplitude sucking.	Sample size (n=24), with an average gestational age of 35 weeks. Experimental Group (n=12) Yoked Control Group (n=12)	Recorded maternal voice with Infant Directed Speech (IDS) and Adult Directed Speech (ADS). Maternal voice played from speakers placed 7cm from each side of infant’s head at 5 dB above background noise, < 60 dB. Exposure occurred two times per day in five-minute sessions for 5 consecutive days.	Researchers found that premature infants respond to maternal voice with increased-nutritive sucking and high amplitude sucking. IDS has a strong effect on sucking, compared to ADS which had little effect. Limitations: possible confounding factor between prematurity and exposer to maternal speech, and the possibility of a non-optimal conditioning paradigm.

Authors(s) and Year	Study Design	Purpose	Sample Size and Demographics	Method of Exposure	Key Findings and Limitations
Chorna, O. D., et al. (2014)	Randomized parallel group trial design	Tested if premature infants using a Pacifier Activated Music Player (PAM) during non-nutritive sucking would improve sucking and lead to increased oral feeding.	Sample Size (n=94), postmenstrual age 34 to 35 and 6/7 weeks, including those with brain injury. Experimental Group (n=49) Control Group (n=51)	Recorded maternal singing delivered via a 510k FDA approved speaker system that was initiated when suck detected. There was an exposure time of 15 minutes each day for 5 consecutive days. Speakers were placed 6 inches above the neonates' head at midline.	Exposure to maternal voice via PAM caused a significant improvement in oral feeding rate, increased volume of oral intake within 24 hours after intervention, increased number of oral feeds per day, increased suck pressure, oral feeds 7 days sooner, salivary cortisol levels did not rise indicating the intervention was not stressful, and a 20% decreased length of stay (not significant). Limitations: absence of a third group treated with PAM using a non-maternal female voice; the suck threshold that activated the PAM was kept the same for all neonates which may not have fit all infant's needs; all maternal recordings were in English vs. preferred in mother's native language.

Authors(s) and Year	Study Design	Purpose	Sample Size and Demographics	Method of Exposure	Key Findings and Limitations
Doheny, L., et al. (2012)	Within-subject design paradigm study	Tested if systematic exposure to maternal sounds could reduce the number of Cardio-Respiratory Events (CRE) in NICU neonates.	Sample Size (n=14) neonates from 26-32 weeks' gestation. Neonates served as their own controls.	Maternal voice and heartbeat were recorded; played via a micro audio system in each incubator. Maternal sound played for 30 minutes, 4x/24hour and compared to routine hospital sound. Sounds attenuated using a low pass filter with a cutoff of 400hz. Sounds delivered at 55-60 dB.	During maternal sound stimulation, there were a decreased number of CRE's, which was significant in infants > or equal to 33 weeks' gestation. This suggests a therapeutic window in which maternal sounds may be most beneficial. Limitations: small sample size; errors in documentation of CRE's.
Gomes Da Silva Leopoldo Portugal, C. M. G., et al. (2017)	Experimental randomized controlled trial	Tested if playing recorded maternal sounds to hospitalized preterm neonates would influence changes in heart rate, respiratory rate, and oxygen saturation when compared to exposure to standard NICU noise over 7-week period.	Sample Size (n=18). Experimental Group (n=9) with an average GA of 28.7 weeks Control Group (n=9) with an average GA of 29.4 weeks.	Recorded maternal heart beat & voice were used to create a 45-minute audio track. Track delivered via 2 speakers positioned outside the incubator at a sound level of 60-65 dB. Exposure 4x/day when neonate was placed inside isolette after being fed. Vital signs 45 minutes before, during, and 45 minutes after intervention.	The experimental group of neonates was found to have a decreased heart rate, increased respiratory rate and increased oxygen saturation when compared to the control group. Limitations: small sample size; errors in medical documentation.

