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REGULAR ARTICLE

Live music reduces stress levels in very low-birthweight infants

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ABSTRACT

Aim: Music might benefit preterm infants in stressful, intensive care environments. However, data on stress level indicators, determined by salivary cortisol levels, are scarce. We evaluated the effect of live harp music on the stress level indicators of preterm infants in a neonatal intensive care unit (NICU).

Methods: We exposed 20 stable preterm infants to music for 15 min on three consecutive days. Saliva was collected before the music was played and 25 min and 4 h after it ended. Salivary cortisol levels were measured by liquid chromatography–tandem mass spectrometry and vital signs, oxygen saturation, bradycardia, apnoeas and oxygen desaturations were recorded. Pain levels were assessed by the Bernese Pain Scale for Neonates.

Results: Salivary cortisol was significantly lower 25 min (18.9 nmol/L [3.9–35.6] $p = 0.001$) and 4 h after music (17.4 nmol/L [3.9–35.3] $p = 0.003$) than at baseline 4 h before exposure (19.5 nmol/L [7.2–51.1]). After music, the number of apnoeas and oxygen desaturations was significantly reduced on all three, days and the number of bradycardia episodes on day one. Pain scores significantly improved after music on all 3 days.

Conclusion: Exposure to live music reduced salivary cortisol and had beneficial effects on the physiologic parameters of stable preterm infants in a NICU.

INTRODUCTION

Infants in a neonatal intensive care unit (NICU) are exposed to painful and stressful procedures, and concerns have been raised about whether this environment contributes to neurodevelopmental morbidity later in life (1). When an infant attempts to cope with a stressful situation, the hypothalamic-pituitary-adrenal (HPA) axis is activated, resulting in an increase in plasma cortisol levels, and, by proxy, in the salivary cortisol levels as salivary cortisol levels have been shown to correlate well with plasma levels in preterm infants (2).

Foetal HPA response can be detected in the second trimester of pregnancy (3), whereas a circadian rhythm of cortisol secretion in preterm infants is not developed until eight to 12 postnatal weeks (4). Previous studies have demonstrated that extremely preterm infants had higher salivary cortisol levels than term infants even at eight and 18 months of corrected age (5) and that preterm born children showed higher morning cortisol levels after waking than full-term controls at eight to 12 years of age (6). Sustained stress in a NICU environment may have further adverse effects on brain development (1).

These data illustrate the importance of stress reduction techniques in preterm infant care. In addition to therapies such as skin-to-skin care, massage or individualised

Abbreviations

BERA, Brainstem electric response audiometry; BPSN, Bernese Pain Scale for Neonates; HPA, Hypothalamic-pituitary-adrenal; IBE, Department of Medical Informatics, Biometry and Epidemiology, LMU-Munich, Germany; LCxLC-MS/MS, Two-dimensional liquid chromatography–tandem mass spectrometry; NICU, Neonatal intensive care unit; TEOAE, Transitory evoked otoacoustic emissions.

Key notes

- Music might benefit preterm infants in stressful, intensive care environments, but data on stress level indicators, determined by salivary cortisol levels, are scarce.
- We exposed 20 stable preterm infants in a neonatal intensive care unit to music for 15 min on three consecutive days, collecting saliva before and after the music was played.
- Exposure to live music reduced salivary cortisol levels and had beneficial effects on the infants' physiologic parameters.

developmental care (7–9), music applications have also been suggested as a tool for stress reduction.

The foetus is reliably able to process auditory stimuli from the 29th gestational week onwards (10). Exposing preterm infants to music has been reported to reduce stress behaviour, improve or stabilise vital signs, increase sleep quality and weight gain and decrease length of hospital stay (11–15). A meta-analysis concluded that music may be beneficial for a range of outcomes among premature infants in the NICU (16). Two further reviews indicated that there was evidence that music might be beneficial with regard to behavioural states, pain reduction and physiological parameters in preterm infants (17,18). However, so far data on endogenous stress hormone response, determined by changes in salivary cortisol levels, have been scarce (19,20).

