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Early exposure to maternal voice: Effects on preterm infants development

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ABSTRACT

Background: Preterm infants complete their development in Neonatal Intensive Care Unit being exposed to environmental stimuli that lead to the early maturation of the sensory systems. It is known that the fetus perceives sounds and reacts to them with movements since the 26th–28th week of gestational age. Maternal voice represents a source of sensory stimulation for the fetus.
Aims: To investigate the effect of the exposure to maternal voice, administered by bone conduction, on preterm infants autonomic and neurobehavioral development.
Study design: Longitudinal, explorative, case control study.
Subjects: 71 preterm infants with birth weight <1500 g, born adequate for gestational age Outcome measures: vital and neurobehavioral parameters at term, neurofunctional assessment at 3 and 6 months of corrected age.
Results: Infants in the treatment group had lower heart rate values and a higher proportion of stable skin color at each study point as compared to the control group. The scores in the visual attention performance and in the quality of the general movements at term were better in the treatment group than in the control one. Neurofunctional assessment score at 3 months of corrected age was higher in the treatment group whereas no difference between the two groups was detected at 6 months of corrected age.
Conclusions: Early exposure to maternal voice exerts a beneficial effect on preterm infants autonomic and neurobehavioral development.

1. Introduction

During intrauterine life the fetus experiences an extremely rapid cerebral growth and neurosensorial maturation. The quality of the experiences undertaken before birth may influence the fetal neurological development both in terms of structural and functional modifications.

Preterm infants are at high risk for developing adverse short and long-term developmental outcomes [1,2]. Disorders have been linked not only to the immaturity of the cerebral structures but also to the sudden interruption of the physiological development of cerebral structures due to preterm birth [3–5]. Preterm infants actually complete their development being exposed to continous adverse environmental stimuli (light, noise, electromagnetic fields, drugs, inadequate manipulations, temperature etc.) during hospital stay [6–9]. Indeed Neonatal Intensive Care (NICU) environment largely differs from that of the protective womb. In addition, the preterm infant is much more sensible and vulnerable than the term one. With regard to the development of the auditory system, exposition to NICU stimuli has been reported to cause an advanced progression of the infant's sensory systems maturation and to deeply affect the cortex functional organization [10].

It is widely acknowledged that the fetus perceives sounds and reacts to them with movements since the 26th–28th week of gestational age (GA) [11]. The sounds perceivable in the environment of a pregnant woman penetrate the tissues and fluids surrounding the fetal head, stimulating the inner ear through a bone conduction route [12]. The sound pressure into the amniotic fluid induces skull vibrations which are transmitted directly into the contents of the cranial cavity and from there into the cochlear fluids, presumably by fluid channels connecting them [13]. It can be therefore speculated that the exposure of preterm infants to maternal voice through bone conduction may mimic the prevalent method of operation of the fetal auditory system.

Developmental Care (DC) is any NICU intervention undertaken to improve neurodevelopmental outcome. It includes NICU design,

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nursing routines, nursing care plan, management of pain, feeding methods and parental involvement [14]. DC aims to provide an extra-uterine environment which positively supports and influences the newborn development [15]. Indeed early interventions may significantly influence the well-being of the infant and his/her parents, reducing the negative effects of prematurity [2].

Maternal voice represents a unique source of sensory stimulation for the fetus and exerts a positive acustic stimuli for its correct development. The exposure to maternal voice within preterm infant's sound environment may therefore contribute to provide the infant a more comfortable and secure surrounding. Few studies addressed the effect of the exposure to maternal voice on preterm infant's development reporting inconsistent results. Some authors did report potentially positive developmental effects (i.e. the development of more adaptative responses such as a greater decrease in heart rates and higher oxygen saturation rates) whereas other did not [16–21].

To our knowledge, there are no data available concerning the effect of the exposure to maternal voice administered by bone conduction on preterm infants development.

The aim of the present study was to investigate the effect of the exposure to maternal voice, administered by bone conduction, on preterm infants autonomic and neurobehavioral development. The hypothesis to be tested was that preterm infants exposed to the stimulation of maternal voice would show better autonomic and neurobehavioral parameters during the intervention period and a better neurobehavioral performance during the first six months of corrected age (CA) than preterm infants that have not been exposed to maternal voice.

