Rev Rene. 2026;27:e96505.
DOI: 10.36517/2175-6783.20262796505
www.periodicos.ufc.br/rene

Original Article

Effect of illuminance inside incubators on the clinical parameters of preterm newborns in intensive care

Efeito da iluminância no interior de incubadoras nos parâmetros clínicos de recém-nascidos prematuros em terapia intensiva

How to cite this article:
Carmo MDJ, Santos LM, Silva BSM, Marcatto JO, Mascarenhas LTS, Pereira JS, et al. Effect of illuminance inside incubators on the clinical parameters of preterm newborns in intensive care. Rev Rene. 2026;27:e96505. DOI: https://doi.org/10.36517/2175-6783.20262796505

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Conflict of interest: the authors have declared that there is no conflict of interest.

ABSTRACT

Objective: to verify the effect of illuminance levels inside incubators on the clinical parameters of preterm newborns in Neonatal Intensive Care Units. **Methods**: a longitudinal and prospective post hoc study conducted with 14 preterm newborns placed in incubators in three Intensive Care Units. Illuminance levels and clinical parameters were measured at 6:00 a.m., 12:00 p.m., 6:00 p.m., and 12:00 a.m. Data were analyzed using descriptive measures and linear regression. **Results**: median illuminance levels were high at 12:00 p.m. (662.5 lux), 6:00 p.m. (115.5 lux), and 6:00 a.m. (114.0 lux). Median heart and respiratory rates were higher at the 6:00 a.m. assessment, whereas systolic and diastolic blood pressure, oxygen saturation, and temperature were higher at 12:00 p.m. No statistically significant differences were found between illuminance levels across the four recording periods and the clinical parameters. **Conclusion**: the high illuminance levels throughout the day did not statistically affect the vital parameters of preterm newborns. **Contributions to practice**: the high illuminance values inside incubators require the implementation of interventions aimed at reducing them in order to mitigate other potential clinical effects in preterm newborns. (RBR-6xww44w).

Descriptors: Intensive Care Units, Neonatal; Light; Incubators; Infant, Premature; Stress, Physiological.

RESUMO

Objetivo: verificar o efeito do nível de iluminância no interior de incubadoras nos parâmetros clínicos de recém-nascidos prematuros em Unidades de Terapia Intensiva Neonatal. **Métodos:** pesquisa *post hoc* longitudinal e prospectiva, com 14 recém-nascidos prematuros em incubadoras de três Unidades de Terapia Intensiva Neonatal. Os níveis de iluminância e os parâmetros clínicos foram mensurados às 6h00, 12h00, 18h00 e 00h00. Os dados foram analisados por medidas descritivas e regressão linear. Resultados: os níveis medianos de iluminância foram elevados às 12h00 (662,5 lux), 18h00 (115,5 lux) e 6h00 (114,0 lux). As medianas da frequência cardíaca e respiratória foram maiores na avaliação das 6h00 e os da pressão arterial sistólica e diastólica, saturação de oxigênio e temperatura, às 12h00. Não se registraram diferenças estatisticamente significativas entre os níveis de iluminância durante os quatro períodos de registro e os parâmetros clínicos. **Conclusão:** os elevados níveis de iluminância ao longo do dia não afetaram estatisticamente os parâmetros vitais dos recém-nascidos prematuros. **Contribuições para a prática:** os elevados valores de iluminância no interior de incubadoras demandam a utilização de intervenções que possam reduzi-los a fim de mitigar outros prováveis efeitos clínicos em recém-nascidos prematuros. (RBR-6xww44w).

Descritores: Unidades de Terapia Intensiva Neonatal; Luz; Incubadoras; Recém-Nascido Prematuro; Estresse Fisiológico.