Authors(s) and Year	Study Design	Purpose	Sample Size and Demographics	Method of Exposure	Key Findings and Limitations
Hamm, E. L., et al. (2015)	Follow-up study	Evaluated the long term nutritional effects of pacifier activated music player. Previous participant's care givers were sent surveys on feeding skills & medical charts were reviewed.	Sample Size (n=72) infants, mean corrected age=17 months @ time of survey Experimental group (n=35). Control group (n=37).	Exposure occurred during the original study by Chorna, O. D., et al. (2014). Exposure details listed above with the original study.	This study indicates that after use of the PAM in the NICU does not slow the developmental progression of feeding skills during the first year. It also suggests that short term PAM use may decrease aspiration events, and decrease hospitalizations related to nutritional diagnoses in the long term. Limitations: possible recall bias; incomplete medical record documentation.
Nöcker-Ribaupierre, M., et al. (2015)	Regional perspective long-term follow-up study	Tested if auditory stimulation of preterm infants with mother's recorded voice would affect language skills and overall development. After exposure developmental tests at 5, 20, 56 months, and 6 years	Sample Size (n=48) of 24-30-week gestation neonates. Experimental group (n=24). Control group (n=24)	Recorded maternal voice, singing and humming was recorded and played via a small loudspeaker placed 20cm from the neonate's ear at 65 to 75 dB. Exposure occurred 5x/day at 30-minute increments.	Researchers found that infants that were exposed to recorded maternal sounds had significantly higher scores on Griffiths Developmental Quotient at 5 months of age, began using 2-word sentences earlier, and had significantly increased speech understanding scores at 6 years old. Limitations: small sample size; Developmental effects cannot certainly be attributed to auditory stimulation as experience driven auditory plasticity as they may be an effect related to the positive maternal effects which increased maternal bond to neonate.

Authors(s) and Year	Study Design	Purpose	Sample Size and Demographics	Method of Exposure	Key Findings and Limitations
Picciolini, O., et al. (2014)	Prospective, longitudinal, explorative, case control study	Maternal voice delivered via bone conduction; assessed for vital signs, and neurobehavioral parameters before, during and after the intervention. Neurofunctional assessments @ 3 and 6 months corrected age.	Sample Size (n=71) Experimental Group (n=34) with a mean GA of 28.8. Control Group (n=37) with a mean GA of 29.6.	Exposure to maternal voice via bone conduction by transducer that delivered vibrations to the wrist. Intervention initiated@ GA 30-32 weeks. The intervention delivered at 48 dB every 8 hours/day x 21 days.	Neonates in the experimental group had lower heart rates and more stable skin color. At term the experimental group had better visual attention and quality of general movements. Neurofunctional assessment scores at 3 months higher in those that received the intervention. No differences in weight gain, feeding, length of stay, oxygen saturation, or neurofunctional assessment scores @ 6 months Limitations: lack of evaluation of parental satisfaction with intervention
Rand, K. and A. Lahav (2014)	Experimental study	Tested if playing recorded maternal sounds would have an effect on neonatal heart rate. Heart rate monitored during gavage feedings with & without maternal sound intervention	Sample Size (n=20) neonates with a GA of 25-32 weeks. Participants served as their own controls.	Maternal voice and heartbeat sounds recorded; attenuated utilizing a low pass filter with a cutoff of 400 Hz. Recordings played via micro audio speakers < 65 dB¸. Exposure occurred 4x/day in 30-minute increments during gavage feedings throughout the first month of life.	Neonates had a significantly lower heart rate during exposure to maternal sound recordings. This positive effect was seen in all neonates in the study, including both those on room air and respiratory support, as well as in neonates receiving caffeine therapy. Limitations: small sample size; evaluation of only one physiological parameter.