Studies with adolescents and adults have shown that music can reduce cortisol secretion (21,22). It is, therefore, possible that similar effects might be observed in preterm infants. The aim of this study was to test the effect of live harp music on salivary cortisol levels, vital signs and the Bernese Pain Scale for Neonates (BPSN) on very low-birthweight infants.

PATIENTS AND METHODS

Ethical approval

The study was approved by the institutional ethical committee of Ludwig Maximilians University, Munich, (Project Nr.: 259-10), and informed parental consent was obtained prior to enrolment.

Design, procedures and music intervention

Individual basal cortisol levels vary largely in preterm infants, and no data regarding the variation of salivary cortisol during music interventions are available. Therefore, we conducted a prospective exploratory pilot study with a baseline-response-paired design (8,20) rather than a controlled trial. Accordingly, a sample size calculation was not carried out, and 20 infants were chosen for this pilot study. Infants were studied on three consecutive days (15,19). On each study day, data were collected at the same time of the day, starting 4 h before music exposure and ending 4 h after music exposure. During this time period, salivary cortisol, heart rate, respiratory rate, oxygen saturation, number of apnoeas, bradycardia, oxygen desaturations and BPSN were recorded repetitively. An oxygen desaturation was defined as a decrease in oxygen saturation of <85%, determined by pulse oximetry, (MASIMO® technique, Software VF8, Masimo Europe, Puchheim, Germany) with an alarm averaging time of 12 sec. Bradycardia was defined as a heart rate of <100 beats per minute and apnoea as no thoracic movements for at least 10 sec, as determined by the electrocardiogram-electrode respirogramme. The same investigator (DS) performed all saliva and data collections. The study protocol, including all the measurements, is outlined in Figure 1.

The music intervention was selected in close consultation with a music therapist (FS) experienced in working with preterm infants. Music was played live on a pentatonic tuned kantele (Musikinstrumente Thomas Schüler, Umkirch, Germany) by DS, a plucked string instrument, comparable to a seven-string harp. Live music was chosen because it has been shown to be superior to recorded music (12). The seven clamped strings of the kantele included the tonal range d'-e'-g'-a'-h'-d''-e''. A pentatonic scale is characterised by five notes per octave, instead of seven, resulting in a very common and calm sound and thereby avoiding dissonance. Music was individually performed for all infants in the morning with the infant lying in a warming bed or incubator with the lid of the bed or the incubator hand port opened next to the infant's head. The preterm infant remained in the same room throughout the study because we wanted to test music exposure under real live conditions, including background noise. A first ascending scale, followed by a descending tone scale, covering the entire range of the kantele was played repetitively for 15 min on each study day. During the first minute, the volume was increased gradually, followed by 13 min

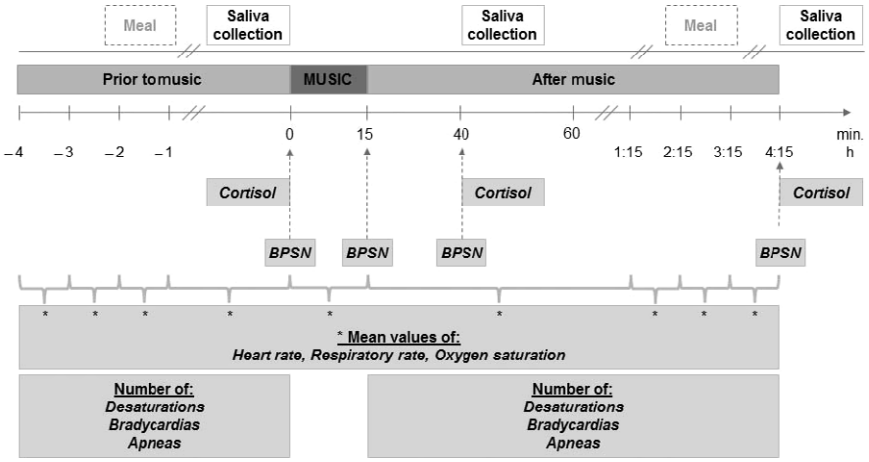

Figure 1 Study protocol. BPSN: Bernese Pain Scale for Neonates; Cortisol: Salivary Cortisol determined by mass spectrometry.

