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Exposure and reactivity of the preterm infant to noise in the incubator

Exposição e reatividade do prematuro ao ruído em incubadora

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ABSTRACT

Purpose: To evaluate preterm infants' exposure and reactions to intense noise during incubator care. **Methods:** An observational and prospective study was performed in the intermediary care unit of a hospital in Ribeirão Preto (SP). Thirty-five preterm infants participated in the first stage of the study (measuring noise) and 20 in the second (analysis of responses to intense noise). Noise was measured for two hours using a dosimeter, and the responses were video recorded by three cameras connected to a computer. The preterm infants' responses to an L_{max} higher than 65 decibels were analyzed. **Results:** Every preterm infant presented L_{eq} above the limit recommended by international organizations, and more than half of the babies had a mean L_{eq} above the limit permitted by the Brazilian standard. Regarding the babies' responses to the intense noise, the majority of them showed blink reflex, startle reflex, facial mimics, changed bodily activities or changed sleep and wake state, all with statistically significant differences. **Conclusion:** The sound levels measured were intense. The noises that preterm infants are exposed to while being cared for in incubators constitute a stressor event. Sudden, intense noises change their behavioral state and causes reflexive and bodily responses, facial manifestations and changes in their sleep and wake state.

Descritores

Incubadoras para Lactentes
Ruído
Recém-nascido Prematuro
Reatividade-estabilidade
Neonatologia

RESUMO

Objetivo: Avaliar a exposição e a reatividade do prematuro ao ruído intenso durante o cuidado em incubadora. **Método:** Estudo observacional prospectivo na unidade de cuidados intermediários de um hospital de Ribeirão Preto (SP). Na primeira etapa do estudo (dimensionamento do ruído) participaram 35 prematuros e na segunda (análise da reatividade diante de um ruído intenso), 20. O ruído foi mensurado durante duas horas por um dosímetro e a reatividade filmada por três câmeras conectadas no computador. Diante de $L_{máx}$ superior a 65 decibéis analisou-se a reatividade dos prematuros. **Resultados:** Todos os prematuros apresentaram L_{eq} acima do limite recomendado por organizações internacionais e mais da metade dos bebês esteve com L_{eq} médios superiores ao limite permitido em incubadora pela norma brasileira. Diante do ruído intenso, grande parte dos bebês desencadeou reflexo cócleo-palpebral, sobressalto, mímica facial, modificou as atividades corporais ou apresentou padrão de sono e vigília, com diferenças estatisticamente significativas. **Conclusão:** Os níveis sonoros mensurados foram intensos. O ruído a que os prematuros estão expostos nas incubadoras durante os cuidados recebidos constitui um evento estressante, modifica o estado comportamental e desencadeia respostas reflexas, corporais, manifestações faciais e mudança no estado de sono e vigília diante dos ruídos intensos e súbitos.

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INTRODUCTION

The neonatal intensive care unit (NICU) is characterized as a fundamental environment to promote the survival of premature and/or critically ill newborns (NBs) that need specialized treatment and intensive and continuous care[1]. However, the different sensory exposures to which the premature baby is subjected, such as noise, lights, repeated techniques and prolonged mechanical ventilation, among others, can damage the immature and developing brain and have negative effects on the long-term neurodevelopment[2].

Developmental interventions began to take priority from the 1980s and minimal stimulation began to be promoted. The minimization of environmental factors became the team's interest and concern and early family interaction was encouraged[3].

In a 2015 study[4], it was found that, according to the perception of professionals of neonatal units, the main source of noise comes from the equipment used in the units, including the incubators. The majority of the professionals interviewed in a 2017 study admitted that the actions of the team generate noise that can be harmful to newborns[1]. Noise is a potent stressor for premature infants and has been compared to aminoglycosides in relation to the detriment in cochlea development. In humans, the interaction between the auditory system and the environment is fundamental for normal hearing development. In neonates, excessive stimulation of the organ of Corti hair cells, caused by loud and continuous noises can result in their destruction, causing progressive hearing loss[5]. The concept of the importance of the NICU environment has led to the reduction of noise and other sources of stress.

The exact relationship between early birth, the intensive care setting, and future hearing sequelae has not been established, however, studies have shown that noise can cause apnea, hypoxemia, alternating oxygen saturation and increased oxygen consumption secondary to elevated heart and respiratory rates and thus decrease the amount of calories available for growth[6]. Therefore, the concern to minimize noise pollution in the neonatal environment is legitimate. In the context of developmental care, from the perspective of managing the environmental to minimize noise in the neonatal unit, the relevance is highlighted of the control of noise from motors and handling of the incubator, life support equipment widely used in the care of preterm newborns (PTNBs), which requires special care regarding its management and control.

This study aimed to evaluate the exposure and reactivity of PTNBs to noise during incubator care.

METHODS

The study was approved by the heads of the institution's Neonatology and Nursing Medical Service and approved by the hospital's ethics committee (HCRP process No. 5.363/2004).

A prospective observational study was conducted in the neonatal intermediate care unit of a tertiary hospital in Ribeirão Preto (SP).

Participants

The study subjects were the preterm infants admitted to this neonatal unit that fulfilled the following inclusion criteria: incubator stay of at least 24 hours prior to the collection period; clinically stable regarding heart rate control; in phase of feeding by gastric tube; had passed the behavioral hearing screening: presence of auditory reflex responses (blink reflex [BR], Moro reflex and/or startle reaction) or awakening from sleep upon intense sound stimulation (agogô). Exclusion criteria were: grade III or IV intraventricular hemorrhage; use of analgesics, sedatives and/or psychotropic drugs within the 24 hours prior to collection; not passing the behavioral hearing screening.