Authors(s) and Year	Study Design	Purpose	Sample Size and Demographics	Method of Exposure	Key Findings and Limitations
Sajjadian, N., et al. (2017)	Experimental study	Investigated the effect of short bursts of recorded maternal sound on physiological reactions (oxygen saturation, heart rate and respiratory rate). Vital signs monitored 5 minutes before, 5 minutes during, and 5 minutes after exposure	Sample Size (n=20) with a mean GA of 31 weeks. Participants served as their own controls.	Maternal voice was recorded and played via speakers at a sound level < 50 dB. Exposure occurred at the bedside 5 minutes 3x/day, x3days	Neonates were found to have an increased oxygen during the intervention: continued 5 minutes post-intervention. Heart rate & respiratory rate decreased during the intervention which persisted during post-intervention period. Limitations: small sample size; short duration of study at three days.
Webb, A. R., et al. (2015)	Randomized controlled trial	Exposed preterm infants to recorded maternal sounds Cranial ultrasound results were compared to the control group to test how the intervention changed brain structure development.	Sample Size (n=40) extremely premature neonates with a GA of 25-32 weeks. Experimental Group (n=21) Control Group (n=19)	Maternal voice and heartbeat were recorded individually for each neonate. Recorded voice of speaking, reading and singing; attenuated using a low pass filter with a cutoff of 400 Hz. Sounds were played via a micro audio system installed in the incubator with a cutoff of <65 dB. Exposure occurred four times per day at 45-minute intervals.	Neonates in the experimental group were found to have significantly larger auditory cortex bilaterally on cranial ultrasounds. All other brain structures showed no changes. This study validates that experience dependent auditory plasticity occurs before neonates reach full gestation; auditory cortex is more adaptive to maternal sound exposure than to environmental NICU noise. Limitations: lack of evaluation of long term developmental effects in relation to auditory cortex functioning.

Authors(s) and Year	Study Design	Purpose	Sample Size and Demographics	Method of Exposure	Key Findings and Limitations
Zimmerman, E., et al. (2013)	Exploratory study with a matched-control design	Tested if exposure to recorded biological maternal sounds in neonates had an effect on weight gain velocity, days spent NPO, days to full enteral feeds, fluid intake, calories.	Sample Size (n=32) very low birth weight premature neonates. Experimental Group (n=16) with a mean GA of 28.8 weeks. Control Group (n=160) with a mean GA of 28.9 weeks.	Maternal vocalizations (talking, singing, reading) and heart beat were recorded and attenuated using a low pass filter with a cutoff of 400 Hz. Sounds were delivered via audio system installed in the incubator at a volume of <65 dB. Exposure occurred 4x/day @ 45-minute increments.	Neonates in the experimental ground were found to have gained significantly more weight in the neonatal period; significantly increased growth velocity Limitations: small sample size and lack of investigation into the interventions' effects on weight gain past neonatal period
Zimmerman, E. Z., et al. (2012)	Study 1 used a matched case-control design Study 2 was a pilot randomized control trial	Used recorded maternal voice in preterm neonates were reported. Study 1: tested for changes in daily weight gain in infants exposed to the intervention and compared it to historical controls. Study 2: tested if neonates exposed to the intervention were able to breath room air sooner than the control group.	Sample Size (n=68) premature neonates <32 weeks GA. Study 1 Sample Size (n=40). Study 2 Sample Size (n=28)	Maternal vocalizations and heart beat were individually recorded Recordings played via micro audio system installed in incubator. Exposure occurred 4x/day for the first 28 days.	Study 1 found that neonates that received the intervention had improved daily weight gain when compared to historical controls. Study 2 found that neonates in the experimental group on room air more quickly than neonates in the control group. Limitations: not reporting sound level of intervention; lack of investigation into the long term respiratory and nutritional effects.

GA= gestational age

REFERENCES

Allen, M. C. (2008). Neurodevelopmental outcomes of preterm infants. *Current Opinion in Neurology*, *21*(2), 123-128. doi:10.1097/WCO.0b013e3282f88bb4

American Academy of Pediatrics. (1997). Noise: a hazard for the fetus and newborn. *Pediatrics*, *100*(4), 724-726. doi: 10.1542/peds.100.4.724

Arnon, S., Diamant, C., Bauer, S., Regev, R., Sirota, G., & Litmanovitz, I. (2014). Maternal singing during kangaroo care led to autonomic stability in preterm infants and reduced maternal anxiety. *Acta Paediatrica*, *103*(10), 1039-1044. doi:10.1111/apa.12744

Benoit, D. (2004). Infant-parent attachment: Definition, types, antecedents, measurement and outcome. *Paediatrics & Child Health*, *9*(8), 541–545.

