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Effect of Light and Noise on Physiological Parameters in a Sample of Preterm Neonates in the Neonatal Intensive Care of Cairo University Teaching Hospital

Tamer A. Abdel Hamid[1], Dalia Khairy Abdel Latif[1], Ahmed Bakeer[1], Alshaymaa A. Ibrahim[2*], Khaled Amin Nasef[1]

1. Pediatric Department, Faculty of Medicine, Cairo University, Egypt
2. Clinical and Chemical Pathology Department, National Research Centre, Cairo, Egypt

ABSTRACT

Background: Some of the neonatal intensive care units (NICUs) partially lack the standard protocols for controlling noise and light. The healthy physical environment of NICUs is crucial for the continued normal development of preterm neonates. The present study aimed to assess the physiological changes (including heart rate, respiratory rate, blood pressure, temperature, and oxygen saturation) induced by noise and ordinary light often existing in NICUs in a sample of preterm neonates admitted to the private ward of NIUCU due to their low-birth weights.

Methods: The present study included 100 preterm neonates, 50 neonates were exposed to noise which is often induced in the open ward of NICU, and the other 50 newborns were exposed to cyclical light.

Results: During noise exposure, neonates in the private ward displayed a significant increase in heart rate, respiratory rate, as well as systolic and diastolic blood pressure. Moreover, they showed a marked decrease in oxygen saturation in the first and second days in the NICU. Furthermore, the neonates exposed to dim light demonstrated a significant decrease in heart rate, respiratory rate, systolic and diastolic blood pressure, as well as a significant increase in oxygen saturation, compared to those exposed to ordinary light on the first and second days. Nonetheless, body temperature did not show any significant change with noise or light exposure either on the first day or the second one.

Conclusion: As evidenced by the obtained results, exposure to excessive light and noise was associated with significant changes in preterm neonates' vital signs. Moreover, the findings highlighted the inadequacy of the current conditions in a sample of Egyptian NICUs for ideal neonatal care. In order to create a favorable environment to help better growth and prevent prematurity complications, it is recommended to devote more assiduous attention to the care conditions of neonates in NICUs in Egypt.

Keywords: Blood pressure, Heart rate, Neonatal intensive care unit, Respiratory rate

Introduction

It is well documented that the normal development and growth of neonates can be affected by different factors (1). There is no doubt that the neonatal intensive care unit (NICU) is not a good substitute for the maternal placental unit. Although NICUs offer specialized medical care, they do not necessarily provide the ideal environment for neonates (2). They are usually inappropriate for neonates' sleep due to the brightness of overhead lights and excessive noise. Moreover, repeated nursing procedures may disturb the sleep cycle of neonates (3).

Different studies have demonstrated that disturbance in the sleep cycles of preterm neonates may lead to various complications, such as increased susceptibility to diseases, cognitive deficits, as well as disorders in consciousness and physiological status which may extend to sudden infant death syndrome (4). The NICU is particularly a noisy place due to the sounds originating from alarms, ventilators, phones, and staff conversation. Premature neonates have an

* *Corresponding author*: Alshaymaa A. Ibrahim, Clinical and Chemical Pathology Department, National Research Centre, Cairo, Egypt. Tel: 01020500501; Email: shaymaa_t@hotmail.com

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immature auditory system (5); therefore, their exposure to high-frequency sounds may also result in language or attention disorders (6).

Moreover, exposure to a high level of noise and light affects the respiratory rate and blood pressure oxygenation. Consequently, it can affect the immune and neuroendocrine systems, leading to physiological stress responses (7-9). Accumulating data suggest that the average sound levels in the NICU should be within the range of 70-80 dB. Furthermore, the American Academy of Pediatrics (AAP) pointed out that the safe noise level should not exceed 45 dB in the NICU. Reduced noises and lighting have been reported to improve stability and growth; moreover, they stabilize the heart and respiratory rates, blood pressure, and motor activity in preterm neonates (10).

In Egypt, there is a dearth of studies regarding the effect of noise and light on neonates in NICUs. In light of the aforementioned issues, the current study aimed to assess the physiological changes (e.g., heart rate, respiratory rate, blood pressure, temperature, and oxygen saturation) induced by noise and ordinary light in NICUs in a sample of preterm neonates admitted to the NICU of Cairo University Pediatric Hospital due to their low birth weights (LBW).