The study potentially included 40 preterm infants. However, four newborns did not participate due to not receiving parental consent, therefore, the collection was performed with the other 36 newborns. One newborn was excluded from the analysis because of problems with the images and the impossibility of redoing the collection because the baby was no longer in the incubator. The study had the participation of 35 PTNBs and their characterization is presented in Chart 1.

The consent form was signed by the parents or guardians of the premature infants before measuring the noise and filming the newborns.

Chart 1. Characterization of PTNBs of the general group (first stage) and subgroup (second stage of the study)

		General group	Subgroup
Sex	Male	20	10
	Female	14	9
	Ambiguous genitalia	1	1
Birth weight	Range	650-2980g	700-2575g
	Mean	1406.9g	1369.75g
Current weight	Range	1050-2900g	1150-2530g
	Mean	1586.0g	1565.0g
Gestational age	Range	185-255d (26w3d-36w3d)	185-225d (26w3d-36w3d)
	Mean	221.80d	221.25d
Postnatal age	Range	1-83d	1-83d
Corrected age	Range	215-272d (30w5d-38w6d)	215 - 272d (30w5d-38w6d)
	Mean	243.7d	246.7d

Source: the authors

Measurement

The study was carried out in two stages: in the first one the noise was quantified and in the second the reactivity of the preterm infants (physiological and behavioral responses) to an intense noise generated during incubator care was analyzed. A total of 35 preterm infants participated in the first stage of the study and 20 in the second. The selection of these 20 preterm infants was based on the following criteria: preterm infants exposed to at least one L_{max} (highest sound pressure level [SPL] measured during the assessed period)[7] greater than 65 dBA; the L_{max} noise source was not crying, sneezing or agitation of the baby itself, but from the care equipment, provided that the manipulation by the team did not interfere with the premature behavioral reactivity, with this L_{max} being a short sudden (sharp) noise for the recording and analysis of the physiological and behavioral manifestations of the premature infants before (previous period) and after (later period) its occurrence.

The noise measurement in the incubator microenvironment was performed simultaneously with the filming of the physiological parameters (heart rate [HR] and oxygen saturation [SaO_2]) and behavioral manifestations (reflex, facial and body activities and change in sleep and wake state) for a continuous period of two hours for each PTNB.

To measure the noise levels, a sound pressure meter - Quest 400 dosimeter, calibrated prior to each moment of data collection, was used. Noise in decibels (dBA) was measured in sound level pressure (SPL), in the A-weighted, slow response condition, with minute-to-minute SPL integration, according to the Consensus Committee on Recommended Design Standards for Advanced Neonatal Care[8]. The dosimeter was fixed to the outside of the incubator and the microphone was inserted into the incubator and fixed to the top of the dome. The microphone was positioned about 10cm from the newborn's head, a distance defined for this study. Other related studies have defined the microphone placement close to one of the newborn's ears, without clearly describing its position[9].

Three wired mini cameras connected to a video card in a computer were used to record the reactivity (physiological and behavioral reactions) of the preterm infants.

The HR and SaO_2 were measured with a pulse oximeter, with the sensor placed on the preterm infant's foot. The filming of these parameters was performed using a camera fixed to a ruler under the monitor (camera one). The behavioral manifestations of the preterm infants were filmed by two cameras: one for the recording of the baby's face (camera two - with audio capability) and the other for filming the full body of the newborn (camera three). These cameras were introduced into the incubator and attached to the upper side of the dome.

Of the 20 infants with the possibility of analyzing the responses before and after the loud noise (L_{max} greater than 65 dBA), five NBs had two or three moments that fulfilled the previous selection criteria. The moment with the highest L_{max} was chosen for data processing. The reactivity of the PTNBs was analyzed before and after the selected L_{max} to verify whether or not there was a change in these responses when presented with sudden and intense noise.

Physiological (HR and SaO_2) and behavioral responses (facial mimicry, body activity, sleep and wakefulness) were observed and analyzed in the 20 seconds before and 20 seconds after the selected L_{max}, with these two periods subdivided into ten intervals of two seconds.

The HR and SaO_2 indexes were recorded at the end of each two-second block, with a total of ten measurements for each period. Blink reflex (contraction of the orbicularis oculi muscle observed through eyelid movement, consisting of a small, rapid blinking or closing of the eyes to a large closure, including eyebrow contraction), startle reaction (overall body reaction; may manifest as a Moro reaction or body tremor with sudden limb movement, small "leap" from the newborn's body, right after the acoustic stimulus; it may or may not follow the Moro reflex) or Moro reflex (violent startle reaction, abrupt movement of the whole body, arms and legs stretched out from the midline of the body, tremor or trembling of the limbs during the movement may also be observed) activities were observed, and their presence (score 1) or absence (score 0) during the periods before (two seconds before L_{max}) and after (during noise and two seconds after L_{max}) was noted.

Facial mimicry was analyzed using the Neonatal Facial Coding System (NFCS) scale. The facial actions of the NFCS scale observed were: brow bulge (protrusion, wrinkle and/or vertical furrows above or between the eyebrows); eye squeeze (compression and/or bulging of the eyelids); nasolabial furrow (elevation and deepening of the nasolabial furrow); open lips (mouth open more than relaxed parted lips); vertical mouth stretch (stretching of the corners of the lips with a pronounced depression of the jaw); horizontal mouth stretch (evident stretching, pulling from the corners of the mouth horizontally, sometimes accompanied by tension in the upper lip); taut tongue (raised tongue, with tense tip and edges); tongue protrusion (forward tongue movement, but not always beyond the baby's lips); chin quiver (obvious frequent up and down movements of lower jaw)[10]. The presence (score 1) or absence (score 0) of each facial activity was recorded.