2. Materials & methods

We conducted a prospective, longitudinal, explorative, case control study. Infants were scheduled to be prospectively followed up to the sixth month of CA. CA was calculated, up to 24 months of life, from the chronological age adjusted for gestational age that is, for the number of weeks different from the expected 40 weeks.

The study design was approved by the departmental ethics committee and written informed consent was obtained from all the infants' parents.

3. Study population

Of all the 405 consecutive infants admitted to NICU, Fondazione IRCCS, Ospedale Maggiore Policlinico, between 2008 and 2012, 87 infants entered the study. The inclusion criteria were: birth weight (BW) <1500 g, being adequate for gestational age (AGA; birth weight ≥10 percentile according to Fenton's growth chart) [22], spontaneous breathing with saturation >=95%, heart rate (HR) between 140 and 170 bpm during the last 48 h, normal cerebral ultrasound. The exclusion criteria were the presence of major congenital malformations, severe neurosensorial deficits (i.e. retinopathy of prematurity, hypoacusia), gastrointestinal, brain and cardiac diseases, chronic lung disease, infections. Infants were enrolled when they had achieved 29 weeks of GA. The enrolment period lasted 5 years due to the strict elegibility criteria of the study protocol that allowed the enrolment of around 15 infants per year.The reason for choosing such strict elegibility criteria relied on the fact that we aimed to explore the effect of the exposure to maternal voice on infants not affected by pathologic conditions that could per se negatively affect the autonomic and neurobehavioral development.

For each infant enrolled to receive the intervention, the next consecutive infant, matched for BW (±100 gr) and GA (±1 week), that fulfilled the inclusion criteria was enrolled as control.

Infants belonging to the intervention group underwent three sessions of exposure to maternal voice recorded in agreement with the American Academy of Pediatrics [23,24] that recommends the following safe sound levels within the NICU: hourly leq of 50 dB; hourly L10 of 55 dB; and 1-second duration Lmax < 70 dB. The passages were played back at 48 dB. Intervention took place daily and lasted 21 days for each infant. A neurobehavioral observation per day during one of the three sessions was also performed. We decided to perform the neurobehavioral observation in the evening time, when the NICU noise levels were lower.

Infants belonging to the control group were not exposed to maternal voice. However, they also underwent one neurobehavioral observation session in the evening time during which the vital parameters were collected (see paragraph below).

Enrolled infants, both in the intervention and in the control group, further underwent a follow up neurobehavioral assessment at 40 weeks, 3 and 6 months of CA.

According to our internal nutritional procedure, enrolled infants, both in the intervention and in the control group, were on continuous enteral feeding. Parents were allowed to come into NICU 24 h/24.

3.1. Intervention procedure

Intervention procedure started at GA between 30 and 32 weeks. Three sessions were performed daily (every eight hours). A transducer Oticon model BC461 bone conductor (BC461, 116Ω, 8.8 mH @ 1 kHz, mechanicaly unloaded, 13Ω DC), device that converts an electrical signal of low frequency in a magnetic vibration, was applied to the wrist of every infant of the intervention group in order to restore the perception of sound through bone conduction [25–27]. The reason for choosing the wrist rather than the skull relies on the fact that its application is more accessible and easy in the premature newborn. The mother's voice was trasmitted through the transducer while reading passages of the "Little Prince" by Antoine de Saint Exupéry. The voice was filtered according to the method by A. Tomatis [28,29] using a system composed of two equalizers (mod. dbX Graphic equalizer 1231) in which the deep frequencies had been attenuated by 60 dB, preserving those superior to 6000–8000 Hz. High frequencies were preserved in order to reproduce the original characteristics of maternal voice as perceived in the womb. We applied the protocol for infant's observation at the beginning, in the middle and at the end of the intervention procedure.

3.2. Parameters collected during the intervention period

For each child the following parameters were collected from medical records: GA and BW, weight at term, days of hospitalization, week of achievement of spontaneous suckling and independent feeding.

3.2.1. Vital parameters

HR and oxygen saturation (SpO_2) of enrolled infants were monitored continuously.

For analysis, HR and oxygen saturation (SpO2) of infants in the intervention group were recorded over 1 minute during one of the three listening sessions of the day at three different stages: at the beginning (before exposure), in the middle (15° min) and at the end of intervention (30° min). The same parameters were collected for every infant belonging to the control group.