Brown, G. (2009). NICU Noise and the Preterm Infant. *Neonatal Network: NN*, *28*(3), 165-173.

Butler, S., O'Sullivan, L., Shah, B., & Berthier, N. (2014). Preference for infant-directed speech in preterm infants. *Infant Behavior And Development*, *37*505-511. doi:10.1016/j.infbeh.2014.06.007

Centers for Disease Control and Prevention. (November 2016). Preterm Birth. Retrieved from https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pretermbirth.htm

Chorna, O., Slaughter, J., Wang, L., Stark, A., & Maitre, N. (2014). A pacifier-activated music player with mother's voice improves oral feeding in preterm infants. *Pediatrics*, *2014133*(3), 462-468.

Dodrill, P. (2011). Feeding Difficulties in Preterm Infants. *ICAN: Infant, Child & Adolescent Nutrition*, *3*(6), 324. doi:10.1177/1941406411421003

Doheny, L., Hurwitz, S., Insoft, R., Ringer, S., & Lahav, A. (2012). Exposure to biological maternal sounds improves cardiorespiratory regulation in extremely preterm infants. *Journal Of Maternal-Fetal & Neonatal Medicine*, *201225*(9), 1591-1594.

Filippa, M., Devouche, E., Arioni, C., Imberty, M., & Gratier, M. (2013). Live maternal speech and singing have beneficial effects on hospitalized preterm infants. *Acta Paediatrica*, (10), 1017.

Glass, H. C., Costarino, A. T., Stayer, S. A., Brett, C., Cladis, F., & Davis, P. J. (2015). Outcomes for Extremely Premature Infants. *Anesthesia and Analgesia*, *120*(6), 1337–1351. http://doi.org/10.1213/ANE.0000000000000705

Gomes Da Silva Leopoldo Portugal, C. G., De Sá, L. O., & Guimarães Pereira Areias, M. F. (2017). Cardiorespiratory effects of maternal sounds in infants bom between 26 and 33 weeks of gestation. *Revista De Enfermagem Referência*, *4*(12), 55-63. doi:10.12707/RIV16075

Graven, S.N., Browne, J., (2008). Sensory Development in the Fetus, *Neonate and Infant: Introduction and Overview. Newborn & Infant Nursing Reviews, 8*(4). 170-172. doi: 10.1053/j.nainr.2008.10.007

Hamm, E. L., Chorna, O. D., Stark, A. R., & Maitre, N. L. (2015). Feeding outcomes and parent perceptions after the pacifier-activated music player with mother's voice trial. *Acta Paediatrica*, *104*(8), e372-e374. doi:10.1111/apa.13030

Krueger, C., Cave, E., & Garvan, C. (2015). Fetal Response to Live and Recorded Maternal Speech. *Biological Research For Nursing*, *17*(1), 112-120

Lee, G., & Kisilevsky, B. (2014). Fetuses Respond to Father's Voice But Prefer Mother's Voice after Birth. *Developmental Psychobiology*, *56*(1), 1-11.

Loewy, J., Stewart, K., Dassler, A., Telsey, A., & Homel, P. (2013). The effects of music therapy on vital signs, feeding, and sleep in premature infants. *Pediatrics*, *131*(5), 902-918.

