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Original Research

Effect of environmental music on autonomic function in infants in intensive and growing care units

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Abstract.
BACKGROUND: The aim of this study is (1) to observe the effect of the background music (BGM) in the incubator on heart rate variability (HRV) during the first few weeks of life in preterm infants in the neonatal intensive (NICU) and growing care units (GCU) and (2) to investigate the effect of environmental music on autonomic function in the infants.
METHODS: Thirty infants, including premature (26 3/7 – 38 4/7 weeks) and low-birth weight (LBW) (946–2,440 g) infants, admitted to the NICU or GCU were involved. The heart rate, low- (LF, 0.05–0.15 Hz) and high- (HF, 0.15–0.4 Hz) frequency HRV components, and LF/HF ratio were measured. The BGM, lullabies for a baby, was delivered through a speaker in the incubator, and the HRV components were compared among before, during, and after intervention with BGM.
RESULTS: The mean HR did not change among the experimental conditions. The LF and HF values decreased during the BGM condition, but not LF/HF, compared with the condition before BGM.
CONCLUSIONS: The present results showed that an auditory environment affected the autonomic function of infants with a range of BGM in the NICU/GCU. The present study also suggested that BGM, a non-invasive and non-pharmacological intervention, could be an evaluation tool for autonomic function in infants in NICU/GCU.

Keywords: Music, NICU, GCU, heart rate variability

1. Introduction

Premature infants often need medical treatments for a number of months in the neonatal intensive (NICU) and growing care (GCU) units. The importance of the auditory environment has been emphasized in care units for infants [1, 2]. The auditory environment, including ambient sound, for infants in the NICU/GCU units might cause stressors and be associated with developmental risks [3–5]. On the other hand, positive effects of music in premature infants have been also reported [6]. However, because of the priority of medical treatments for infants in the NICU/GCU, the auditory environmental setting has not been sufficiently considered [7, 8]. Although the American Academy of Pediatrics recommended a noise level between 45 and 65 dB in the NICU [9], such levels are not always adhered to in hospitals [10].

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Regarding the auditory environment for babies, parents of infants often request their babies' favorite music as a background music (BGM), expecting the positive effects of music on infants [11]. Music might have positive effects on the physical and mental conditions of infants [12, 13], although the effects of music on the conditions of infants have not been confirmed. It is difficult to evaluate the effects of music on infants, especially in the NICU/GCU, since the responses of infants are not interpretable, except for crying in response to unpleasant stimuli. Only a few studies have been carried out regarding the effect of music on the physical condition of newborns, e.g., on sleep evaluated with electroencephalography (EEG) [14] and vital signs [15]. We considered that BGM could be an important factor in the environmental setting of the NICU/GCU, as reported in the previous reports [12, 13]. Other modalities of intervention, e.g., intervention with touching or visual stimulation are limited when infants are in incubators, although the combination of stimuli was effective for infants [16]. Therefore, the objective of the present study was to identify the effect of BGM on preterm infants in the NICU/GCU.

One of the problems when evaluating the effects of an intervention is that the outcome of the intervention is not clearly identifiable in preterm infants. Developmental outcome after an intervention for infants could be hardly evaluated, since long term observation over years might be needed and multiple factors might affects their physical and mental conditions during their development. In the present study, we evaluated facilitated or prompt effects of BGM on the condition of infants. To assess the condition of infants, we recorded heart rate variability (HRV) as a biomarker of infants obtained by electrocardiography (ECG) [17, 18]. ECG monitoring is routinely used in the NICU/GCU for preterm infants to evaluate their physical condition. The HRV components, low- (LF, 0.05–0.15 Hz) and high- (HF, 0.15–0.4 Hz) frequency HRV components, reflect the autonomic function with information on the balance between sympathetic and parasympathetic activities in adults and infants [17, 18]. The HF is considered a major contributor to the efferent vagal tone, while the LF component represents a quantitative index of the sympathetic and parasympathetic activities [19]. Consequently, the LF/HF ratio was considered to reflect the balance between sympathetic and parasympathetic functions [18–20]. We considered that the HRV measurement could be suitable to monitor the infant's condition with changes in the autonomic function. Since the effect of music might include wakefullness, pleasantness, or unpleasantness in infants, observation of the autonomic function may be suitable to observe the effect of music, although the HRV does not simply indicate stressful or pleasant conditions in infants.

