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The Effect of Moderating Noise Pollution on Premature Infants' Behavioral and Physiological Responses in Neonatal Intensive Care Unit Running Title: Noise Pollution and Premature Infants' Response

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Abstract

Background: *The aim of the study was to determine the effect of moderating noise pollution on premature infants' behavioral and physiological responses in a neonatal intensive care unit (NICU).*
Methods: *110 premature infants hospitalized in the NICU ward of hospitals in Tehran were selected. All the infants who met the research criteria were allocated and assigned to the experimental and control group (n=55). The sampling method was non-probability and convenient. In the first section of time, each infant with inclusion criteria, inserted in the control group and then in the second section of time, infant with inclusion criteria placed in the experiment group. In the first section, the educated nurse measured the LAeq, LC, LA, infants' behavioral responses, and physiological responses. In the second section, noise modifying interventions were implemented in the experimental group for 6 weeks, and then LAeq, LC, LA, infants' behavioral responses and physiological responses were measured with the same methods.*
Results: *Infants' heart rate in the experimental group was significantly lower than the control group (Pvalue<0.05), and atrial blood O_2 Saturation was significantly higher than the control group (Pvalue<0.05). There was no statistically significant difference in the mean number of crying, sleeping, and Moro reflex of premature infants in the two groups. Also, the sound-pressure level in the C-weighted network in the experimental group was lower than the control group (Pvalue=0.021). The sound-pressure level of the C-weighted network was obtained in the same way (Pvalue=0.008).*
Conclusions: *Based on the results, moderating noise pollution in NICU can lead to heart rate deceleration and atrial blood O_2 saturation acceleration in premature infants.*

Keywords: Noise pollution, Premature infants, Behavioral responses, Physiological responses, Neonatal intensive care unit.
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Introduction

Today, there is a significant increase in the survival of preterm infants; however, such babies need a long-term stay in the intensive care unit.[1,2] It is very important to take measures that help the development of these infants under such conditions. Maximum fetal brain development occurs between weeks 29 and 41 of gestation age;[2] but premature infants at this sensitive time and before proper development of their hearing system, pass through the safe environment of the mother's uterus to a cold and noisy environment.[3] Premature infants admitted to the intensive care unit usually close their eyes to dazzling lights, but they cannot lift their ears in response to noises.[4] They can understand and respond to the surrounding sounds, and the NICU noise is the first stressor for them.[5]

Unlike the term infants who are born after 37 weeks of gestational age, premature infants cannot adapt to outside the uterus stresses such as loud noises, because their autonomic nervous system is not mature as well as neurons of the brain cortex of the premature infants are not matured because the myelination of the nervous system begins in the third trimester of pregnancy.[6] Hearing, vision, and nervous systems of an immature infant must be developed after the birth in the incubator in an intensive care environment. Environmental noises are an undesirable phenomenon that not only affects the baby's hearing system but also has direct effects on the development of its central nervous system and can also affect its future growth and development.[7,8]

Human activities and nursing interventions that produce loud sounds can reduce the amount of arterial oxygen saturation to less than 80 percent.[6] Extra auditory stimulation would result in many physical changes like an increase in heart rate, blood pressure, and respiration rate and a reduction in arterial oxygen saturation.[6,9] As well, it can lead to significant changes in the behavior of newborns in the intensive care unit.[10] For example, it causes the infant to startle and disturb her/his sleep.[11] These changes enhance the infant's need for calories, so he will not have sufficient calories to grow which result in long term negative effects.[6,10]

Environmental noises should be controlled in terms of the time of exposure, type of sound and volume, to provide an appropriate caring situation for infants, otherwise, they will be at risk of neural deafness, speech, and language impairment, and other dysfunctions.[12,13] Also, in response to these stimuli, infants will suffer from behavioral changes like irregular sleep and crying.[14]

In general, noise pollution is known as unwanted sounds which have different physiological and psychological impacts on individuals.[7] American academy of pediatrics (AAP) mentioned that the optimal level of environmental noise in the neonatal intensive care unit is less than 58 dB and committee on environmental health determined the standard level of these noises is 45 decibels or lower.[13,15,16] World Health Organization (WHO) stated that the level of noise pollution should not exceed 35 decibels in hospitals.[17] However, prior studies showed that noise pollution is more than 45 dB during the day and more than 35 dB at night in NICUs.[18,19] But results of the studies showed that usually sound levels in NICUs are higher than the limit values proposed by these organizations.[20-22]