plucking at a frequency of 50 tones per minute, and a sound level of 60–70 dB(C) measured nearby the preterm infant's head. During the last minute, the volume was continuously reduced. We chose the musicological principles of simplicity in melody and repetition to create trust and to counteract an acoustic overtaxing of the preterm infant. When the music was finished, the incubator was closed or the lid was put back down and the infant was left without any further communication. Music exposure was equal in all infants. Parents were not present during music exposure. None of the infants were exposed to music prior to enrolment, and there was no other music exposure during the study days.

Setting

The study was conducted in a NICU and intermediate care setting. All infants were initially treated at our NICU. Due to our referral practice, 13 of the 60 study days had to be performed in three other NICUs with a comparable noise background to the initial NICU.

Patients

Infants were eligible for participation if: (i) their birthweight was between 500 and 1500 g and appropriate for gestational age, (ii) they were on full enteral nutrition, (iii) they had not received any analgesia or sedation for at least 2 days and (iv) they had no infection, surfactant application, arterial hypotension, steroids, intraventricular haemorrhage, hypoglycaemia, blood transfusion or tracheal or pharyngeal ventilation for at least 48 h before the first music exposure.

We excluded infants with genetic anomalies, chromosomal aberrations, congenital heart malformations except patent ductus arteriosus or persisting foramen ovale, history of intraventricular haemorrhage more than grade II on ultrasound, disorganisation of the HPA axis, as indicated in the given infant or family history, or negative hearing test performed by transitory evoked otoacustic emissions (TEOAE) or by brainstem electric response audiometry (BERA) were excluded. A hearing test was performed in all infants enrolled prior to discharge. We decided that we would retrospectively exclude infants from the study if their hearing test was negative, but all infants had normal hearing tests.

Salivary cortisol

Saliva was collected using a commercial device (Salivette® Cortisol Sarstedt AG&Co., Nümbrecht, Germany). These cuvettes are characterised by high cortisol recovery and saliva extraction rates as indicated by the manufacturer. Prior to use, the polyester filter of the device was split longitudinally into four equal parts under sterile conditions in order to adjust for the patients' small mouths. One of these pieces was held in place manually with the tip close to the buccal mucosa. In an individual infant, the first saliva sample of each study day was collected in the morning at approximately the same time.

Previous studies investigating the influence of massage or skin-to skin care on salivary cortisol in preterm infants collected the saliva 20 to 30 min after the intervention (7,8). Thus, saliva was collected immediately prior to music exposure and 25 min and 4 h after the end of music.

No stimulant was used for saliva collection. To minimise the risk of contamination with cortisol or cortisol-like substances in breast milk or formula milk (23), saliva samples were collected at least 45 min after feeding. All infants except for one were fed by gravity drainage bolus feeds through a nasogastric tube prior to music exposure. After saliva collection, the polyester piece was placed in the cuvette and centrifuged (at 2600 g for 10 min) as recommended by the manufacturer. Collected saliva was stored at −20°C.

Salivary cortisol levels were measured by two-dimensional liquid chromatography–tandem mass spectrometry (LCxLC-MS/MS) at the Institute for Laboratory Medicine of the LMU Munich-Grosshadern. The process was as previously described, but with two modifications: (i) for sample preparation, 25 μL of internal standard (threefold deuterated cortisol) working solution was added to 50 μL of calibrator, quality control and saliva samples, respectively and (ii) injection volume was 40 μL (24). Because there are no normal values for salivary cortisol in preterm infants, we evaluated intra-individual changes in salivary cortisol.

Vital signs

As most other music exposure studies have focused on vital signs, we additionally assessed stress levels by recordings of vital signs – heart rate, respiratory rate and oxygen saturation – obtained from the standard intensive care monitoring (Infinity Delta ® with Masimo SET® SmartPod®, VF 8 software, Draeger medical, Lübeck, Germany). Data were collected every 5 min for 4 h prior to, during and 4 h after music exposure. The total number of oxygen desaturations, bradycardia and apnoeas during the 4-h periods prior to, and after, music were re-evaluated and checked for artefacts retrospectively from the monitor recordings.