March of Dimes. (2016). 2016 Premature Birth Report Card. Retrieved from http://www.marchofdimes.org/materials/premature-birth-report-card-united-states.pdf

Matricardi, S., Agostino, R., Fedeli, C., & Montirosso, R. (2013). Mothers are not fathers: Differences between parents in the reduction of stress levels after a parental intervention in a NICU. Acta Paediatrica, 102(1), 8-14. doi:10.1111/apa.12058

Mayo Clinic Staff. (2014, November). Premature Birth. Retrieved from http://www.mayoclinic.org/diseases-conditions/premature-birth/basics/definition/con-20020050

McMahon, E., Wintermark, P., & Lahav, A. (2012). Auditory brain development in premature infants: the importance of early experience. *Neurosciences and Music Iv: Learning and Memory*, *1252,* 17-24. doi: 10.1111/j.1749-6632.2012.06445.x

Medline Plus. (2017, April 4). Neonatal Weight Gain and Nutrition. Retrieved from https://medlineplus.gov/ency/article/007302.htm

Nöcker-Ribaupierre, M., Linderkamp, O., & Riegel, K. P. (2015). The effects of mothers' voice on the long term development of premature infants: A prospective randomized study. *Music And Medicine: An Interdisciplinary Journal*, *7*(3), 20-25.

Noort-van der Spek, I., Franken, M., & Weisglas-Kuperus, N. (2012). Language Functions in Preterm-Born Children: A Systematic Review and Meta-analysis. *Pediatrics*, *129*(4), 745-754.

Panagiotidis, J., & Lahav, A. (2010). Simulation of prenatal maternal sounds in NICU incubators: a pilot safety and feasibility study. *Journal Of Maternal-Fetal & Neonatal Medicine*, *23*106-109.

Picciolini, O., Porro, M., Meazza, A., Giannì, M. L., Rivoli, C., Lucco, G., & ... Mosca, F. (2014). Early exposure to maternal voice: Effects on preterm infants development. *Early Human Development*, *90*287-292. doi:10.1016/j.earlhumdev.2014.03.003

Pineda, R., Neil, J., Dierker, D., Smyser, C., Wallendorf, M., Kidokoro, H., ... Inder, T. (2014). Alterations in Brain Structure and Neurodevelopmental Outcome in Preterm Infants Hospitalized in Different Neonatal Intensive Care Unit Environments. *Journal Of Pediatrics*, *164*(1), 52-60.

Rand, K., & Lahav, A. (2014). Maternal sounds elicit lower heart rate in preterm newborns in the first month of life. *Early Human Development*, 90(6), 79-683. doi:10.1016/j.earlhumdev.2014.07.016

Sajjadian, N., Mohammadzadeh, M., Alizadeh Taheri, P., & Shariat, M. (2017). Positive effects of low intensity recorded maternal voice on physiologic reactions in premature infants. *Infant Behavior And Development*, *46(1),* 59-66. doi:10.1016/j.infbeh.2016.11.009

Soleimani, F., Zaheri, F., & Abdi, F. (2014). Long-Term Neurodevelopmental Outcomes After Preterm Birth. *Iranian Red Crescent Medical Journal*, *16*(6), e17965. http://doi.org/10.5812/ircmj.17965

Webb, A. R., Lahav, A., Heller, H. T., & Benson, C. B. (n.d). Mother's voice and heartbeat sounds elicit auditory plasticity in the human brain before full gestation. *Proceedings Of The National Academy Of Sciences Of The United States Of America*, *112*(10), 3152-3157.

World Health Organization. (2016, November). Preterm Birth. Retrieved from http://www.who.int/mediacentre/factsheets/fs363/en/

Zimmerman, E., Keunen, K., Norton, M., & Lahav, A. (2013). Weight Gain Velocity in Very Low-Birth-Weight Infants: Effects of Exposure to Biological Maternal Sounds. *American Journal Of Perinatology*, *30*(10), 860-866.

Zimmerman E, McMahon E, Doheny L, Levine P, Lahav A. (2012). Transmission of biological maternal sounds does not interfere with routine NICU care: assessment of dose variability in very low birth weight infants. *Journal of Pediatric Neonatal Individualized Medicine*, *1(1),* 73-80. doi: 10.7363/010107

Zimmerman, E., Norton, M., McMahon, E., Arnorld, A., Ringer, S., & Lahav, A. (2012). The effects of maternal voice and biological sounds on nutrition and respiratory outcomes in preterm infants. *Journal Of Maternal-Fetal And Neonatal Medicine*, *20122*537-38.