3.2.2. Neurobehavioral and autonomic parameters

Neurobehavioral assessment investigated the presence of tremors and changes in skin color and the quality of spontaneous motor activity. According to item 56 of the Neonatal Intensive Care Unit Network Neurobehavioral Scale (NNNS) [30], tremors were defined as "absent" (score = 1, 2 or 3), "occasional" (score = 4, 5 or 6) and "frequent" (score = 7, 8 or 9). Spontaneus motor activity was defined as "poor" (score = 1 or 2), "good" (score = 3, 4 or 5) and "hyperkinetic" (score = 6), according to item 54 of the NNNS. Changes in skin color were defined as "mottling", "cyanosis" and "paling" according to item 58 of the NNNS. The behavioral states using Prechtl's grading [31] were recorded. For analysis, active awake state and quiet awake state were grouped and named "wakefulness".

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3.3. Assessment performed during follow up

The neurobehavioral assessment was carried out by one specialized physician blinded to the intervention at term (40 weeks), 3 months ±1 week and at 6 months ± 1 week of CA.

3.3.1. Assessment at term correct age

The evaluation at term was performed using GMs, described in details by Prechtl [32]. Scores were assigned as follows: 0 = GMs score ranging from 13 to 16, 1 = GMs ranging between 11 and 12, score 2 = GMs ranging between 9 and 10. Inanimate visual and auditory orientation was further assessed using the instruments proposed by the NNNS (items 35–36). The following scores were given: score = 0 (visual orientation and tracking about 60° on horizontal axis and 30° in vertical axis or performing an arch complete of 180°, corresponding to 7/8/9 scores on the NNNS); score = 1 (visual orientation and tracking on the horizontal axis for at least 30° or visual tracking with eyes and head for at least 30°, corresponding to 4/5/6 scores on the NNNS); score = 2 (visual fixation or occasional visual tracking impossible, corresponding to 1/2/3 scores on the NNNS). With regard to the auditory orientation, we awarded score = 0 in case of evidence of alert orientation with eyes and head towards the sound source at least once over 4 stimuli (corresponding to 7/8/9 scores on the NNNS); score = 1 in case of alerting and reactions of orientation by shifting the eyes with the head turning to source once or twice (corresponding to scores 4/5/6 in the NNNS) and score = 2 in case of modification in the behavioral state and alertness related to the sound stimulus (corresponding to scores 1/2/3 in the NNNS).

3.3.2. Assessment at 3 and 6 months of corrected age

A neurofunctional assessment (NFA) was performed at 3 and 6 months [33,34]. Neurofunctional assessment is based on the evaluation of evoked and spontaneous motricity, postural adaptability, variability of motor patterns, and neuromotor and behavioural skills. The items are evaluated according to the emerging functions, characteristic of each age considered. Score = 0 indicated normal, complete motor patterns and interactions; score = 1 indicated mild abnormalities that change with facilitation during the exam; score = 2 indicated abnormalities with function moderately disturbed, but possible.

4. Statistical methods

Descriptive data were presented as mean ± SD or n (%). The differences between the two groups were assessed by means of the T-Student test (for continuous variables) and the Chi Square test (for categorical variables). All obtained results were confirmed, when necessary, with the Wilcoxon–Mann–Whitney or the Fisher exact test.

Significance of multiple comparisons was adjusted by Bonferroni corrections.

All analysis were performed using the statistical software SAS 9.2 (SAS Institute Inc., Cary, NC), with two-tailed test (statistical significant a p-value < than 0.05).

5. Results

Sixteen infants dropped out of the study either during hospital stay (n = 13 due to the occurrence of infections and cardiorespiratory instability) or after discharge (one due to the development of cerebral palsy and two because the parents failed to bring them to the scheduled follow up assessments) so that the study population was composed by 71 infants. The intervention group comprised 34 infants.

The two groups resulted homogeneous when compared by gender, ethnicity, GA and BW (Table 1).

All enrolled infants underwent the scheduled 21 observations during hospital stay. Both groups started the neurobehavioral observations at a mean GA of 31 weeks so that the 21st observation took place at 34 weeks of GA.

Table 1
Basal neonatal features.

		Treated	Untreated	p-value[a]
		(N = 34)	(N = 37)	
Gender				
	Male	20(58.8)	17(46.0)	0.36
	Female	14(41.2)	20(54.0)	
Ethnicity				
	Caucasian	31(91.2)	30(81.9)	0.31
	Other	3(8.9)	7(18.2)	
GA		28.8 ± 1.6	29.6 ± 1.5	0.11
BW		1215.3 ± 185.3	1186.3 ± 210.7	>0.50

Data are expressed as mean ± DS or n(%).
[a] p-values calculated using the T-Student test for continuous variables and Chi Square test for categorical variables.