Behavioural evaluation

Behavioural responses to music were assessed using the BPSN (25), which has been used at the NICU for several years. It consists of seven behavioural variables (alertness, duration of crying, time to calm, skin colour, eyebrow bulge with eye squeeze, posture and breathing pattern) and two physiological variables (change of heart rate and transcutaneous measured oxygen saturation) (25). Physiological variables were collected from the patient's cardiorespiratory monitor recordings. The BPSN demonstrated inter-rater reliability of $r = 0.86–0.97$ and intrarater reliability of $r = 0.98–0.99$ (25). It was collected in real-time over an observation period of 3 min immediately before the start and after the end of music exposure, as well as 25 min and 4 h after end of music.

Statistical analysis

The study protocol was designed after consultation with the Department of Medical Informatics, Biometry and Epidemiology (IBE), LMU-Munich, Germany. The software SPSS 18.0 for Windows (SPSS Inc. Chicago, IL, USA) and R

2.14.1 (http://www.r-project.org) were used for statistical analysis. A p-value of <0.05 was considered statistically significant. The nonparametric paired Wilcoxon test (one-sided) was used to compare paired data at two different times, before and during or after music. Unadjusted p-values are reported, but to determine which null hypotheses could be rejected, the Bonferroni–Holm correction was performed to correct for multiple testing when several time points were tested simultaneously.

Continuously measured data on vital signs were preprocessed further: heart rate, respiratory rate and oxygen saturation measured using pulse oximetry. First, vital signs data were averaged hourly for the periods prior to and after music and for the music exposure period. This yielded four values before, one value during and four values after music exposure. Secondly, the null hypotheses that the four hourly mean values during periods prior to music did not differ in terms of median values were tested successively using the nonparametric Friedman test for each study day and each considered vital sign. The same tests were performed for each study day and each vital sign for the four hourly values during periods after music. As almost none of these null hypotheses were rejected, the vital signs were further averaged to finally retrieve one value prior to, one value during and one value after music exposure, respectively. These mean values obtained prior to, during and after music were compared using the nonparametric paired one-sided Wilcoxon test.

The nonparametric Friedman test was subsequently applied to test the equality of cortisol values on the three different days for each successive time point. As these tests did not reveal any significance, the data of the 3 days were pooled together and the differences between the time points – before music, 25 min after music and 4 h after music – were assessed using a Wald test within a linear mixed model with the cortisol value as a dependent variable, the time point as an independent variable with *before music* being the reference category and a random intercept to account for differences between infants. Model fit was checked by visual inspection of the residuals.

If a patient's data were missing at certain time points, for example because of insufficient amount of saliva, the infant's data of the affected variable for this study day were excluded from analyses.

RESULTS

The characteristics of all infants are outlined in Table 1. There was no change in caffeine dosage or the necessity of breathing support in any infant during the study period.

A total of 180 saliva samples were collected and 164 samples (91%) contained sufficient volumes of saliva (≥50 μL) for analysis. Sufficient amounts of saliva at all three time points were available for analysis from 17 infants on days one and three and from 16 infants on day two. No samples were excluded due to contamination with blood or milk, and 93% of the saliva samples were obtained without disturbing the child, as determined by observation of facial and body expression and vital signs. None of the infants cried during saliva collection.

Table 1 Clinical data of the study participants (n = 20)

Variable	n = 20
Birthweight, median (range), g	1290 (700; 1480)
Gestational age at birth, median (range), w	30 + 4 (23 + 4; 33 + 0)
Five-minute Apgar score, median (range)	9 (7; 10)
Male/Female, n	11/9
Antenatal steroids, n	19
Postnatal steroids, n	3
Weight at first study day, median (range), g	1510 (1080; 2350)
Gestational age at first study day, median (range), w	32 + 6 (30 + 1; 35 + 5)
Caffeine, n	11
Nasal cannula/HFNC/without breathing support, n	1/6/13
Breast milk/Formula/Both, n	14/4/2

w = gestational weeks, HFNC = high-flow nasal cannula.