Received: Feb. 26th 2026; Accepted: May 8th 2026

Introduction

Prematurity is a health problem that globally affects the lives of many families. Worldwide, one in every 10 newborns is born preterm, which corresponds to one every two seconds[1]. This condition is associated with an increased risk of health problems, many of which are related to the hospitalization of preterm newborns in Neonatal Intensive Care Units (NICUs) and their exposure to the lighting conditions of this environment and other stressors.

The NICU is an environment with high levels of lighting[2-3], with intensities exceeding 200 lux during the day and falling below 20 lux at night in units that use cycled lighting[4]. The national recommendation for general lighting in Intensive Care Units is up to 500 lux[5]. Excessive ambient lighting may reach the interior of incubators and can exceed 500 lux[6]. In the first days of life, such exposure affects the brain maturation of preterm newborns, with long-term consequences for the health of these children[7].

Exposure of preterm newborns to excessive lighting and other stressors considerably compromises long-term neurodevelopment and the internal circadian cycle[7-9]. These alterations occur due to the entry of excessive light into the network of suprachiasmatic nuclei through the retinohypothalamic tract, which synchronizes the internal and external circadian cycle[10]. The suprachiasmatic nuclei play a crucial role in the generation of the circadian cycle by sending information to peripheral oscillators, which are present in virtually all cells of the body[11].

Excessive lighting may alter essential biological processes, such as immune system function, the autonomic nervous system, and the hypothalamic-pituitary-adrenal axis, in addition to affecting gene expression and, consequently, brain structure and function[9]. Preterm newborns are also able to perceive variations in lighting levels, exhibiting changes in physiological parameters[8,12] and sleep patterns[13].

Therefore, several strategies have been used to reduce lighting inside incubators, such as covers placed over the hood[14], the near-darkness model[4], and and scheduled 'quiet time' interventions[15]. Even with the implementation of these measures, preterm newborns may detect fluctuations in illuminance levels greater than 50 lux[8,12]. Thus, to understand the interaction between light exposure and clinical outcomes in preterm newborns in the NICU, it is necessary to perform a precise analysis of the lighting environment and characterize the variations within and between patients in a clinical setting[16].

Although some evidence has demonstrated a relationship between excessive lighting and changes in the clinical parameters of preterm newborns in NICUs, to date there are no Brazilian clinical studies that have investigated whether the level of lighting inside incubators affects these parameters over a 24-hour period.

Globally, there is a report of a cohort study involving 27 preterm newborns born before 32 weeks of gestational age and admitted to the NICU, in which illuminance levels inside incubators were monitored over a 10-hour period. In this study, only heart rate, respiratory rate, and oxygen saturation (SpO_2) were monitored, highlighting the need for further investigations with this purpose[12] that also include other vital parameters.

Thus, this study aimed to verify the effect of illuminance levels inside incubators on the clinical parameters of preterm newborns in Neonatal Intensive Care Units.

Methods

Study design

This was a longitudinal and prospective post hoc analysis linked to a randomized, crossover, open-label clinical trial that evaluated the effectiveness of eye protectors compared with usual care on the physiological stability of preterm newborns hospitalized in the NICU, reported in accordance with the recommendations of the Consolidated Standards of Reporting Trials (CONSORT).

Study period and setting

Data collection was carried out from September 2023 to February 2024 in three NICUs (A, B, and C) of a high-complexity public pediatric hospital in Feira de Santana, Bahia, Brazil. These three units comprise a total of 30 beds, with 10 beds in each unit.

NICUs A and C have similar structures, with transparent glass windows that allow the incidence of natural light and artificial lighting provided by fluorescent lamps positioned in the center of the units and above the area where the bassinets and incubators used for the care of each newborn are located. NICU B has no windows.

These units provide care for newborns in critical health conditions, predominantly preterm infants with perinatal asphyxia and respiratory, cardiac, intestinal, and metabolic disorders, as well as congenital malformations. In all three NICUs, a scheduled quiet time intervention is implemented from 1:00 p.m. to 3:00 p.m. and, whenever possible, from 12:30 a.m. to 2:30 a.m., during which the central lighting of the units and the areas near the beds is reduced, creating a dim-light environment.