2. Method

2.1. Participants

Thirty premature or low-birth weight (LBW) infants in the NICU or GCU were involved in the present study. The mean gestational age was 35.6 ± 2.4 (SD) weeks (range, 26 3/7 – 38 4/7 weeks). The present experiment was applied to the participant once in the NICU/GCU with a mean corrected gestational age of 37.3 ± 1.4 weeks (range, 33 4/7 – 39 5/7 weeks). The corrected gestational age indicated the sum of the gestational age at birth and days after birth. Profiles of participants are shown in Table 1. The participants did not suffer from diseases or organ failure, but they were preterm or LBW. Infants under complete mechanical ventilation were excluded. Infants with brain damage and auditory disturbance, which were revealed by magnetic resonance imaging (MRI) and auditory brainstem response (ABR), respectively, were also excluded.

Written informed consent was obtained from their parents with an agreement for participation in the present study after receiving a document exploring the study. The present study was approved by local ethical committees at the Faculty of Medicine, Nagoya University, and Nagoya City Hospital (No. 15-604), based on the Declaration of Helsinki [21].

Table 1
Characteristics of the study population

Male/female	10 males and 20 females	
	Mean ± SD	Range
Gestational age	35.6 ± 2.4 (weeks)	26 3/7 – 38 4/7 (weeks)
Corrected gestational age at the time of the experiment	37.3 ± 1.4 (weeks)	33 4/7 – 39 5/7 (weeks)
Days of the experiment after birth	14.9 ± 17.6 (days)	3 – 89 (days)
Birth weight	1,936.6 ± 340.8 (g)	946 – 2,440 (g)
Body weight at the time of the experiment	2.031.7 ± 233.8 (g)	1,576 – 2,538 (g)

*Corrected gestational age: sum of gestational age at birth and weeks after birth.

2.2. Experimental design

The present experiment was carried out for 30 minutes from 1:30 to 4:00 p.m., which was approximately 30 minutes after feeding time. The behavioural condition of each infant at the time of the experiment was drowsy or quiet but alert, as assessed by the neonatal behavioural assessment scale of Brazelton [22, 23].

The ECG signals were obtained by two electrodes attached to both shoulders via an electrocardiogram monitor (M8004A, Philips), and heartbeats at the peak of the QRS complex of the ECG were recorded by a digital recorder at a sampling rate of 500 Hz (RR-US310, Panasonic, Japan). The ECG signals were sequentially recorded under three conditions for 10 minutes each: 1) environmental condition with only ambient noise (Con-1), 2) environmental condition with BGM (BGM condition), and 3) environmental condition with only ambient noise 10 minutes after BGM (Con-2). The ECG recording for 10 minutes included more than 512 beats of ECG, which could be applied to HRV analysis. The songs used for the BGM were lullabies for a baby with sounds of a music box. The BGM was delivered through a speaker placed in the incubator. The mean sound intensity at the head of the infant was 55 dB, and the sound was always less than 65 dB. The recording was carried out three times on different days within a period of four weeks for each infant.

2.3. Data analysis

All data on heartbeats recording were digitally transferred off-line and analyzed using a signal processor (Spike-2, CED, UK). R-R interval of each heartbeat was obtained, and the R-R intervals for 10 minutes in each recording condition were sequentially collected. The sequential R-R interval included HRV during each recording condition for 10 minutes. Frequency analysis of HRV was then applied using fast Fourier transform, which provided a power value for each frequency of HRV. Summations of power values between 0.05 and 0.15 Hz and between 0.15 and 0.40 Hz were defined as LF and HF components of HRV, respectively. The LF/HF value was the ratio of LF to HF. Each value of the HRV component was compared among the three environmental conditions using one-way repeated measures analysis of variance (ANOVA) followed by Bonferroni-Dunn correction for multiple comparisons. The relationship between the HRV values and birth weight, gestational age, and corrected gestational age or body weight at the time of the experiment was calculated. The correlation between values was tested by Pearson's test. A p-value less than 0.05 was considered to be significant.