Changes in body activity were analyzed at each two-second interval according to the score of each pattern: 0 = no or very little movement (no or minimal movement, general relaxation of muscle tone); 1 = regular, small, continuous, relaxed movements (gentle and small spontaneous movements of the arms, legs and fingers; the baby is relaxed and not irritated); 2 = tense, irritated, not relaxed (baby cries momentarily; regular movements overlapping with rapid shaking, trembling or gentle trembling of the upper limbs. Baby is troubled, but calms down quickly after the movement); 3 = abrupt, intentional, strong (movements occur suddenly - strong and/or intentional, directed); 4 = strenuous movements, very tense (elaborate movements - very tense, stretched, may involve facial mimicry and crying); 5 = frantic movements (spastic, chaotic and agitated movements - fast, progressive and uncoordinated); 6 = motionless, no movement, flaccid (limbs are held motionless and extended. Normal integration of limbs absent); 7 = abrupt, uncoordinated tremors (abrupt arm movements - may occur with trembling movements of the hands)[11]. The body activity that predominated during the ten two-second intervals was considered, even if other patterns occurred during the anterior and posterior periods.

Changes in sleep and wakefulness were recorded according to each state's score [1 = deep sleep (eyes firmly closed and immobile, little or no motor activity except occasional tremors or rhythmic mouth movements; and relatively slow, deep and regular abdominal breathing); 2 = active sleep (eyes closed but rapid eye movements present; body activity from short jerks to twitching and stretching; irregular, costal breathing faster than quiet/deep sleep; facial movement may produce frowns, grimaces, smiles, pulled, mouth and sucking movements, however, facial movements are not easily observed); 3 = drowsy (eyes open or closed, partially or fully open, motionless and seems to be dazed; some generalized motor activity may occur; more or less regular breathing); 4 = alert (relatively quiet and still body and face; bright and alive eyes); 5 = restless (similar to alert, constant soft or agitated vocalizations; crying may occur); 6 = crying (alert characteristics, but more intense motor activity and continuous crying attacks)][12]. The predominant sleep and wake state of each period was considered, although the babies may have presented other states in the same period.

The observation of the images and the coding of the behavioral manifestations were performed by a research assistant that was unaware of the specific objectives of the study, with the researcher not participating in the coding of the data related to the behavioral manifestations. The reliability of the coding and analysis of the behavioral manifestations performed by the assistant was assessed through the percentage of agreement[10], with analysis performed simultaneously by another research assistant, selecting a 40% random sample from the filming for this purpose. To calculate the random sample, the SPSS (Statistical Package for the Social Sciences), version 15.0 was used, and the Seed No. 987654321 program for the random number generator. The two research assistants that participated in the analysis of the behavioral manifestations were familiar with the theme and methodology being used. For the analysis of concordance of the NFCS, a formula suggested in another study[10] was used, and for the body activity and the behavioral state, the percentage of concordance between the evaluators was calculated. The concordance between the coders was 91.80% for the NFCS, 99.84% for body activity and 98.96% for sleep and wakefulness, higher than the 80.00% limit recommended by other studies[10,11]. The reactivity data of the premature newborn (HR, SaO_2, state change, facial mimicry, and reflex and body activities), recorded before and after the L_{max} selected for each of the NBs, were entered into Excel spreadsheets. The process of double data entry in the spreadsheets was performed for the measurement of these data.

Data analysis

The highest L_{max} and L_{peak} (highest unfiltered instantaneous SPL that occurred during the minute[8]), L_{max} greater than 65 dBA (loud noise moments), L_{min} [lowest SPL measured during the evaluated period[7]] and mean L_{eq} [SPL integration period; variation of sound exposure measured over the period; mean of the sound level[8]] of the period were identified. After recognition of the moments of intense noise, the images filmed by the three cameras were observed at the times previously defined for the analysis of the reactivity of the newborn.

Data were processed using SPSS version 15.0. The sound levels found for L_{eq} and L_{max} were compared with the levels established by the Consensus Committee on Recommended Design Standards for Advanced Neonatal Care[8] and the Brazilian standard IEC 601-2-19[13]. The combination of continuous background sound and transient sound in any child care area should not exceed, in SPL, 45 dBA L_{eq} or 65 dBA L_{max}, according to the Consensus Committee on Recommended Design Standards for Advanced Neonatal Care in 2007[8]. The American Academy of Pediatrics[14] also suggests that the sound level in NICUs and incubators should not exceed 45 dBA. The sound level inside the NB compartment in the incubator should not exceed 60 dBA[13], according to the Brazilian standard. The variability of L_{eq}, L_{max} and L_{peak} (lower and higher values) and the L_{min} found were also analyzed.

The reactivity of the preterm infants before and after the L_{max} selected for each of the 20 NBs was analyzed to verify whether or not there was a change in physiological and/or behavioral responses due to the sudden and intense noise. The NFCS and BR were analyzed in 19 of the NBs because one of the PTNBs had eye protection (phototherapy); the other behavioral activities were analyzed in the 20 NBs. Mean values and standard deviations for the mean, minimum and maximum HR and SaO_2 values were calculated in the periods before and after the L_{max} selected. In these analyses, the nonparametric Wilcoxon test with significance level $\alpha = 0.05$ was used to verify whether or not there was a significant difference between the values obtained in the two periods.