Methods

Subjects

- Study design and setting: The current interventional study was conducted based on a pretest-posttest design in the NICU of preterm children in Cairo University Teaching Hospital, Egypt, from June 2019 to January 2020.

- Sample size calculation: Sample size was determined at 50 neonates using an online sample size calculator (11) for comparing paired differences, guided by a power test of 90%, an effect size of 0.5, and α error of 5%. Moreover, it was conducted based on a previous study (5) that revealed some differences in vital signs upon exposure to noise on a sample of Egyptian neonates with nearly the same inclusion and exclusion criteria as the current study.

-This study included 100 preterm LBWs neonates that were randomly selected concerning the inclusion and exclusion criteria. These neonates were admitted to a private section in NICU where preterm neonates were admitted to be under observation. These neonates were categorized as:

• Group A (Noise group):

A total of 50 neonates were exposed to a noise level equivalent to that in the open ward of NICU (including sounds of monitors, ventilators, and staff members) for 10 min on two consecutive days. Physiological data (namely heart rate, respiratory rate, blood pressure, temperature, and oxygen saturation) were immediately recorded before and after 10 min of continuous noise exposure.

• Group B (Light group):

A total of 50 neonates were exposed to cycled light (12 h from 8 a.m. to 8 p.m. with the room light switched on and from 8 p.m. to 8 a.m. with the room light dimmed) and physiological data, including heart rate, respiratory rate, blood pressure, temperature, and oxygen saturation, were recorded every 3 h over 2 days.

- The included cases were preterm neonates with gestational age<2000 grams requiring admission to the private NICU rooms due to their LBWs.

- The exclusion criteria were as follows: congenital malformation, congenital heart diseases, hypoxic-ischemic encephalopathy, severe respiratory distress disorders, severe neonatal jaundice, and poor Moro reflex.

- Informed consent was obtained from the parents of all neonates included in the study. The study was approved by the Ethics Committee of Cairo University in agreement with the Helsinki Declaration of 2015.

- A sound level meter (an application on an Android system called sound meter software (version 3.2.4) last update 7/2017 after being calibrated with sound level meter device) was used to measure in decibels the sound level in the NICU. These sounds originate from ventilators, monitors, and staff members in this room. It is worth noting that the private ward (no monitors or ventilators) is a separate partition from the open ward of NICU that is further subdivided into different partitions (with monitors and ventilators or with monitors only). The sound level was measured three times at different times of the day by putting the sound level meter at the newborn head level and measuring every single sound. The measurement of every sound and exclusion of others was performed by keeping the ventilators on, switching off the monitors, and restricting the sounds of staff members in the partition with ventilators. On the other hand, in the partition with no ventilators, we could measure the sound of monitors and restrict the sound of staff members. Thereafter, we turned the monitors off and measured the sounds of staff members. The participants were exposed to the same noise

level using the same environmental equipment, including monitors, ventilators, and staff members, by moving the neonates from the private ward to the open ward for 10 min over 2 days.

- LUX meter application (an application on an Android system called LUX meter software (version 2.0) last update 3/2017 after being calibrated with the light meter device) was used to measure the intensity of light the neonates are exposed to in the open ward of NICUs. The light meter was placed at the same level as the neonates' head and facing the ceiling to measure the light intensity in the lux unit in the ordinary light the preterm neonate is often exposed to all day long. It was tried to dim the light at nighttime for 3 days. Subsequently, the average light intensity was measured after dimming the light over 3 days. According to these measurements, preterm neonates (light group) were exposed to ordinary light (280-290 lux) from 8 a.m. to 8 p.m., and vital signs were recorded every 3 h over 2 days. To avoid overlapping of both effects, the effect of the intensity of light on enrolled neonates in group B was assessed after the examination of the effect of noise on the neonates of group A.

Statistical analysis

SPSS software (version 17) was used to analyze all the data reported in the study. Continuous data were presented as mean± standard deviation (SD), while the categorized data were reported as frequencies. The student's t-test was employed to detect the differences between the two groups of patients. The paired t-test was utilized to compare different light and noise measurements within the same group. A p-value less than 0.05 was considered statistically significant.

Results

- Demographic and clinical data of the neonates included in the study are displayed in Table 1.

- The intensity of the sound in the open ward of NICU was measured three times at different times of the day, and the measurements were repeated for three days. The average of each measurement in the three days are depicted in Table 2. The ventilators are regarded as the strongest source of noisemaking (P=0.02), compared to the noise made by staff members (P=0.001) and incubators (P=0.001). However, the noises made by staff members were higher than those of incubators (P=0.001).