On days one and three, salivary cortisol was lower 25 min after music exposure compared to values prior to music (p = 0.001 and p = 0.01934, respectively), remaining significant after Bonferroni–Holm correction (Fig. 2). There was a further decrease in salivary cortisol 4 h after music on day one (Fig. 2). The salivary cortisol values on all three consecutive days for each of the three different time points were not statistically different, according to the Friedman test (p = 0.256; p = 0.847; p = 0.330). Therefore, the data from all three study days – prior to, 25 min after and 4 h after music exposure – were pooled together. In summary, salivary cortisol decreased 25 min and 4 h after intervention (baseline median [range]: 19.5 nmol/L [7.2–51.1]; 25 min: 18.9 nmol/L [3.9–35.6], p = 0.001; 4 h: 17.4 nmol/L [3.9–35.3], p = 0.003) (Fig. 3) and p-values computed based on the Wald test within the linear mixed model.

Although a significant difference in heart rate was observed on day two and in pulse oximetry on days two and three, vital signs changes in response to live music were not clinically relevant (−4 beats/min and +2% pulse oximetry change). In contrast, the number of apnoeas and oxygen desaturations significantly decreased on all 3 days after live music as compared to the period prior to music (Table 2). However, it should be noted that all infants were examined in a relatively stable state. Thus, the number of events was generally low.

All infants enrolled in the study scored low values for the BPSN prior to music. Nevertheless, BPSN significantly improved further immediately and 25 min after music intervention on all 3 days, and 4 h after music on days one and two (Table 2).

DISCUSSION

In this study, we demonstrate that in very low-birthweight infants, salivary cortisol levels and other indicators of