The main sources of noise pollution in NICU are monitoring system and equipment alarms, nursing and medical procedures, staff conversations, moving metal equipment and unit furniture, closing and opening of the shelves, phone rings, and parent's presence in the ward, infants crying, and the sound of falling equipment from the height.[17,23] Changing the NICU environment to moderate noise pollution will provide a proper situation for infants to grow and develop. Nurses can have a significant effect on moderating environmental noise by talking and laughing in a gentle voice, closing the incubator door and drawers gently and responding quickly to alarms, and reporting far from the beds and incubators.[6]

Several studies confirmed that appropriate nursing interventions moderate NICU noise pollution and have a positive impact on infants. Ahamed et al. mentioned that education and increasing awareness of providers or staff in the NICU, behavioral changes or bringing about change in their culture, and environmental changes such as modifying the equipment related sources of noise, decreased the noise level in the NICU.[8] Implementing interventions for staff education as well as changes in the environment were critical to sustaining appropriate noise levels, recommended in Casavant et al. review.[11] Slavin et al by moderating NICU noise pollution encountered a decrease in infants' blood pressure and their sudden movement.[24] Taheri et al. concluded that establishing a silent period can improve arterial oxygen saturation.[25] Brandon et al. stated that the implementation of a period of light and noise reduction would increase infants' sleeping period.[26]

In this regard, Altunco et al. moderated noise pollution by applying insulation panels around the incubator.[13] Other studies have introduced environmental changes in NICU as the main factor to moderate noise.[14] In fact, by moderating sound-pressure level in NICU, there will be benefits such as increased physiological stability, a relatively normal and progressive improvement in the development of a newborn's nervous system, and the comfort of the parent.[8,14]

Infants are exposed to unwanted sounds due to their inevitable exposure to medical equipment, procedures, staff, and parent presence in NICU that can have a damaging impact on their health, development, and growth. These conditions can affect the comfort of the infants and cause stress for them and lead to adverse changes in their vital signs and behaviors such as increases in respiration and heart rate, crying, tremor, and sudden movements. Overall evidence suggests that in the NICU modifying the noise is warranted to enhance infant growth and neurodevelopment. Since such interventions have not been implemented in our country, as much as conducted in the NICUs, therefore, the present study aimed to reduce the noise pollution and attempted to determine its effect on the physiological and behavioral responses of premature infants admitted to NICUs.

Materials and Methods

This research was a quasi-experimental study. According to previous studies and considering the probable loss of subjects, the sample size was 110 preterm infants hospitalized in NICU. The sampling method was non-probability and convenience from infants hospitalized in NICU wards of hospitals in Tehran; these hospitals belong to the Tehran university of medical sciences and were similar in routine care for the neonates in NICUs. Infants were allocated equally in two groups of 55 experimental and control. To access samples that met the eligibility criteria and to prevent the effect of the intervention on the control group, in the first period, every infant eligible for inclusion in this study was placed in the control group and after the data gathering, eligible infants were placed in the experimental group.

Inclusion criteria included preterm infants with gestational age lower than 37 weeks (mean of 32±2.2 weeks) and weight less than 2500 grams (mean of 1555.2±390.6 gr) at birth. These infants were in similar incubators in terms of coverage, temperature, humidity, and oxygen. There was no mechanical ventilation. At the time of data collection, infants were under the age of 28 days (mean of 10.54±7.07 days) and hospitalized for at least two days in NICU. Criteria for exclusion were unwanted noise at the time of data collection for both groups. During the data collection, if there were unavoidable events such as abdominal pain and spasm in the infant, and as a result of restlessness, the data gathering was temporarily discontinued and restarted when infants were calm.

Data collection tools included a questionnaire on demographic characteristics of infants and NICU, a checklist of audio records, a checklist of infants' behavior responses, and a checklist of infants' physiological responses which were made by the researchers. Since we only wanted to observe and record the behavioral and physiological responses of neonates, we used a checklist and did not need a questionnaire. A trained nurse collected all the data of two groups; she filled questionnaire on demographic characteristics using infants' documents and interviewing staff in both groups. The checklist of audio records consisted of three items about the sound-pressure level in A and C weighted network and equivalent the sound-pressure level in A-weighted network that was filled 12 times over a 10-minute interval according to the number showed by an audiometer. The checklist of infants' behavioral response had also three items and was completed by a trained nurse regarding the frequency of crying, sleeping, and Moro reflex for 12 times over a 10-minute interval. The checklist of physiological responses that included three items was filled with information on respiratory rate, heart rate, and arterial oxygen saturation in the same way. These checklists were filled in two shifts (evening and morning) for a total of 24 times for each infant.