During the quiet time period, healthcare professionals handle the newborn only when necessary, except in cases of clinical complications. During these periods, the incubator hood remains covered with a blanket in order to reduce illuminance inside the incubator.

Study sample

A convenience sample was used, consisting of 56 measurements of vital signs collected every six hours (6:00 a.m., 12:00 p.m., 6:00 p.m., and 12:00 a.m.) and 80,640 measurements of illuminance levels inside the incubator from 14 preterm newborns over a 24-hour period. These measurements were obtained during data collection for the clinical trial, when the newborns were allocated to the control group (absence of eye protection from 8:00 a.m. to 8:00 p.m.) and during the washout period (in which the preterm newborns remained without eye protection from 8:00 p.m. to 8:00 a.m.).

Preterm newborns were included when they presented physiological stability (heart rate between 120 and 180 beats per minute, respiratory rate between 35 and 60 breaths per minute, and oxygen saturation greater than or equal to 95% within the previous 24 hours), were placed in incubators, and had completed phototherapy treatment at least 24 hours earlier, when applicable. It should be noted that all preterm newborns were subjected to the quiet time period.

Preterm newborns undergoing phototherapy, invasive or noninvasive mechanical ventilation, with congenital malformations, grade II to IV periventricular hemorrhage, use of central nervous system depressants, opioid analgesics, or sedatives within the previous 24 hours, corticosteroid therapy, need for surgery, and those whose mothers had a history of illicit drug or antidepressant use during pregnancy were not included in the sample.

Preterm newborns who, after the research protocol had begun, experienced clinical deterioration and required reintubation for the initiation of mechanical ventilation, continuous positive airway pressure, central nervous system depressants, opioid analgesics, sedatives, corticosteroids, or phototherapy indication were excluded.

Instruments and data collection

The data collection team consisted of four undergraduate research fellows (funded by the National Council for Scientific and Technological Development and the Research Support Foundation of the State of Bahia) and two master's-level nurses who were trained to assemble and position the equipment, as well as to administer the data collection forms. This training took place over four hours in one of the NICUs that served as a research setting.

After the inclusion of the preterm newborn in the study, the team installed inside the incubator, near the newborn's head, a plastic film-wrapped box con-

taining a light-dependent resistor sensor intended to measure lighting levels. The device was developed by a Physics professor and calibrated through comparison with a digital lux meter (Instrutherm Mod. LD-900).

The sensor was programmed to record illuminance levels inside the incubator every 15 seconds over a 24-hour period, during which the data collection team remotely monitored the functioning of the device through the ThingSpeak™ website[17], a digital platform that enables real-time data visualization and analysis[18].

At the end of the data collection period, all illuminance records were stored in spreadsheet format using Microsoft Office Excel on a computer for subsequent analysis.

The variables were grouped into: sample characterization, exposure, and outcome. The following variables were collected from the medical records of the preterm newborns for sample characterization: demographic variables (sex – male and female), gestational variables (mode of delivery – vaginal or cesarean; gestational age at birth in weeks; chronological and corrected age), and clinical variables (reasons for NICU admission – by body systems; length of NICU hospitalization in days).

Gestational age at birth was calculated based on the date of the last menstrual period and the New Ballard method performed by the team of neonatologists immediately after birth. Chronological age was determined by the difference between the date of data collection and the birth date of the preterm newborns. Corrected gestational age was calculated by adjusting chronological age according to the degree of prematurity at the time of data collection. Considering that the ideal gestational age at birth is 40 weeks, the number of weeks remaining for the gestational age to reach 40 weeks was subtracted from the chronological age[19].

Illuminance levels inside the incubator, measured in lux at 6:00 a.m., 12:00 p.m., 6:00 p.m., and midnight, were considered exposure variables. The mean illuminance values recorded one hour before and one hour after each time designated for the assessment of the preterm newborns' vital signs were used to control for variations in the potential effect on the investigated parameters and abrupt fluctuations that could bias the exposure measurement at the time of evaluation, in addition to ensuring the robustness of the point association.