- After being exposed to the same level of noise displayed in Table 2, the neonates in the private ward showed a significant increase in the heart rate, respiratory rate, systolic and diastolic blood pressure. Moreover, they demonstrated a marked decrease in oxygen saturation in the first and second days in the NICU (tables 3 and 4 respectively). Nonetheless, the temperature did not display any significant change with noise exposure either on the first day (P=0.42) or the second one (P=0.43).

- The intensity of light in the open ward of NICU was measured three times per day over three days. The light intensity ranged from 280-290 lux in ordinary light and 30-40 lux in dim light (P<0.001; Table 5).

- After being exposed to the same level of cycled light illustrated in Table 5, preterm neonates showed a significant decrease in heart rate, respiratory rate, as well as systolic and diastolic blood pressure. Moreover, they demonstrated a significant increase in oxygen saturation in the dim light, compared to ordinary light in the first and second days in NICU (tables 6

Table 1. Demographic characteristics among the studied neonates (Group A and Group B)

Variable	Group A (50 neonates)	Group B (50 neonates)
Age (days)	3.2±2.7 (2-8)	2.9±4.1 (2-9)
Gestational age (weeks)	32.7±2.2 (30-36)	32.8±1.9 (30-36)
Gender (male/female)	26/24	28/22
Consanguinity		
Positive	13	21
Negative	37	29
Mode of delivery		
Normal labor	15	18
Cesarean section	35	32
Gestational weight (Kgs)	1.6±0.4 (1.2-2.4)	1.5±0.3 (1.2-2.6)

Table 2. Measurements of noise in the NICU's high-risk room by sound level meter application

Sounds in NICU	Average of first measurement	Average of second measurement	Average of third measurement	Range	Average
Alarm of monitor	50 dB	48 dB	52 dB	48-52	50dB
Staff members	64 dB	62 dB	58 dB	58-64	61 dB
Ventilators	62 dB	66 dB	63 dB	62-66	63 dB

Table 3. Vital signs before and after noise exposure among the neonates of group A in day 1

Vital Signs	Before	After	p-value
Heart rate (beats/min)			
Mean ±SD	136.4 ± 11.8	148.8 ± 6.6	<0.001
Range	120-166	138-174	
Respiratory rate (breath/min)			
Mean ±SD	41.3± 2.3	44.3±2.3	<0.001
Range	38-47	42-52	
Oxygen saturation (%)			
Mean ±SD	99.0±0.7	96.9±0.8	<0.001
Range	98-100	95-98	
Temperature (ºc)			
Mean ±SD	36.6±0.2	36.6±0.2	0.42
Range	36.2-36.6	36.5-36.6	
Systolic BP (mmHg)			
Mean ±SD	65.7±6.0	76.4±5.7	<0.001
Range	48-81	58-90	
Diastolic BP (mmHg)			
Mean ±SD	40.3±4.2	48.4±3.2	<0.001
Range	31-52	37-55	

Table 4. Vital signs before and after noise exposure among the neonates of group A in day 2

Vital Signs	Before	After	p-value
Heart rate (beats/min)			
Mean ±SD	135.2 ± 11.3	148.2 ± 6.3	<0.001
Range	122-164	139-174	
Respiratory rate (breath/min)			
Mean ±SD	41.1± 1.9	43.4±2.5	<0.001
Range	37-47	44-53	
Oxygen saturation (%)			
Mean ±SD	98±0.8	95.5±0.7	<0.001
Range	99-101	94-98	
Temperature (ºc)			
Mean ±SD	36.7±0.2	36.6±0.2	0.43
Range	36.4-36.6	36.5-36.7	
Systolic BP (mmHg)			
Mean ±SD	63.9±7	76.9±5.9	<0.001
Range	48-80	58-92	
Diastolic BP (mmHg)			
Mean ±SD	40.2±4.2	48.8±2.91	<0.001
Range	30-52	39-55	

and 7, respectively). Moreover, body temperature did not show any significant change either in the dim light or the ordinary light on the first or second days.