The mentioned tools were prepared with the use of books and published papers by the research team and to gain access to the face and content validity used experts' ideas and then 12 faculty members commented on how to improve the tools. The reliability of these scales was estimated through test-retest in a sample of 30 infants with a two-week interval.

Infants' physiological responses include respiratory rate and heart rate were recorded by using the numbers of monitoring devices attached to the infant. Arterial oxygen saturation percentage was obtained through the skin with the use of a pulse oximeter. A medical engineer was in charge of the calibration of the monitoring device and pulse oximeter.

In this study, the synchronous audiometer machine with an analyzer (Model: TES 1358, made in Taiwan) was used for the measurement of sounds. This machine has the potency to measure LAeq and sound-pressure levels in the A and C weighted network. The measurement range is 30 to 130 decibels and was calibrated according to the manufacturer's instruction and using standard sounds of NICU by a sound level meter expert.

Since sounds change over time, a numerical value is needed to describe the sound level. Sound-pressure level in weighted network or LAeq (Equivalent continuous A-weighted sound pressure level) is the average sound level per unit of time and is obtained through mathematical calculations. It is noteworthy to mention that with measuring the average sound-pressure level, changes in sound levels and their durability is taken into consideration. Sound-pressure levels in A-weighted network or LA (A-weighted Sound Level) and C weighted network or LC (C-weighted sound level) indicate the result of a sound measurement that adapts to the human auditory system. LA can adapt to lower levels and LC at higher levels. In other words, LA and LC are referred to as different sensitivity scales for measuring noise pollution.

The sound-pressure level in an A-weighted network is a level in which sound levels with different frequencies are collected and reach a weight to achieve on frequency sensitivity of the human hearing system. The significance of this level is due to its relation to human hearing damage. Furthermore, it is used to assess noise pollution and decide about it. This is the most common scale for measuring environmental noise pollution.

Sound-pressure level in C-weighted network states the frequency sensitivity of the human ear to extreme noise pollution and is consistent with the physical reality of sound, in a wide range of comprehensible human frequencies. Thus, in many cases, it played the role of an index that shows the real amount of environmental sound.

To determine the probable sound differences in incubators of the three hospitals, and collecting the basic data, a trained nurse put an audiometer in incubators and recorded the LAeq equivalent sound level of all incubators with no cover and baby.

Using an audiometer, a trained nurse collected and recorded all the data regarding the control group in two stages. These were such as sounds of devices and machines, routine care process, opening and closing the incubators, doctors and nurses' conversation in the ward and near the incubators, shoes of people at the unit, moving the portable equipment, alarms of the telephones, monitors, incubators, etc. At the same time, data from infants' physiological and behavioral responses were measured and recorded in a checklist in two phases in the morning and evening shifts. In each of the shifts, data from sound measurement (the equivalent sound-pressure level in the weighted network (LAeq) and sound-pressure level in A and C weighted network) as well as infants' physiological (heart and respiratory rate and atrial O_2 saturation) and behavioral responses (Frequency of crying, sleeping and Moro reflex) were measured and recorded in 12 times, over 10-minute intervals. In other words, 24 consecutive measurements were conducted for 4 hours. It should be noted that data collection lasted for 2 hours in the morning shift from 8 AM to 2 PM, and also 2 hours in evening shifts from 2 PM. to 8 PM, randomly. Data were collected on workdays with the same congestion and not on the weekends. If an infant were out of the incubator for breastfeeding or any other reason, 2-hour data measurement and recording began again.

After the data collection for the control group, the intervention of moderating noise pollution was applied. All the staff was informed of the adverse effects of noise pollution in NICU and they were asked to talk in a low voice, avoid shouting, open and close incubators by a special clamp and with caution, and talk far from the incubators. Some individuals remind people to be quiet and a warning sign was installed in a suitable place as a reminder.

Actions have been taken to reduce environmental noise included placing a thick insulator over incubators, providing disposable shoe covers for staff and parents and rubber covers for trolley legs and other portable equipment, reduction of sounds generated by drawers, using blinking lights or visual warnings whenever possible, minimizing the ringing sound of phones and entrance door to the ward, quick response to alarms, performing nursing interventions quietly and refraining from putting any kind of means on incubators.

6 weeks after employing these changes in NICU, a trained nurse collected and recorded data obtained from the sound measurement and infants' behavioral and physiological responses in morning and evening shifts, for 12 times and over a 10-minute interval. 24 consecutive measurements over 4 hours were done.

This study is done by the permit of the nursing and midwifery faculty of Tehran university of medical sciences. All the demographic information of the study samples is completely confidential. Using noise pollution interventions had no contradiction with the infants' usual care process and it was not harmful. The present research is confirmed by the Ethics Committee of Tehran university of medical sciences by the code of 1234/140/D/91.