Mothers of infants belonging to both groups visited their infants daily and had a similar educational level.

5.1. Vital parameters

HR and SpO_2 values were similar between groups at onset of intervention.HR values of the infants in the intervention group, measured as an average of the values collected at the same time during the observation period (onset, middle, end) throughout the 21 days of intervention (summation effect of the previous day), were significantly lower than those of the infants in the control group at the beginning, in the middle and at the end of intervention. HR values evaluated as a mean of the values collected during the three different periods of the observation throughout the 21 days of intervention were significantly lower in the intervention group than in the control group (Table 2).

No difference in SpO_2 between the two groups was found.

5.2. Neurobehavioral and autonomic parameters

Table 3 shows the mean percentage values related to the neurobehavioral parameters assessed for each of the two groups at the three different time points during the observation period and throughout the study. No significant differences between the two groups were found with regard to tremors and motricity. GMs were assessed in Precthl state 2 to 4.

Treated infants showed a higher proportion of stable (no changes) skin color and lower frequency of mottled skin (stress sign) at each study point (onset, middle and end). No significant differences were

Table 2
Vital parameters during intervention.

	Treated	Untreated	p-value[a]	p-value[b]
	(N = 34)	(N = 37)		
HR (bpm)				
Onset	151.5 ± 14.3	154.8 ± 15.1	<0.01	<0.01
Middle	151.9 ± 14.7	154.0 ± 13.9	0.02	0.14
End	151.3 ± 14.3	154.4 ± 15.1	<0.01	<0.01
All[c]	151.5 ± 14.4	154.4 ± 14.7	<0.01	<0.01
SpO_2				
Onset	0.97 ± 0.05	0.97 ± 0.03	>0.50	>0.50
Middle	0.97 ± 0.04	0.97 ± 0.04	>0.50	>0.50
End	0.97 ± 0.06	0.97 ± 0.04	0.13	>0.50
All[c]	0.97 ± 0.05	0.97 ± 0.03	0.18	>0.50

Data are expressed as mean ± DS.
[a] p-values calculated using T-Student test.
[b] p-values adjusted by Bonferroni correction.
[c] Value calculated in each of the two groups in the totality of the study.

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Table 3
Behavioral parameters in each and all sessions.

	Treated (N = 34)					Untreated (N = 37)			p-value[a]	p-value[b]
Tremors	Absent	Occasional	Frequent			Absent	Occasional	Frequent		
Onset	87.5	12.3	0.2			85.8	12.6	1.6	>0.50	>0.50
Middle	77.9	20.1	2.0			80.2	17.3	2.5	0.45	>0.50
End	83.5	14.5	2.0			83.3	15.1	1.6	>0.50	>0.50
All[c]	82.8	15.6	1.6			83.1	15.0	1.9	>0.50	>0.50
Motricity	Poor	Good	Hyperkinesia			Poor	Good	Hyperkinesia		
Onset	51.5	46.8	1.7			50.3	47.9	1.8	>0.50	>0.50
Middle	44.3	52.3	3.4			48.4	49.8	1.8	0.17	>0.50
End	46.3	50.3	3.4			48.8	50.0	1.2	0.06	>0.50
All[c]	47.3	49.8	2.9			49.2	49.2	1.6	0.06	>0.50
Skin color	No change	Mottled	Cyanotic	Pale	No change	Mottled	Cyanotic	Pale		
Onset	92.9	5.5	0	1.6	84.3	13.1	0	2.6	<0.01	<0.01
Middle	91.8	7.6	0	0.6	84.6	13.6	0	1.8	<0.01	<0.01
End	92.1	7.1	0.2	0.6	86.7	11.4	0	1.9	0.01	0.25
All[c]	92.3	6.7	0.1	0.9	85.4	12.7	0	1.9	<0.01	<0.01
Crying		yes	No			yes	No			
Onset		2.7	97.3			4.5	95.5		0.14	>0.50
Middle		5.5	94.5			5.4	94.6		>0.50	>0.50
End		5.3	94.7			5.3	94.7		>0.50	>0.50
All[c]		4.5	95.5			5.1	94.9		0.45	>0.50
State	Wakefulness	Active sleep	Deep sleep		Wakefulness	Active sleep	Deep sleep			
Onset	20.0	44.4	35.6		17.6	45	37.4		0.49	>0.50
Middle	19.4	47.1	33.5		16.3	48.3	35.4		0.40	>0.50
End	17.1	42.5	40.4		15.0	49.6	35.4		0.06	>0.50
All[c]	18.8	44.7	36.5		16.3	47.6	36.1		0.10	>0.50