The newborns were distributed according to the most incident behavioral activities in the anterior and posterior periods, by frequency and percentage distribution to characterize the most frequent activities and states. The scores of facial and body activities and changes in sleep and wakefulness in the anterior and posterior periods were presented as frequency and percentage of occurrence. In these analyses, the nonparametric Wilcoxon test with significance level $\alpha = 0.05$ was used to verify whether or not there was a significant difference between the values obtained in the two periods.

RESULTS

Noise levels were collected from four national (brands: A - 22 examples; B - two examples) and three imported incubator brands (brands: C1 - six examples; C2 - four examples; D - one example).

The SPLs were measured over 4,200 minutes (70 hours). Of this total, all minutes presented L_{eq} above the 45 dBA limit recommended by the American Academy of Pediatrics[14] and by the Consensus Committee on Recommended Design Standards for Advanced Neonatal Care[8], 713 (17.0%) minutes were above the 60 dBA allowed by the Brazilian standard for the mean sound level in incubators and 985 (23.4%) minutes, above the 65 dBA limit for the highest SPL (L_{max}) according to the Consensus Committee on Recommended Design Standards for Advanced Neonatal Care[8] in 2007.

The sound levels in L_{eq} ranged from 47.6 to 88.7 dBA during the two hours of noise measurement to which each preterm was exposed in the incubator, with L_{eq} above the 45 dBA recommended by international standards for all newborns. The L_{eq} ranged from 54.0 to 75.3 dBA, with a mean of 62.3 dBA; 54.3%[15] of premature infants remained with mean sound levels above the 60 dBA allowed by the Brazilian incubator standard. The L_{min} ranged from 46.9 to 61.6 dBA, meaning no baby had the sound level within the internationally specified standard, as can be seen in Figure 1.

The L_{max} ranged from 49 to 97.2 dBA. All 35 of the infants surveyed had moments with L_{max} levels greater than the 65 dBA specified by the Consensus Committee on Recommended Design Standards for Advanced Neonatal Care[8]. The number of times the noise reached L_{max} higher than that specified by the standard ranged from four to 111 times, 3.3% to 92.5% of the measurement time. The L_{peak} ranged from 87.0 to 135.7 dBA. Table 1 shows the sound levels to which all the preterm infants were exposed during daily incubator care.

The variability of the mean HR was between 114.0 and 182.9 beats per minute (bpm) in the period before the intense noise analyzed, with a mean of 140.6 bpm, a minimum HR of 114.0 and a

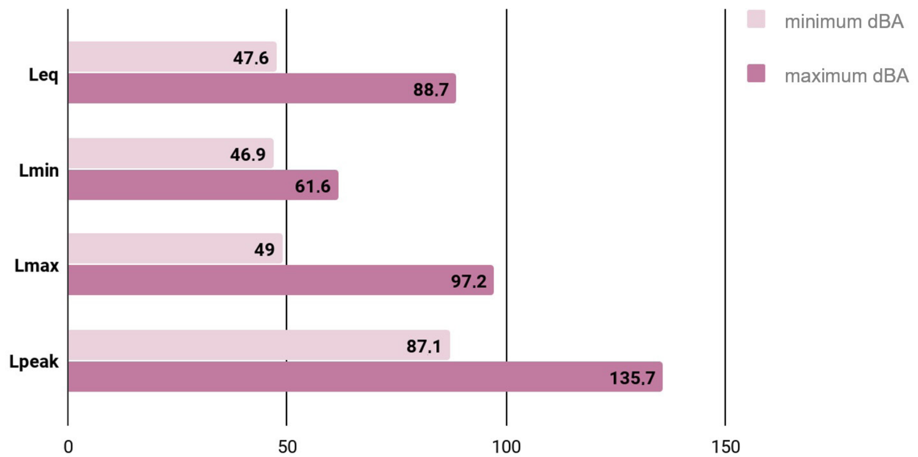

Figure 1. Noise levels in L_{eq}, L_{min} and L_{max} to which the PTNBs were exposed during the daily care in an incubator; minimum dBA; maximum dBA. Source: the authors

Table 1. Noise levels to which the PTNBs were exposed in L_{eq} (mean and percentages above norm), L_{min}, L_{max} (maximum and percentage above the norm) during daily incubator care

General group						
NB	L_{eq}			L_{min}	L_{max}	
	Mean	% >45 dB*	% >60 dB**		L_{max}	% >65 dB*
01	57.7	100	3.3	54.3	79.9	14.2
02	61.2	100	8.3	54.8	89.8	19.2
03	66.6	100	25.8	52.3	85.3	37.5
04	67.5	100	10.8	53.8	92.3	19.2
05	57.7	100	4.2	55.0	81.3	15.0
06	57.8	100	7.5	54.9	80.7	20.0
07	60.9	100	6.7	49.5	88.7	14.2
08	55.5	100	2.5	52.1	85	5.8
09	56.6	100	5.0	53.6	81	18.3
10	71.4	100	12.5	52.2	95.6	27.5
11	59.7	100	20.0	55.6	82.1	37.5
12	56.4	100	3.3	52.7	85.7	12.5
13	71.9	100	15.0	48.8	90.8	26.7
14	57.5	100	11.7	51.8	82	20.8
15	62.5	100	15.0	53.6	85.1	23.3
16	65.1	100	8.3	55.1	87.6	12.5
17	62.7	100	29.2	48.9	86.3	45.8
18	74.4	100	25.8	51.9	92.1	33.3
19	66.2	100	20.0	47.1	89	29.2

*Limit set for neonatal care environment by the Consensus Committee on Recommended Design Standards for Advanced Neonatal Care[8] and recommended for the NICU and incubators by the AAP[14]; **Limit set for incubators by the Brazilian standard IEC 601-2-19[13]. Source: the authors

Table 1. Continued...