SPSS was used for data analysis. To summarize and organize results, descriptive statistics like relative and absolute frequency distribution table, dispersion, and central tendency index were applied, and to achieve research objectives chi-square test and T-test were used.

Results

Analysis of demographic characteristics of research units indicated no statistically significant difference between control and experimental groups (table 1). There was no statistically significant difference between the mean LAeq equivalent sound level of incubators without coverage and infants in three hospitals (Pvalue=0.38).

There was a statistically significant difference in the mean sound-pressure level in C-weighted network in the two groups. The experimental group had a lower level than the control group (Pvalue=0.021). Moreover, the mean sound-pressure level in the A-weighted network was lower for the experimental group (Pvalue=0.008). Two groups showed no statistically significant difference in LAeq equivalent sound-pressure level (Pvalue=0.056) (table 2).

Statistical analysis of data in two experimental and control groups showed no statistically significant difference in the frequency of crying (Pvalue=0.500), sleeping (Pvalue=0.696), and Moro reflex (Pvalue=0.125) (table 3).

It was found that the mean heart rate of infants in the experimental group was significantly lower than the control group (Pvalue=0.001), as well as there was a significant difference between the control and experimental group in the percentage of arterial blood O_2 saturation (Pvalue=0.014) as in the experimental group, higher percentage of arterial blood O_2 saturation was observed. But there was no significant difference between the control and experimental group in respiratory rate (Pvalue=0.781) (table 4).

Table 1. Comparing the demographic variables in experiment and control groups

Variables	Groups		Pvalue
	Experiment	Control	
Hospital N (%)	-	-	
Valiye-asr	18(32.7)	18(32.7)	
Mahdiye	19(34.6)	18(32.7)	
Mirza-kochak-khan	18(32.7)	19(34.6)	0.973
Incubator type N (%)	-	-	
Tusan	34(61.8)	38(69.1)	
YP	19(34.5)	13(23.6)	
other	2(3.7)	4(7.3)	0.365
ype of labor N (%)	-	-	
Natural	6(10.9)	6(10.9)	
Caesarean section	49(89.1)	46(83.6) Missing: 5.5%	0.918
Infant gender N (%)	-	-	
Male	32(58.2)	24(43.6)	
Female	23(41.8)	30(54.5) Missing: 1.9%	0.151
Infant age (Day) (M±SD)	10.6±7.2	10.5±7.0	0.945
Gestational age (week) M±SD	31.74±2.18	32.24±2.11	0.227
Birth weight (gr) (M±SD)	1509.5±360.0	1601±417.2	0.221
Infant weight in time of sound control (M±SD)	1477.8±384.7	1575.8±328.3	0.154
Day number of hospitalized to sound control time (M±SD)	12.53±6.22	12.69±6.93	0.897

*Significant level=0.05

Table 2. Comparing the sound-pressure level in C & A weighted network and L_{Aeq} in experiment and control groups

variable	Groups				Pvalue
	Experiment		Control		
	Mean	Std. deviation	Mean	Std. deviation	
Sound-pressure level in C weighted network	66.95	3.13	67.27	3.25	0.021*
Sound-pressure level in A weighted network	62.78	6.91	65.54	3.05	0.008*
L_{Aeq} equivalent sound-pressure level	79.15	2.34	80.05	2.66	0.056

*Significant level=0.05

Table 3. Comparing the behavioral responses in experiment and control groups

variable	Groups				T	df	Pvalue
	Experiment		Control				
	Mean	Std. deviation	Mean	Std. deviation			
Crying number	1.55	4.05	2.02	3.11	-0.68	105	0.500
Sleeping number	20.26	4.17	19.96	3.77	0.39	105	0.696
Moro reflex number	3.25	1.71	2.51	3.00	1.55	82.46	0.125

*Significant level=0.05

Table 4. Comparing the physiological responses in experiment and control groups

variable	Groups				t	df	Pvalue
	Experiment		Control				
	Mean	Std. deviation	Mean	Std. deviation			
Respiratory rate	50.38	3.53	50.20	3.10	0.28	106	0.781
Heart rate	94.69	7.83	99.50	7.03	-3.39	108	0.001*
Atrial blood O_2 saturation	97.01	5.03	95.12	2.50	2.49	107	0.014*

*Significant level=0.05

Discussion

Noise in the neonatal intensive care unit is an environmental stressor, especially for neonates who have a medical problem, it can be dangerous. Health care providers are responsible for identifying and managing stressors. The American academy of pediatrics (AAP) considers reliable behavioral indicators (body movement, crying, and sleep) and physiological indicators (oxygen saturation level, blood pressure, respiration rate, etc.) to evaluate and manage stress in infants.[27]