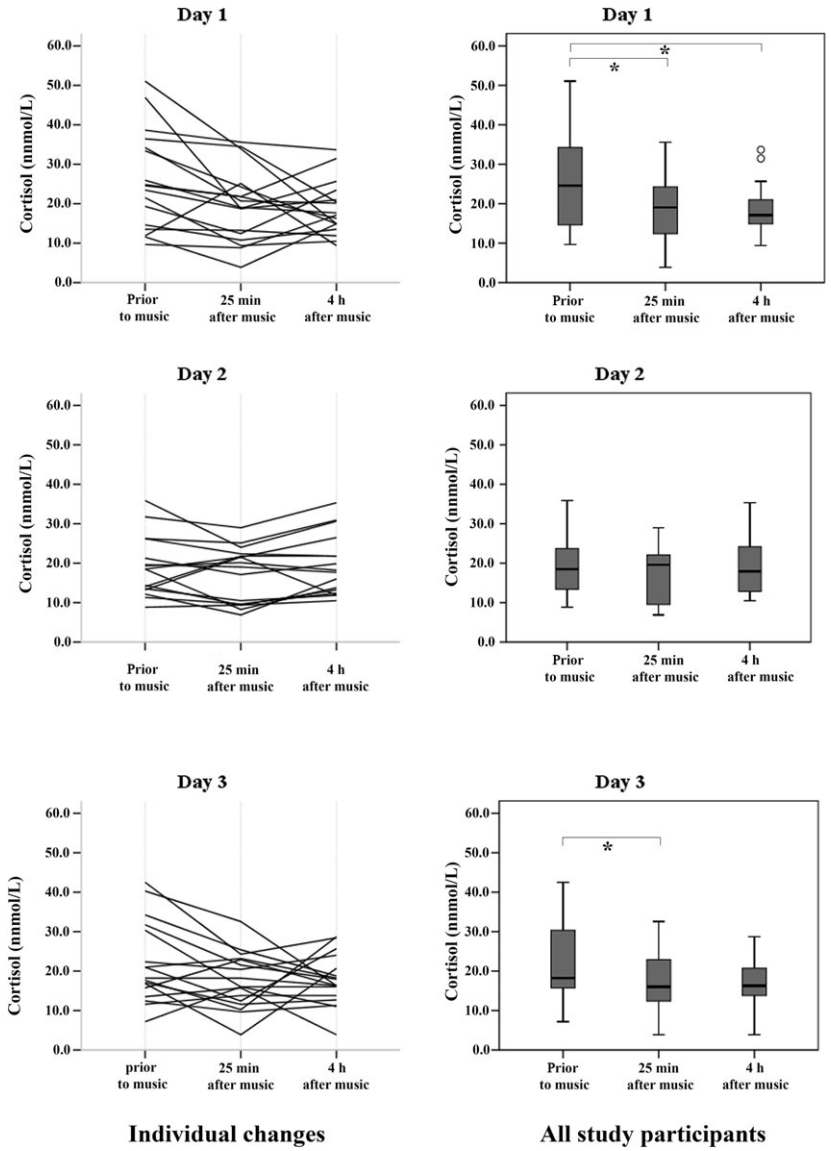

Figure 2 Change in salivary cortisol concentration (Cortisol) after pentatonic music exposure. *significant at the level 0.05 (one-sided Wilcoxon test with Bonferroni–Holm correction).

distress were reduced after exposure to live pentatonic harp music.

The finding of a decrease in salivary cortisol level after receptive music exposure is consistent with previous observations in preterm infants (20) and adults (21,22). In five preterm infants, Block et al. measured a reduction of salivary cortisol in response to live harp music (20). In contrast, Kemper and Hamilton studied a total of eight near-term infants on three consecutive days. Four of these infants remained in the normal NICU environment, whereas the others were taken to a quiet room where only two babies were additionally exposed to live harp music. There was no difference in salivary cortisol changes among the three groups (19). We are unable to judge whether the drop of salivary cortisol in our study was clinically relevant, because, to the best of our knowledge, no study data have been published to define clinically or physiologically significant changes of cortisol levels, in response to music, in infants, children, adolescents or adults.

Throughout the daily study period, the nurse in charge was asked to refrain from disturbing or carrying out painful interventions on the infant and leave the infant in his or her crib with only minimal handling. As this was also true for the 4-h period prior to music, it seems unlikely that an observed reduction of cortisol after music exposure is due to this condition. Nevertheless, it could be possible that nursing actions, such as food intake via nasogastric tube or a necessary stimulation of a relevant apnoea, might have had an influence on the stress level of the infants.

In our study, the effect of live music on salivary cortisol was most pronounced on the first study day. This observation may indicate a possible habituation to music in our

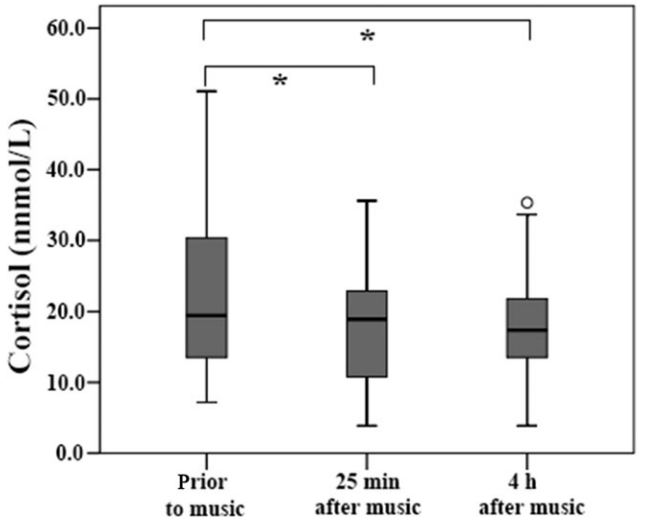

Figure 3 Combined salivary cortisol before (baseline) and after pentatonic music exposure across the three study days. *significant (Wald test within a linear mixed model with Bonferroni–Holm correction).

study cohort. Habituation to acoustic stimuli has been described previously for foetuses *in utero* (26).