NB	L_{eq} Mean	L_{eq} % >45 dB*	L_{eq} % >60 dB**	L_{min}	L_{max} L_{max}	L_{max} % >65 dB*
General group						
20	55.8	100	0.8	53.1	78.7	3.3
21	67.9	100	39.2	55.7	90.6	48.3
22	70.7	100	49.2	52.3	95.9	59.2
23	68.1	100	15.0	56.6	90.3	22.5
24	63.4	100	10.8	54	86.7	17.5
25	56.3	100	2.5	54	77.2	5.8
26	54.0	100	1.7	48.3	82.4	12.5
27	65.6	100	100	61.6	89.8	27.5
28	56.6	100	0.0	55.3	67.7	3.3
29	56.7	100	5.8	46.9	85	20.8
30	75.3	100	25.8	54.4	96.8	33.3
31	64.3	100	10.8	54	97.2	14.2
32	65.4	100	90.8	52.3	81.4	92.5
33	56.5	100	2.5	52.9	79.5	14.2
34	58	100	2.5	56.5	80.1	5.8
35	55.6	100	1.7	52.6	76.1	7.5
Subgroup						
NB	L_{eq} Mean	L_{eq} % >45 dB*	L_{eq} % >60 dB**	L_{min}	L_{max} L_{max}	L_{max} % >65 dB*
02	61.2	100	8.3	54.8	89.8	19.2
03	66.6	100	25.8	52.3	85.3	37.5
04	67.5	100	10.8	53.8	92.3	19.2
05	57.7	100	4.2	55.0	81.3	15.0
06	57.8	100	7.5	54.9	80.7	20.0
07	60.9	100	6.7	49.5	88.7	14.2
09	56.6	100	5.0	53.6	81	18.3
10	71.4	100	12.5	52.2	95.6	27.5
11	59.7	100	20.0	55.6	82.1	37.5
12	56.4	100	3.3	52.7	85.7	12.5
14	57.5	100	11.7	51.8	82	20.8
17	62.7	100	29.2	48.9	86.3	45.8
22	70.7	100	49.2	52.3	95.9	59.2
23	68.1	100	15.0	56.6	90.3	22.5
24	63.4	100	10.8	54.0	86.7	17.5
25	56.3	100	2.5	54.0	77.2	5.8
26	54.0	100	1.7	48.3	82.4	12.5
27	65.6	100	100	61.6	89.8	27.5
30	75.3	100	25.8	54.4	96.8	33.3
32	65.4	100	90.8	52.3	81.4	92.5

*Limit set for neonatal care environment by the Consensus Committee on Recommended Design Standards for Advanced Neonatal Care[8] and recommended for the NICU and incubators by the AAP[14]; **Limit set for incubators by the Brazilian standard IEC 601-2-19[13]. Source: the authors

maximum of 187.0 bpm. In the subsequent period, the variability of the mean HR was from 101.4 to 162.5 bpm, with a mean of 138.0 bpm, a minimum of 69.0 and a maximum of 187.0 bpm. The mean SaO_2 ranged from 87.2% to 97.8% in the previous period, with a mean of 95.3%, a minimum of 86.0% and a maximum of 99.0%. In the subsequent period, the mean SaO_2 was between 90.0% and 98.0%, with a mean SaO_2 of 95.5%, a minimum of 84.0% and a maximum of 98.0%. The differences in the mean, minimum and maximum HR and SaO_2 in the periods before and after intense noise were not statistically significant (p >0.05). None of the HR and SaO_2 means were found to be above 146 bpm and below 95.0%, respectively, with all means within the normal range in both periods, as shown in Table 2.

None of the PTNBs showed any reflex pattern prior to the loud noise. Nine newborns (47.4%) triggered the blink reflex (BR) when exposed to the intense noise, one NB (5.0%) the startle reaction and three NBs (15.0%) the BR and startle. The BR was the most frequent reaction (62.4%) among the 19 PTNBs and seven babies (35.0%) did not show reflex activity when exposed to the intense noise.

Table 2. Variability, mean, standard deviation and median of the HR and SaO_2 in the periods before and after intense noise and their *p* values

Responses physiological		Previous period			Subsequent period			p (α = 0.05)
		Var	Mean (SD)	M	Var	Mean (SD)	M	
HR (bpm)	mean	114.0-182.9	140.6 (16.0)	138.0	101.4-162.5	138.0 (15.6)	136.9	0.983
	minimum	114.0-162.0	134.2 (14.2)	135.0	69.0-154.0	129.7 (19.3)	132.0	0.679
	maximum	114.0-187.0	145 (16.3)	144.5	114.0-187.0	146.3 (17.2)	148.0	0.517
SaO2 (%)	mean	87.2-97.8	95.3 (2.7)	96.2	90.0-98.0	95.5 (2.1)	95.9	0.679
	minimum	86.0-97.0	93.8 (3.5)	95.0	84.0-98.0	94.0 (3.3)	95.0	0.566
	maximum	88.0-99.0	96.2 (2.7)	97.0	90.0-98.0	96.5 (1.9)	97.0	0.206