Table 5. Measurements of light intensity in ordinary light and dim light

Light intensity In NICU	Average of first measurement	Average of second measurement	Average of third measurement	Range	Average
In ordinary light (room lights on)	285 lux	280 lux	290 lux	280-290 lux	285 lux
After dimming the light	40 lux	30 lux	35 lux	30-40 lux	35 lux

Discussion

The NICUs do not offer an ideal environment for the growth of preterm neonates, especially in developing countries, such as Egypt (2). The NICUs in Egypt partially lack the standard protocols for controlling noise and light. The neonates exposed to excessive noise and light in NICUs may be subjected to a risk of abnormal brain development which would adversely affect long-term neuro-developmental outcomes. Therefore, the healthy physical environment of NICUs is crucial for the continued normal development of preterm neonates (12).

The current study aimed to assess the physiological changes induced by light and noise in NICUs in preterm neonates admitted to the private ward of the NICU in Cairo University Pediatric Hospital due to their LBWs. It was found that after noise exposure, the studied neonates showed a significant increase in heart and respiratory rates, as well as systolic and diastolic blood pressures. Moreover, they displayed a significant decrease in oxygen saturation with no

Table 6. Vital signs in ordinary and dim light in the first day

Vital signs (First day)	Ordinary light	Dim light	p-value
Heart rate (beats/min)			
Mean ±SD	155 ± 3.2	142.2 ± 2.6	0.001
Range	146.5-161.2	136-148	
Respiratory rate (breath/min)			
Mean ±SD	45.3± 0.5	43.5±0.5	0.01
Range	44.2-46.7	42.5-44.5	
Oxygen saturation (%)			
Mean±SD	96.4±0.3	99±0.4	0.01
Range	96.2-97.5	97-99	
Temperature (ºc)			
Mean ±SD	36.5±0.2	36.4±0.2	0.19
Range	36-37	36-37	
Systolic blood pressure (mmHg)			
Mean ±SD	70.2±1.3	62.2±2.5	<0.001
Range	67.2-73.2	57-67.2	
Diastolic blood pressure(mmHg)			
Mean ±SD	48.7±0.9	39.1±0.7	<0.001
Range	46.2-50.7	38-41	

significant change in temperature. The same findings were reported in a study performed by Aly et al. on 100 full and preterm newborns exposed to noise ranging from 60-30 dB for about 10 min (5).

Along the same lines, Cardoso et al. conducted a study among 61 LBW newborns in which physiological changes were measured two times. The first measurement was carried out when the greater flow of people and the use of medical equipment made the highest noise levels. Moreover, the second measurement was made during the "nap time" when the health care staff members decrease their activities, and the alarms of devices were turned down. Tachycardia and decreased oxygen saturation were reported when neonates were exposed to noise (13).

However, Romeu et al. evaluated the physiological parameters of preterm neonates continuously after exposure to different intervals of silence and noise. The results revealed the occurrence of short-term bradycardia, decreased oxygen saturation, and short-term increase of mean arterial blood pressure (14). On the other hand, Sinha et al. experienced a bi-phasic heart rate response, showing an initial decrease in the heart rate, followed by heart rate acceleration. In the mentioned study, 11 extremely low-birth-weight (ELBW) neonates (766-910 g) were exposed to routine incubator noise at baseline levels of 50-60 dBA over a period of 2 h. Moreover, the low-birth-weight neonates (454-694g) showed an increase in their heart rate when exposed to loud noises (15).

On the contrary, Robert et al. did not observe any significant changes in heart rate or oxygen saturation in preterm neonates after being exposed to noise (1). Different studies reported that average noise levels in NICUs range from 53.9-60.6 dBA(16, 17) and 4-55 dBA(18). In addition, it was documented that sound levels exceeded the recommended standards in more

Table 7. Vital signs in ordinary and dim light in the second day

Vital Signs (second day)	Ordinary light	Dim light	p value
Mean heart rate (beats/min)			
Mean±SD	137.2± 1.9	132.6± 2.3	<0.001
Range	132.2-142.5	127.7-137.7	
Mean respiratory rate (breath/min)			
Mean±SD	42.4± 0.5	40.4±0.5	<0.01
Range	41.2-43.5	39-41.2	
Mean oxygen saturation (%)			
Mean±SD	96.9±0.3	98±0.4	<0.01
Range	96-97	96-99	
Mean temperature (ºc)			
Mean±SD	36.4±0.2	36.3±0.02	0.06
Range	36-37	36.3-36.4	
Mean systolic BP (mmHg)			
Mean±SD	65.5±0.9	54.4±1.4	<0.001
Range	63.5-67.7	50.7-57.4	
Mean diastolic BP (mmHg)			
Mean ±SD	44.3±1.2	36.8±0.6	<0.001
Range	42.2-46.7	35.2-37.7	

than 70% or 96% of NICUs (19,20). In the present study, one of the highest levels of noise was recorded where it exceeded 174 dBA. The maximum noise levels recorded by some authors were 78.0 dBA, 97.2 dBA, and 135.7 dBA (1,21).