Although salivary cortisol levels decreased after music exposure in most infants on all study days – the number of infants with reduced salivary cortisol levels on study days one, two and three were 19, 12 and 11, respectively – seven infants showed a heterogeneous cortisol response. No child continuously reacted with an increase. Demographically, no pattern regarding gestational age at birth or postnatal age on the first study day could be observed in these seven infants. Heterogeneous responses to other potential beneficial interventions in neonatal care, such as skin-to-skin care, have been described previously (7,8). This might be a result of an immature control of the HPA axis (8) or there might be an optimal cortisol level in each individual infant (7). Thus, we speculate that it might be beneficial to adapt music exposure individually, and further research might help in resolving these issues.

In our cohort, 19 infants were exposed to antenatal steroids and three infants received postnatal steroids. The latter showed a decrease in salivary cortisol shortly after music on all study days. Despite the small numbers, this consistent response might be an indication that postnatal steroid exposure has no further influence on the HPA response. Furthermore, it is noteworthy that basal salivary cortisol levels did not differ between infants exposed to postnatal steroids compared to nonexposed infants.

In this study, the interindividual range of salivary cortisol levels measured prior to music ranged from 7.2 nmol/L to 51.1 nmol/L. Both absolute values and the range of our measurements largely correspond to values previously measured in preterm infants of similar gestational ages (2,8,27,28).

The collection of saliva has previously been described as non-invasive, painless and stress free (4,23). However, obtaining enough saliva for analysis in preterm infants is a challenge, and many different methods have been discussed (7–9,27,28). Sufficient probe volumes were reported in 46% to 99% of infants. In our study, we collected saliva with a success rate of 91%. It should be mentioned that the method of mass spectrometry that was used in this study, despite being more accurate, requires a minimum of 50 μL, while most of the immunoassays reported in the literature may be performed from 25 μL. We were able to collect more than 25 μL in 99% of our patients. Some authors describe the use of stimulants to enhance salivation without being able to demonstrate major improvements in saliva volumes collected (7). As we were able to collect sufficient amounts of saliva without using stimulants, we prevented the potential impact of these agents on the quality of our probes (7).

In our study, heart rate and pulse oximetry were measured continuously before, during and after live pentatonic harp music. Although the changes on individual days were significant for many infants studied, the absolute mean differences of both parameters were not clinically relevant. Other music intervention studies in preterm infants have also been able to demonstrate significant changes with regard to vital signs. However, as in our study, these were scarcely of clinical relevance (11,13,20). In contrast, Arnon et al. detected a clinically relevant reduction of 23 beats per minute 30 min after live music exposure (12). Interestingly, this effect was not detected after exposure to recorded music. Our study demonstrated a reduction of bradycardia, apnoeas and oxygen desaturations after music, compared to the time prior to music on all 3 days, yet again these changes were not clinically relevant given the low baseline frequency of these events. The number of such events has rarely been subject of research. Cassidy and Standley found no effect on the number of apnoeas and bradycardia when comparing the periods 24 h before and after playing of recorded lullabies (14). In the Standley and Moore study (15), the number of oxygen desaturations was slightly lower in the 10 min period after playing lullabies compared to the same period before.

Immediately after music intervention, the BPSN improved on all three study days. Considering the low BPSN levels in most infants prior to music, this reduction does not seem to be clinically relevant. It is obvious that stable preterm infants, as defined by our inclusion criteria, often exhibit values far below the pain threshold of 10 points (27). The BPSN has been validated to measure pain rather than stress (25,27). Pain is only one trigger of the HPA axis, and changes in pain scores usually do not correlate with hormonal stress response (8,28). The currently available pain scores in stable preterm infants might therefore not be suitable to measure individual stress level. However, there are no validated stress scores available for preterm infants.