Caption: Var: variability; SD: standard deviation; M: median. Source: the authors

A total of 18 PTNBs (94.7%) had no facial activity on the NFCS scale and one NB (5.3%) had a score of 0.8 for facial activity in the period prior to the loud noise. Eleven newborns (57.9%) had no facial activity as a reaction to the intense noise evaluated and eight newborns (42.1%) had scores between 0.2 and 1.4. There was a statistically significant difference between the NFCS scores obtained in the periods before and after the intense noise ($p = 0.012$), as shown in Figure 2. In this figure, it can be observed that, according to the NFCS scale, in the period before L_{max} greater than 65 dBA, the NB13 obtained a score of 0.8 for facial activity, showing the protruding forehead activity and narrowed eye. The other 18 newborns (94.7%), before noise, were not presenting facial activity according to the NFCS scale. After noise, the same NB13 presented longer activities of protruding forehead, narrowed eye and open mouth, obtaining a score of 1.44. The most prevalent facial activities when exposed to the intense noise were: brow bulge (26 times), eye squeeze[15], open lips (9), nasolabial furrow (7), taut tongue (5) and tongue protrusion (3). There were no facial activities, such as vertical mouth stretch, horizontal mouth stretch and chin tremor.

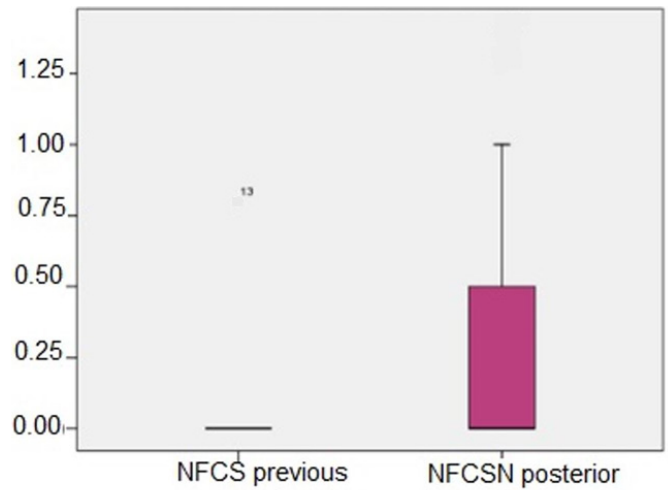

Figure 2. Boxplot indicating the distribution of the NFCS scores before and after the occurrence of a loud noise. Source: the authors

The majority of the PTNBs (19 NBs) had no or very little movement in the period prior to the loud noise. After the noisy stimulus, body activities ranged from no or very little movement (nine NBs), regular small and continuous movements, relaxed (six NBs), tense, irritated and not relaxed (three NBs) and strenuous movements, very tense (two NBs). There was a statistically significant difference ($p = 0.003$) between body activities before and after the noise, with the most frequent and strained activities after the noise, as shown in Figure 3, which demonstrates that in the period before the loud noise, only the NB13 presented body activity, performing regular, small and continuous movements - relaxed, according to the scale of the general body movement by Warnock[11].

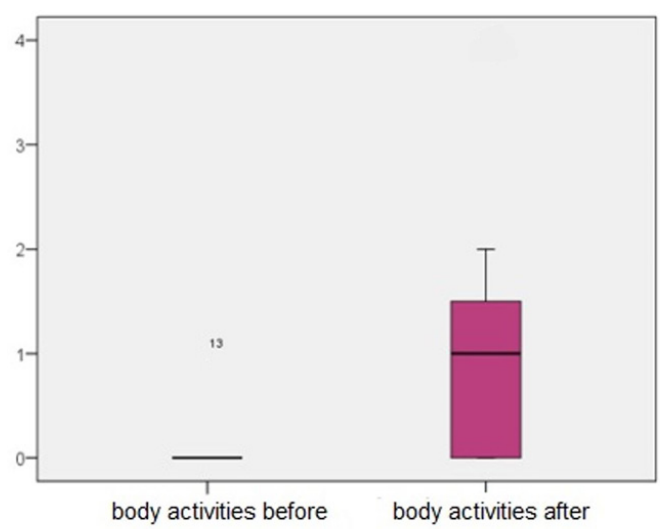

Figure 3. Boxplot with the distribution of body activity scores before and after the occurrence of a loud noise. Source: the authors

Of the 19 newborns with body activity score 0, nine remained in this pattern, six changed to score 1, two to score 2 and two babies to score 4; the NBs that were in body activity score 1 went to 2. Thus, it was found that 55.0% of preterm infants changed the pattern of body activity with more movement when exposed to the intense stimulus, as presented in Figure 4.

The predominant sleep and wake state in the period before the intense noise was deep sleep (14 NBs); there was also active sleep (four NBs) and drowsiness (two NBs). In the presence of the noisy stimulus, the active (eight NBs) and deep (seven NBs) sleep states were the most prevalent, however, the restless (three NBs), drowsiness (one NB) and alert (one NB) states were also present. There was a statistically significant difference ($p = 0.005$) between the periods before and after the noise analyzed.