To moderate noise pollution in NICU in this study, the following changes were made: training staff how to open and close incubators carefully, moderating environmental noise at the time of staff conversations and reporting, using a sound insulator over incubators, disposable shoe covers, drawer sound reduction, quick response to alarms and replacing them with visual alarms, running nursing intervention with the minimum sound and manipulation, and avoiding putting things on the incubators. These changes reduced LC sound average (sound corresponding to the sound in the environment) for 0.42 dB and also reduced LA sound average (sound matches human hearing) for 2.76. Average LAeq sound level reduced to 0.9 dB, but it was not statistically significant. These changes had no impact on behavioral responses. Considering that there was a statistically significant difference before and after the intervention in the LC and LA sound, But the US Environmental protection agency's noise standards for hospitals are 45 dB per day and 35 dB per night are recommended not to exceed 45 dB in NICU environments.[28] This is while the noise level in our study was higher than this level. Hernández-Salazar and his colleagues reported an environmental noise level of the intensive care unit of 63.3 dB.[29]

In a study that aimed to determine the effect of nurses' training on noise pollution in the intensive care unit, it was found a significant decrease in LA but still reported sound level 53.89 dB after the intervention.[30] However, the higher environmental noise than the recommended level is a factor that is increased sympathetic system activity.[31] And increase the sound level in the baby care environment associated with an increased metabolic need for oxygen which can lead to an increase in cardiac function.[32] The results of the present study showed that reducing noise pollution is associated with improved arterial blood O_2 saturation and decreased heart rate. Similar to these findings Cardoso and colleagues (2015), reported significant differences in the heart rate and oxygen saturation were noted when newborns were exposed to noise.[33] In a study in Ireland, implementation of a NICU quiet hour protocol consisted of moderating noise pollution and educating staff to minimize the sounds generated by conversations and activities and move infants cautiously had significantly reduced infants 'movement and Moro reflex, however there was no statistically significant effect on infants' heart rate and arterial oxygen saturation.[24]

Studies show that loud noises, intense light, and sudden movements can trigger a baby’s Moro reflex. In the present study, the effect of moving infants cautiously on the behavioral responses was not examined. Brandon et al (2007), observed that creating periods of noise and light reduction increase infants' sleep periods,[26] but in present study only noise was reduced whit such implementation. In the book "Universal declaration of rights for the premature baby", article VII states: "Every premature baby has the right to rest and one should therefore comply with its period of light and deep sleep, which will henceforth be taken as essential to its proper psychic development and its biological regulation. Interrupting randomly and irresponsibly, without due cause, the sleep of a premature baby is indicative of abuse". And in article VIII: "Every premature baby has the inalienable right to silence, that allows the baby to feel as close as possible to the intrauterine sound environment, in respect to its thresholds and sensitivity. Any sound sources that disrespects this right shall be deemed criminal, heinous, and repugnant”.[34]

Despite the changes resulting from the intervention of noise pollution moderation at the level of NICU noises, the sound-pressure level for the two groups is above the standard level. Therefore, there is a crucial need for conducting measures in NICUs to moderate noise pollution and prevent its detrimental effect. In addition to noise pollution, other factors harm infants' behavioral and physiological responses such as extra light, different drugs, pain, and cure. Many factors lead to prolonged hospitalization and the lack of proper facilities in wards makes it hard to control them. These factors have not been discussed in the present research and further research and investigation are needed to control them.

A specific feature of this study was that to avoid the intervention effect on the experimental group, data were collected firstly in the control group and then in the experimental group. Reducing the negative effect of the time difference, statistical analysis was done and no statistical difference was found between two groups regarding demographic and environmental variables. Furthermore, samples were collected at random hours in two morning and evening shifts on workdays. It is recommended to conduct studies employing precise methodologies to identify the effects of reducing noise pollution in NICU.

As confirmed by many studies, peace and quiet in NICU provides an optimal setting for infants' brains to mature.[35] Based on the result of this study and several other studies in this field, it can be said, a healthy environment free from noise pollution can have a substantial influence on infants' growth and development, and it is beneficial for staff as well. Investigating the effect of interventions on staff's behavioral and professional responses is worthy of further research.

In general, it should be said that the noise pollution level in our NICUs is higher than the international standard. In this study, interventions had no effect on preterm infants' behavioral and physiological responses and did not reduce noise pollution and its level remained above 58 decibels. Further research and investigations are needed to determine the real effects of nursing interventions on reducing noise pollution and infants' behavioral responses.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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