Data are expressed as %.
[a] p-values calculated using Chi Square test.
[b] p-values adjusted by Bonferroni correction.
[c] Value calculated in each of the two groups in the totality of the study.

observed between groups with regard to crying, sleeping and wakefulness state.

5.2.1. Feeding and anthropometric parameters

No significant differences between the two groups were observed with regard to the lenght of hospitalization, the timing of suckling, the achievement of independent feeding and weight at term (Table 4).

5.3. Neurobehavioral parameters: follow up

The percentage of infants belonging to the intervention group that showed a score = 0 (i.e. the best perfomances in visual orientation) with regard to the visual orientation and the GMs was significantly higher as compared to that of the infants in the control group (Table 5). We also observed a clear tendency towards a better auditory orientation in the intervention group than in the control one. At 3 months of CA, the percentage of infants in the intervention group that showed a score equal to 0 in the NFA was significantly higher than that of the infants of the control group.

No significant difference in the NFA was still present when the two groups were compared at 6 months of CA.

6. Discussion

The findings of the present study indicate that the exposure to maternal voice filtered according to the Tomatis' method exerts a beneficial effect on preterm infants' maturation of autonomic functions and neurobehavioral outcome at term and at three months of CA. Indeed, with regard to the vital parameters, infants belonging to the intervention group showed consistently lower HR values while being exposed to maternal voice either during the single observations or throughout the whole intervention period as compared to the infants belonging to the control group. In addition, a higher proportion of infants belonging to the intervention group did not show any sign of stress in terms of skin color changes during the exposure to maternal voice as compared to the infants in the control group. With regard to the neurodevelopmental outcome assessed at term, significantly better general movements and visual orientation were observed in the intervention group in comparison to the control group. We also observed aclear tendency towards better auditory orientation in the intervention group. At three months of CA, infants that had been exposed to maternal voice during hospitalization showed a better neurofunctional evaluation than infants belonging to the control group whereas no more differences were found in the neurofunctional evaluation at six months of CA between the two groups.

Table 4
Feeding and anthropometric parameters.

	Treated (N = 34)	Untreated (N = 37)	p-value[a]	p-value[b]
Day of hospit	55.6 ± 19.8	54.6 ± 15.8	>0.50	>0.50
Suckling (weeks)	34.0 ± 1.4	34.2 ± 1.5	0.48	>0.50
Independent feeding (weeks)	35.1 ± 1.3	35.2 ± 1.9	>0.50	>0.50
Weight at 40 weeks	2781.1 ± 403.8	2688.1 ± 525.0	0.41	>0.50

Data are expressed as mean ± DS.
[a] p-values calculated using T-Student test.
[b] p-values adjusted by Bonferroni correction.

Table 5
Developmental parameters.

	Treated (N = 34)	Untreated (N = 37)	p-value[a]	p-value[b]
Visual orient. 40 weeks				
Score 0 (7/8/9 NNNS)	76.5	25.8	<0.01	<0.01
Score 1 (4/5/6 NNNS)	20.6	51.6		
Score 2 (1/2/3 NNNS)	2.9	22.6		
Auditory orient. 40 weeks				
Score 0 (7/8/9 NNNS)	65.6	35.5	0.01	0.06
Score 1 (4/5/6 NNNS)	25.5	58.1		
Score 2 (1/2/3 NNNS)	8.9	6.4		
GMs 40 weeks				
Score 0	79.4	35.5	<0.01	<0.01
Score 1	20.0	54.8		
Score 2	0.0	9.7		
NFA 3 months CA				
Score 0	64.0	23.9	<0.01	0.01
Score 1	28.0	76.9		
Score 2	8.0	0		
NFA 6 months CA				
Score 0	48.0	44.0	>0.50	>0.50
Score 1	48.0	52.0		
Score 2	4.0	4.0		

Data are expressed as %.
[a] p-values calculated using T-Student test for continuous variables and Chi Square test for categorical variables.
[b] p-values adjusted by Bonferroni correction.