Of the 14 PTNBs who were in deep sleep, six remained in this state after the loud noise, seven switched to active sleep and

Table 3. Distribution of the newborns (NBs) according to behavioral reactivity in the periods before and after an intense noise and the level of significance

	Previous period	Subsequent period	p ($\alpha = 0.05$)
Activity reflex (19 NBs: BR 20 NBs: Startle and Moro)	20: no reflection pattern	9: BR 1: startle reaction 3: BR + startle 7: no reflex activity	-
Facial mimicry (19 NBs)	18: no facial activity 1: score 0.8	11: no facial activity 8: score 0.2 to 1.4	0.012
Bodily activity (20 NBs)	19: no or very little movement 1: regular, small and continuous movements, relaxed	9: no or very little movement 6: regular, small and continuous movements, relaxed 3: tense, irritated and not relaxed 2: movement with a lot of force, very tense	0.003
Sleep and wake state (20 NBs)	14: deep sleep 4: active sleep 2: drowsy 0: alert 0: restless 0: crying	7: deep sleep 8: active sleep 1: drowsy 1: alert 3: restless 0: crying	0.005

Source: the authors

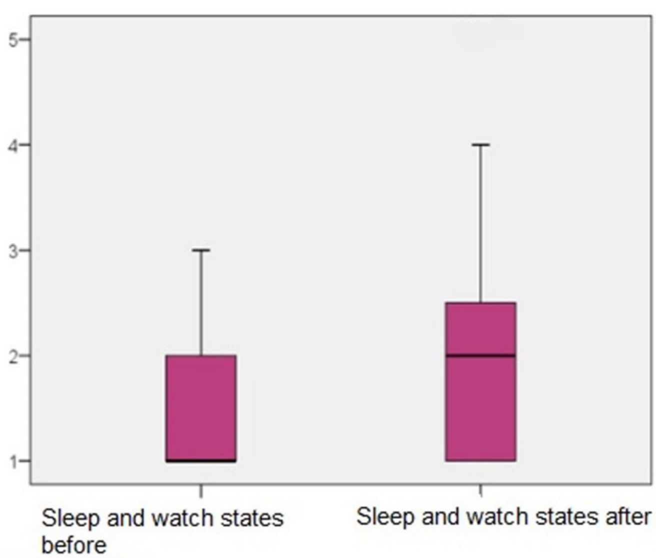

Figure 4. Boxplot with the distribution of sleep and wake state scores before and after the occurrence of a loud noise. Source: the authors

one to the restless state. Of the four babies who were in active sleep, one went to deep sleep and two became restless. Of the two preterm infants that were drowsy before the noise, one became alert and the other remained drowsy. Thus, there was a change in sleep and wakefulness in 60.0% of the newborns when exposed to the intense noise. Table 3 shows the behavioral reaction that the preterm infants had before and after the intense noise and the level of significance.

DISCUSSION

Although the negative effects of noise on NBs have been described in the literature, the neonatal care environment remains very noisy, as shown by a recent study that found an L_{max} of 83.70 dB at night in the NICU environment(16). Efforts to minimize sound levels are necessary and extremely relevant, as noise is considered a public health problem. Noise levels in the NICU environments continue to exceed levels recommended by the AAP, confirming that the recommended noise levels are not being achieved in these modern units(14).

The sound levels measured here were quite intense; all L_{eq} were above the 45 dBA limit set by current international standards and recommendations and more than half had a mean L_{eq} above the 60 dBA limit allowed by the Brazilian technical standard. All the NBs had moments with L_{max} above the 65 dBA limit specified by the international standard.

Despite the methodological differences (measurement conditions and scales, collection time, presence or absence of NBs, among others) among the studies in incubators, it was found that the mean noise level measured in the present study (62.3 dBA) was similar to that found in other studies, such as 61.0 dBA and 65.9 dBA(17), although higher than that shown by some authors, such as 49.6 dBA(15). The variability of L_{eq} found (47.6 to 88.7 dBA) was greater than that of some studies, such as 51.3 to 64.5 dBA(18), 53.6 to 79.7 dBA(19) and 56.0 to 77.0 dBA(17).

The maximum noise levels recorded by some authors ranged from 53.0 to 68.0 dBA(18) and presented a mean of 78.0 dBA(17), maximum noise levels much lower than those of up to 97.2 dBA recorded here. L_{peak} greater than 120 dBA was measured, reaching 135.7 dBA, very loud sound levels when considering that it was premature babies that were exposed to these noises. It should be highlighted that noise peaks greater than 135 dBA can cause mechanical damage to the cochlear hair cells in the inner ear(20).

When comparing the SPLs measured in the incubators in the present study and those registered in the neonatal units, it can be observed that the sound levels in the incubators ranged from 47.6 to 88.7 dBA in L_{eq}, a variability higher than that recorded in the neonatal units. These differences were between 14.79 and 18.57 dBA[21] above the 45.0 dBA limit set by current international standards and recommendations, noting that more than half had the mean L_{eq} above the 60.0 dBA limit allowed by the Brazilian technical standard. This is a matter of concern because, in most cases, newborns in incubators are high risk preterm infants and during neonatal care are exposed to SPLs more intense than those of the environment.

Even without finding significant differences in the physiological responses measured, it is believed, based on other studies, that the changes may be clinically relevant for an immature infant growing, developing and dependent on special care technologies, as exposure to loud sound (≥ 60 dB) in the womb or NICU is capable of altering "heart rate, oxygenation, gastrointestinal motility, pressure and sleep" and increasing the risk of hypoxia and bradycardia, as sick infants have no reserve or self-regulatory ability[2]. Statistically significant behavioral manifestations when exposed to intense and sudden noise show the stress condition to which preterm infants are exposed.