3. Results

Heartbeats were recorded successfully in all infants. There was no complication or unexpected effects of the experimental settings. The birth weight was correlated with the gestational age ($r = 0.74$, $p = 0.0001$), but the body weight at the time of the experiment was not correlated with the corrected gestational age at that time ($r = 0.32$, $p = 0.061$) (Fig. 1). The mean heart rate was 141.2 ± 13.2 (SD) and 139.9 ± 13.3 beats per minute under the Con-1 and Con-2 condition, respectively, and the mean heart rate during BGM condition was 139.4 ± 12.7 beats per minute. The mean HR did not change among conditions of the present experiment (F (24, 2) = 1.158, $p = 0.322$, ANOVA) (Fig. 2). The mean heart rate at the time of the experiment (Con-1) was negatively correlated with the birth weight ($r = -0.58$, $p = 0.0012$, Pearson's test) and gestational

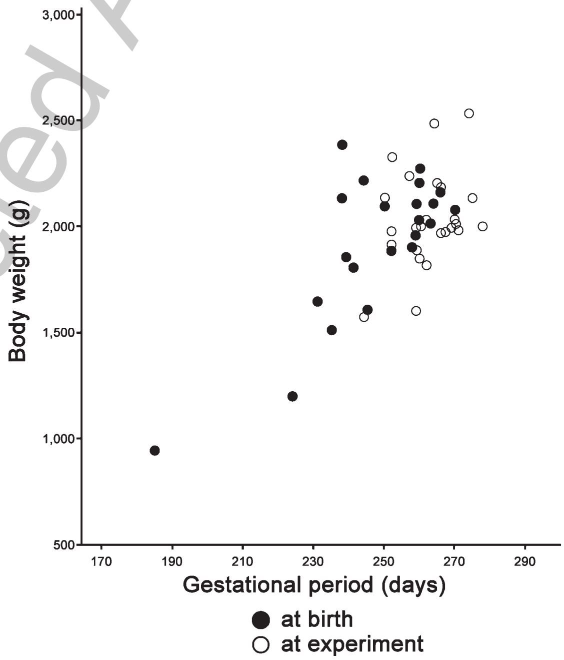

Fig. 1. Correlation between the birth weight and gestational age at birth (•) and at the time of the experiment (○). The birth weight was correlated with the gestational age ($r = 0.74$, $p = 0.0001$, Pearson's test), but the body weight at the time of the experiment was not correlated with the corrected gestational age at that time ($r = 0.32$, $p = 0.061$).

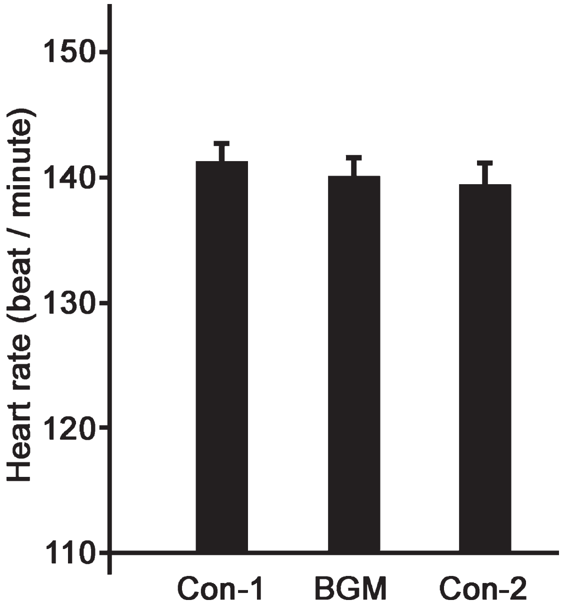

Fig. 2. Mean heart rate (HR) among auditory environmental conditions. There was no difference in the mean HR among experimental conditions: control condition before background music (BGM) (Con-1), BGM, and 10 minutes after BGM (Con-2).