To our knowledge, this is the first study that investigates the effect of the exposure to maternal voice by bone conduction according to the Tomatis' method [28,29] on preterm infants development. Fetal audition has been investigated in very few studies. Indeed, so far, it has not been elucidated which kind of frequencies the fetus perceives and prefers [11,35,36]. According to Tomatis' studies, this type of stimulus, that is preferentially oriented towards high frequencies, reproduces the characteristics of maternal voice as it was perceived into the womb. The findings of the present study could be therefore explained by the fact that the exposure to maternal voice through bone conduction may mimic the prevalent method of operation of the fetal auditory system [13] and, hence, promote a physiological development of the infant's sensory systems maturation, that, in turns, could positively affect the cortex functional organization. Indeed, according to the key role played by parents in developmental care programs, maternal voice represents an important acoustic stimulus in promoting sensorial and neurodevelopmental outcome of preterm infants [5,16,17,20,36–38].

The absence of a persistent positive effect of the exposure to maternal voice during hospitalization on infants' neurodevelopmental outcome at 6 months of CA could be partly explained by the fact that, even though the infants belonging to the intervention group have reached adequate autonomic maturation and neurobehavioral skills in a shorter length of time, the control group infants succeeded in developing the same competencies as the infants in the intervention group by the end of the sixth month of CA, so that no more differences between the two groups could be detected. However, it can be speculated that the early achievement of adequate autonomic maturation and neurobehavioral skills by the infants belonging to the intervention group could promote the development of better performances in other neurodevelopmental domains (i.e. fine and gross motor performance or visual–spatial coordination) at later ages.

Several studies have addressed the effect of various kind of auditory stimulations (i.e. physiological sounds like heartbeat, lullabies, various kinds of music therapy and maternal voice) on preterm infants development reporting inconsistent results [5,10,16,17,20,21,39–41]. This may be partly explained by differences in the study protocols with regard both to the early developmental intervention programs trialed and the different gestational ages of the preterm infants included. Results from a recent meta-analysis conducted by Standley suggest benefits for live music therapy performed early in the infant's NICU stay with regard to vital and feeding parameters, behavioral state and promotion of attachment with the infants' mothers [18].

Our findings are consistent with those previously reported by Doheny et al. that investigated the effect of the exposure to maternal voice on preterm infants (26–32 weeks of gestation) in NICU. The results from this study provide preliminary evidence that the early exposure to maternal voice promotes the physiological stability (especially HR, respiratory rate and SpO_2) and capacity of self-regulation. Loewy et al. conducted a clinical randomized multisite trial with the inclusion of 272 premature infants aged >32 weeks in NICU. The authors reported that live music therapy (rhythm, breath, and parent-preferred lullabies) may positively affect the physiologic (eg, HR and respiratory rates, SpO_2, activity levels) and developmental functions (eg, sleep, feeding behavior, and weight gain) in premature infants [19,21].

In contrast with previous published studies [21,37,42–44], we did not find any advantage in terms of length of hospital stay, timing of suckling, independent feeding achievement and ponderal growth during hospitalization. The absence of an advantage with regard to these parameters could partially rely on the fact that in the present study we have adopted very strict inclusion criteria so that the infants that could probably most benefit from the intervention in terms of feeding, growth parameters and length of hospital stay (i.e. infants affected by major congenital malformations and/or diseases) have not been enrolled.

The main strength of the present study is represented by the fact that, to our knowledge, this is the first study that analyzed the effect of the exposure to maternal voice by bone conduction on the maturation of autonomic functions and neurobehavioral outcome in a cohort of relatively "healthy" preterm infants (i.e. not affected by any condition that could potentially negatively interfere with the investigated variables).

In addition, the fact that the treated preterm infants were followed up to the sixth month of CA, allowed us to evaluate the potential persistence of the effect of the intervention performed during hospital stay in the medium term.

In contrast, we did not evaluated parental satisfaction with regard both to the intervention itself and to the outcomes investigated, and that may represent a limitation of the present study.

7. Conclusion

Our study provides evidence that hospitalized preterm infants benefit from the early exposure to maternal voice with regard to the autonomic maturation and the neurofunctional outcome. Further additional larger studies are desiderable in order to confirm the present findings.

Conflict of interest statement

Authors have no conflict of interest to declare. The follow-up program is funded through the National Health Service, with no outside funding or charitable contributions.

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