This discrepancy in the results of previous studies can be ascribed to variations in study design, sample size, degree, and duration of noise exposure, methodological assessment. Moreover, the inclusion and exclusion criteria were effective in this regard since preterm neonates' vital signs were seriously affected by noise, as compared to those of full-term newborns. Nevertheless, the results of studies regarding overall sound levels in NICUs and those of the present study support and confirm the need for qualified methods to measure and regulate the acoustic environment in NICUs.

Recent studies recommended that intense light should be avoided in the rooms of pre-term neonates since their pupillary light reflexes are not fully developed in this stage. Accumulating data have demonstrated that a supportive light environment regulates the levels of cortisol and circadian rhythm, extends sleep duration, and increases the levels of growth hormones. Therefore, continuous bright lighting is hazardous for preterm neonates. However, in common practice, three different approaches may be recommended. The first approach is exposing preterm neonates to cyclical light in two phases(once during the day and the other at nighttime), the second one is dimming the light whenever the neonate is asleep, and the third approach is always keeping preterm neonates in dim light (22,23).

Several studies recommended the cyclical light as the best regimen to control the light environment in NICUs (24,25). The environment of Egyptian NICUs provides significant light exposure and limited cycled light due to the lack of instructions regulating the amount of light preterm neonates should be exposed to and the behavior of individual nursery practices. The present study aimed to assess the differences in physiological parameters in preterm neonates after dimming the light if they were exposed to light intensity equal to the intensity already measured in the open ward of NICUs.

The results pointed to decreased heart rate, respiratory rate, systolic and diastolic blood pressure, as well as, increased oxygen saturation, in the included preterm neonates with no significant change in temperature after dimming the light. Lee et al. designed a case-control study in which the case group (26 preterm neonates) was exposed to lights-out at night for 5 h, while the control group was exposed to ordinary continuous light. The case group showed a decreased heart rate when lights were out associated with the stability of behavioral status (25). In a similar vein, Vásquez et al. demonstrated that the neonates who were admitted to NICU and exposed to a light/dark cycle gained weight faster, in comparison with those exposed to continuous traditional light (10).

Guyer et al. found that preterm neonates exposed to cyclical lighting showed longer sleep periods at nighttime, compared to those exposed to dim light only (24). Zores et al. designed a study to detect the responses of preterm neonates to light level variations (332 light level changes) in incubators. They reported the respiratory rate (decreased) as the only variable which showed a significant change during exposure to 50 or lower delta lux was. Moreover, increased heart and respiratory rates, as well as oxygen saturation, were only observed when delta lux was over 50 (26).

Inconsistent with the findings of the present study, Lebel et al. compared the effects of cycled lighting versus continuous lighting near darkness on the physiological stability level of 38 preterm neonates and observed no significant difference (27). This is comparable to the study conducted by Reyhani et al. who assigned 38 included neonates to two groups. The first group was exposed to cycled light, while the control group was exposed to continuous lighting. The results of the stated study demonstrated higher oxygen saturation and lower respiratory rate in the first group, compared to the second group (28).

Conclusion

As evidenced by the results of the present study, excessive light and noise exposure was associated with significant changes in preterm neonates' vital signs. Moreover, the findings highlight the inadequacy of the current conditions in Egyptian NICUs for ideal neonatal care. In order to create a favorable and efficient environment to help better growth and prevent the complications of prematurity, it is recommended to devote more attention to the care conditions of neonates in NICUs in Egypt. The intensity of noise and light in NICUs should be routinely measured and managed to the extent possible. The staff members of NICUs should take different courses about developmental care addressing the adequate management of the NICU environment. Furthermore, all incubators

should be equipped with acoustical foam inside and covered shield outside to minimize the exposure to sound and light as much as possible. Further prospective studies are needed to assess the long-term adverse effects of exposure to noise and light on neonates' development.

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Conflicts of interest

All authors declared that they have no conflict of interest.

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