age ($r = 0.41$, $p = 0.021$), but it was not correlated with the body weight or corrected gestational age at that time of the experiment (Table 2). The LF and HF values decreased under the BGM condition compared with the Con-1 condition ($p < 0.05$, ANOVA, Bonferroni-Dunn's correction, Fig. 3), but the difference between the BGM and Con-2 conditions did not reach significance for LF ($p = 0.07$) or HF ($p = 0.06$). The LF/HF ratio did not change among the conditions ($p = 0.21$). The LF, HF, and LF/HF values under the Con-1 condition were not correlated with the body weight or corrected gestational age at the time of the experiment (Table 2). The LF and HF at the time of the experiment (Con-1) were not correlated with the birth weight or gestational age at birth. However, the LF/HF at the time of the experiment was correlated with the birth weight ($r = 0.39$, $p = 0.025$), but not with the gestational age at birth (Table 2).

4. Discussion

The present results indicated that the values of the LF and HF components decreased under the BGM condition without a significant change in the LF/HF ratio. With the interpretation of HRV components in previous studies [18–20], the decrease in the LF and HF values without LF/HF change under the present experimental conditions suggested decreases in parasympathetic tone and levels of sympathetic and parasympathetic activities without a change in balance between activites.

One piece of evidence from the results of the present study was that the auditory environment with BGM affected the autonomic condition of preterm infants. From this results of the prsnt study, there may be at least two useges of BGM for infants in NICU/GCU. One was that BGM could be used for intervention to facilitate development of infants. A recent study reported that intervention with BGM for preterm infants was positive in general, although some exceptional results were obtained [2, 6], and effective outcomes following sensory-motor intervention with music have been reportred for children [24, 25]. However, evidence regarding the mechanisms of the music effect to infants is not enough [11], and it has not been well established how non-pharmacological intervention, including music, should be used for infants [26]. The present study showed that BGM modulated autonomic function and it shifted vagal tone down, i.e., decreased HF, during awake state. As reporeted in a previous study using evaluation with respiratory and heart rates, music could be also used for possible effect to ameliorate stress in premature infant in NICU [6]. The present and previous results indicated that BGM could be used as a non-pharmacological intervention to infants in NICU.

Another possibility regarding usage of BGM was that BGM, a non-invasive stimulation, could be used to evaluate responsiveness of infants. Previous papers reported that poor response in autonomic function,

Table 2
Correlation between HRV values (Con-1) and gestational age, birth weight, and gestational age or body weight at the time of the experiment

r value (*p*-value)	HR	LF	HF	LF/HF
Gestational age	–0.41 (0.021)*	0.013 (0.53)	0.0035 (0.99)	0.32 (0.11)
Birth weight	–0.58 (0.0012)*	0.27 (0.19)	0.12 (0.57)	0.39 (0.025)*
Corrected gestational age at the experiment	–0.11 (0.31)	0.049 (0.82)	0.019 (0.93)	–0.051 (0.41)
Body weight at the experiment	–0.072 (0.37)	0.099 (0.64)	–0.0044 (0.98)	0.053 (0.40)

*HR: heart rate, LF: low-frequency heart rate variability (HRV) component, HF: high-frequency HRV component. Corrected gestational age: sum of gestational age at birth and weeks after birth. *$p < 0.05$, gray columns, Pearson's test.