No studies were found in the literature on the reactivity of newborns to noise generated during care received in incubators. Studies were found in which the noise was artificially provoked by the researcher a few times, for longer periods and with more intense SPLs.

The current study found that none of the HR and SaO_2 means were above 146 bpm and below 95%, respectively, with all means within the normal range during both periods, according to studies previously performed for HR[22] and SaO_2[23]. Findings found in another study[24] demonstrated that PTNBs present a significant increase in mean HR and a significant decrease in mean SaO_2 when exposed to a 10 to 15 dBA increase in background noise during active sleep, while another study[5] also found significant changes in the HR and SaO_2 of newborns when exposed to noise in the neonatal unit.

The present investigation did not verify significant changes in HR or SaO_2 for the general group of preterm infants due to loud noises[25], unlike other studies[26], a fact that may be justified by methodological differences between them.

However, it should be highlighted that in five (25%) preterm infants, HR variability was above 20 bpm. In one of these NBs, the minimum HR (69 bpm) was below the normal range and in another premature infant the minimum SaO_2 (84%) was below the normal range and the maximum HR (187 bpm) above after the loud and sudden noise. These premature infants are believed to have clinically relevant variations when exposed to intense noise due to the bodily prematurity found, which is in line with other studies[25,26].

The reflex reactivity among the premature infants investigated was lower than the proportion found in other studies[27,28], a fact that is justified by the methodological differences regarding the characteristics of the subjects, the intensity and the noise source. Nevertheless, the data from the present study corroborate the literature which states that intense noise is stressful and triggers reflex responses in infants.

In the present study, the NFCS scale scores did not indicate the presence of pain (NFCS >3 points) in the preterm infants due to the intense sound stimulation, however, the preterm infants were disturbed and/or stressed in some ways by the presence of noise. Before the sound stimulus, 94.7% of the preterm infants presented no facial activity. After the noise, this rate dropped to 57.9%, with 42.1% of the premature infants beginning to show some facial activity.

The brow bulge facial activity is considered an indicator of stress[29], being the most prevalent facial mimic in the present study, a fact that corroborates the suggestion that noise is a stressful event. The tongue protrusion activity was present, although its frequency was the lowest of all registered facial activities. This activity is also seen as indicative of full-term newborn stress[29], however, there is still some doubt as to whether it is indicative of pain or stress in preterm infants.

Studies on auditory behavior demonstrated that 14.7%[28] and 21.0%[27] of infants presented behavioral reaction through facial activities when exposed to sound stimulation. In the present study, there was a higher index of facial activity (42.1%) when exposed to intense noise when compared to other studies[27,28], which characterizes one of the stress responses generated by loud noise.

There was a significant increase in body activities in the preterm infants when exposed to intense noise[25,28]. Changes in sleep and wakefulness of the preterm infants were also recorded when exposed to the intense noise[4,25,28]. However, crying was not observed after the loud noise, unlike in another study[25].

Even in deep sleep, the newborns triggered behavioral responses to the sound stimulation. This fact was observed in the current study in half of the preterm infants that were in deep sleep, because, due to the noisy stimulus, they no longer remained in this sleep pattern.

It is believed that babies in the NICU may suffer more from the effects of stress, as noise is a repetitive and prolonged stimulus in this care unit and it is virtually impossible to prevent some of it, with much being typical of the intensive care environment[6]. However, unintentional noise produced by staff could be controlled to reduce the level of stress in the babies. Studies have highlighted that NICU workers are aware of noise and that noise can interfere with both the baby's development and the routine of the workers exposed to it[4].

With an intervention protocol for the reduction of light, noise, staff activity and baby manipulation, it is conceived that careful manipulation of the incubator, which minimizes the sudden and intense noises generated during its handling[15], would be a way to reduce noise in this microenvironment. This would favor the physiological and neurobehavioral stability of the NBs in incubators, save these babies from the risk of unnecessary energy expenditure and favor the growth and development process, from the perspective of individualized and developmental care. In addition to the reduction of noise that is harmful to newborns, the possibility of incorporating adequate acoustic stimuli for development in the baby's environment[30] or the use of silicone hearing protectors[6] could also be evaluated for protecting babies from excessive but unavoidable noise from intensive care and therapy units.

It is believed that making care providers aware of their fundamental participation in the process of reducing sound levels is an effective way to reduce the noise to which newborns are exposed during care in the neonatal unit. Intense and sudden noise during incubator handling can be effectively reduced by careful manipulation of the incubator.

The importance of continuing education with the use of participatory methodology is emphasized in order to make care providers (health team and those responsible for the baby) subjects of the work transformation process in the neonatal unit and make them aware of attitudes that can minimize noise pollution in the microenvironment of this equipment and in the neonatal unit to favor the auditory health of these children.

The involvement of all care providers to improve neonatal care is of the utmost importance. Therefore, noise level research within the NICU must be continuous.

CONCLUSION

The sound levels measured were intense. The noise to which the preterm infants are exposed in the incubators during the care they receive constitutes a stressful event and modifies their behavioral state, with reflexes, body responses, facial manifestations and changes in sleep and wakefulness triggered when exposed to intense and sudden noises.

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Authors' contributions

MDOR participated in the conception of the study, the collection, analysis, synthesis and interpretation of the data and the writing of the article; CIF and AML participated in the data synthesis and interpretation; CMS and CGS participated in updating the bibliographic references and reviewing the article; CGSS participated, as the advisor, in the conception of the study, the analysis, synthesis and interpretation of the data and the writing of the article.