So far there is no standard protocol for the presentation of aural stimuli to preterm infants. Previous studies looking at the effects of receptive music applications in preterm infants used several different music interventions. These

Table 2 Summary of salivary cortisol, vital signs and pain scale before and after music

	Day 1	Day 2	Day 3
Cortisol (nmol/L)	N = 17	N = 16	N = 17
Prior to music	24.6 (9.7; 51.1)	18.5 (8.8; 35.9)	18.2 (7.2; 42.5)
25 min after music	19.0* (3.9; 35.6)	19.6 (6.9; 29.0)	16.0* (3.9; 32.6)
4 h after music	17.1* (9.4; 33.7)	17.9 (10.5; 35.3)	16.3 (3.9; 28.7)
HR (bpm)			
Prior to music	160 (142;174)	162 (142;178)	167 (146;173)
During music	158 (142;178)	158* (129;170)	162 (141;185)
After music	162 (139;175)	165 (139;177)	166 (146;178)
RR (bpm)			N = 19
Prior to music	63 (37;93)	57 (45;90)	56 (43;84)
During music	59 (33;101)	59 (39;95)	52 (37;93)
After music	57 (43;97)	57 (44;88)	52 (37;88)
SpO_2 (%)			
Prior to music	95 (91;98)	94 (92;98)	94 (89;98)
During music	96 (88;99)	96* (93;100)	96* (92;98)
After music	96 (90;98)	95 (91;98)	96* (92;98)
Bradycardia			
Prior to music	0 (0;6)	0.5 (0;5)	1 (0;4)
After music	0* (0;2)	0 (0;6)	0 (0;4)
Apnoeas			
Prior to music	0 (0;4)	0.5 (0;5)	0 (0;5)
After music	0* (0;2)	0* (0;4)	0* (0;3)
Oxygen Desaturations			
Prior to music	0 (0;18)	1.5 (0;14)	1.5 (0;29)
After music	0* (0;12)	1* (0;10)	0* (0;8)
BPSN			
Prior to music	1.5 (0;6)	2 (0;10)	1.5 (0;8)
Immediately after music	1* (0;5)	0* (0;6)	0* (0;5)
25 min after music	0* (0;3)	1* (0;8)	0.5* (0;5)
4 h after music	0.5* (0;3)	0.5* (0;8)	0.5 (0;6)

Salivary cortisol, physiological outcome parameters (heart rate HR, respiratory rate RR, oxygen saturation SpO_2, bradycardia (HR<100 beats/min), apnoeas (no thoracic movements for at least 10 sec), oxygen desaturations (SpO_2 <85%, alarm mean of 12 sec) and Bernese Pain Scale for Neonates (BPSN) prior to and after live pentatonic music on three consecutive days. Median (Min.; Max.); *significantly different from prior to music at the level 0.05 (Cortisol, HR, RR, SpO_2 and BPSN: one-sided Wilcoxon tests with Bonferroni–Holm correction within each day; all others one-sided Wilcoxon tests without correction). For all Wilcoxon tests, the reference was prior to music.

ranged from playing recorded instrumental and, or, vocal music, a mother's voice, or the voice of an independent person (12–15), the Gato box (11), live sung lullabies (11,12) or live harp music (19,20). Our study was not designed to examine whether pentatonic music, covering a small tonal range, was more appropriate than other methods and instruments. However, we speculate that a dissonance avoiding music, such as pentatonic music, and repetition within a small tonal range and rhythm may be related to the observed effects.

This study was limited to immediate changes over a short period of time. Studies are scarce on long-term and sustained effects of music application, such as the influence of music on the development of the auditory system and other sensory systems on the brain, cognition and psychology. An interesting new aspect for planning future studies is the influence of stress on the development and structure of the preterm brain (29). Magnetic resonance imaging studies with former preterm infants in adolescence showed that whole brain volume, cortical grey matter volume and hippocampal volume were lower compared to children born at term (30). Thus, future research could compare the medium-term and long-term structural and functional brain development of a music intervention group with a control group without music exposure.

CONCLUSION

Our findings indicate that pentatonic music exposure may decrease cortisol levels of preterm neonates in a NICU environment. Small preterm infants responded to live harp music by a decrease in salivary cortisol level, heart rate, number of apnoeas, oxygen desaturations and bradycardia, by an increase of oxygen saturation and an improvement of the BPSN. Thus, our data support previous findings of positive effects of live music on preterm infants during their potential stressful period in neonatal intensive care units (16).

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COMPETING INTERESTS

None.

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