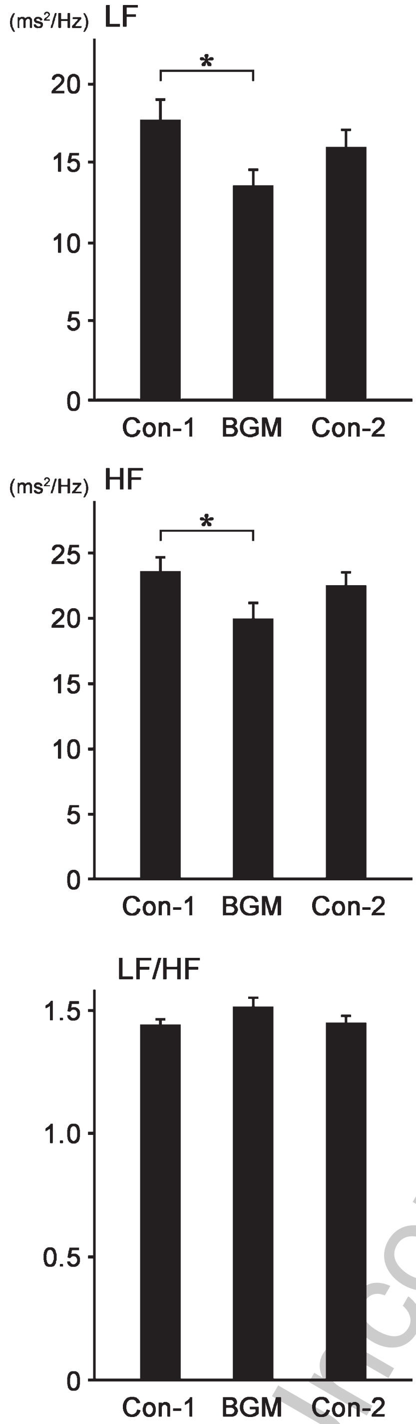

Fig. 3. Difference in HRV values among auditory environmental conditions. The low- (LF) and high- (HF) frequency HRV components under the background music (BGM) condition were lower than under the control condition before BGM (Con-1). Under the control condition 10 minutes after BGM (Con-2), LF and HF values tended to increase to those of Con-1, but the change was not significant. The LF/HF ratio was not significantly changed. *$p < 0.05$, Bonferroni-Dunn's correction.

HRV, indicated poor cardiac and respiratory development in infants [27, 28]. By observing autonomic responsiveness in HRV during non-invasive and non-pharmacological intervention, including BGM, development of autonomic function could be evaluated in infants in NICU/GCU [29]. Regarding HRV in infants in the present study, the development of the autonomic function in preterm infants was slower after birth than the increment of the body weight. The birth weight of the preterm infants was correlated with the gestational age and the HRV components in the present study. The infants gained weight until the experiment, their HR and LF/HF values were still correlated with the birth weight at the time of the experiment in the present study. The HF showed an increase with the gestational age in previous reports [17], but Mulkey et al. [29] reporeted that impaired autonomic function development remained, at least until 39 weeks gestational age, in preterm infants without brain injury. The discrepancy between body weight and HRV components observed at the time of the experiment in the present study might be due to premature autonomic function sustaind in the preterm infants.

Interpretation of the HRV values in infants was not simple in the previous study [18]. The HRV components were affected by sleep stages [30], the ambient temperature [31], and attention [32] in infants. The awake-sleep condition and attention may have influenced the present results, from based on a previous report of a decrease in HRV values during attention [32]. However, interpretation in the change of HRV components of infants should be carefully addressed, as mentioned above. The HRV components could be a marker of stress [33]. The sympathetic activity increases hear rate under mental and physical stressors, and parasympathetic activity, on the other hand, facilitates homeostasis of the body resulting in reduced heart rate [34]. However, the heart rate did not change among conditions in the present study, which indicated stable sympathetic activity among conditions at least regarding the effect on the heart rate. We considered that the BGM condition was not a stimulus that unsettled the infants because of the stable heart rate during BGM.

4.1. Limitation

In the present study, experimenal conditions were limited to two pieces of music. We should avoid unnecessary risks to infants, and we used a relatively low-risk intervention with music, with agreement of parents of participants, was planned. Additional studies are needed to clarify which acoustic environment is suitable for infants, an important issue affecting care given by mothers to infants. Since the present study observed instantaneous effect of BGM on autonomic function in infants in NICU/GCU, developmental processes of HRV in preterm infants and long-term effects of intervention with BGM remain unclear, so additional investigations are needed regarding autonomic function development and factors affecting the function.

5. Conclusion

We observed a change in the autonomic function during the first days of life in preterm infants in the NICU/GCU using HRV analysis. There was a significant change in the autonomic function based on HRV among environmental conditions with BGM. The present results showed that an environment with a range of BGM affected the autonomic condition of infants. The present study also suggested that BGM, a non-invasive and non-pharmacological intervention, could be an evaluation tool for autonomic function in infants in the NICU/GCU.

Disclosure statement

The authors declare no conflicts of interest associated with this paper.

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