The outcomes were the clinical parameters of the preterm newborns: heart rate in beats per minute, respiratory rate in breaths per minute, systolic blood pressure and diastolic blood pressure, both measured in millimeters of mercury (mmHg); peripheral oxygen saturation (SpO_2) expressed as a percentage; and body temperature in degrees Celsius.

The clinical parameters were measured by members of the NICU nursing staff assigned to the care of the preterm newborns, according to the routine of each unit. Heart rate, respiratory rate, systolic and diastolic blood pressure, and SpO_2 measurements were obtained using multiparameter monitors available in the NICUs. The oscillometric method was used to measure systolic and diastolic blood pressure. SpO_2 levels were measured using a pulse oximeter connected to the multiparameter monitor of the respective study unit. Body temperature was measured using a digital thermometer placed in the axillary region of the preterm newborn and routinely used in NICU clinical care. Clinical parameters were assessed every six hours (6:00 a.m., 12:00 p.m., 6:00 p.m., and 12:00 a.m.).

All study variables were recorded in a form developed and previously validated by researchers affiliated with the Research Laboratory to which the authors belong.

Data analysis

Data were entered and analyzed using SPSS statistical software, version 22.0. Absolute and relative frequencies were used to describe categorical variables, whereas minimum, maximum, median, quartiles, and interquartile range were used for numerical varia-

bles, as these variables did not follow a normal distribution according to the results of the Shapiro-Wilk test.

To assess the association between the exposure and outcome variables, simple linear regression was used, considering a significance level of 5% and 95% confidence intervals. Residual diagnostics and the coefficient of determination (R^2) were calculated to evaluate the goodness of fit of the model.

Ethical aspects

Post hoc analyses were planned in the clinical trial from which this study was derived, and the study was approved by the Research Ethics Committee of the State University of Feira de Santana, in accordance with National Health Council Resolutions 466/2012, 510/16, and 580/18 (Opinion No. 6.287.516/2022 and Certificate of Presentation for Ethical Consideration No. 67259223.5.0000.0053). The clinical trial is duly registered (RBR-6xww44w).

Results

The 14 preterm newborns included infants of both sexes (7; 50%) and were predominantly born by cesarean delivery (9; 64.3%). In the medical records analyzed, 43 diagnoses related to NICU admission were identified among the preterm newborns, with low birth weight and early respiratory distress being the most frequent (7; 16.3%). Other diagnoses identified included infectious and metabolic risk, birth trauma, anemia, neonatal asphyxia, hypoglycemia, neonatal jaundice, risk for hip dysplasia, risk for congenital toxoplasmosis, rubella, cytomegalovirus, herpes, and syphilis, neonatal sepsis, and Rh factor and ABO system incompatibility.

Table 1 presents the minimum and maximum values, first and third quartiles, medians, and interquartile ranges for the gestational ages of the preterm newborns (at birth, corrected, and chronological) and length of NICU hospitalization in days.

Table 1 – Descriptive statistics of gestational age and length of stay in the NICU of preterm newborns. Feira de Santana, Bahia, Brazil, 2024

Variables	Minimum	Maximum	Median	1st Quartile	3rd Quartile	Interquartile Range
Gestational age						
Birth (weeks)	26.4	31.4	30.1	28.9	30.7	1.8
Corrected (weeks)	29.0	35.3	32.2	31.4	33.1	1.7
Chronological (days)	1.0	42.0	15.5	10.7	25.2	14.5
Length of NICU* hospitalization (days)	1.0	42.0	15.5	10.7	22.7	12.0

*NICU: Neonatal Intensive Care Unit

The highest median illuminance value was recorded at 12:00 p.m. (662.5 lux) throughout the 24-hour recording period of this parameter, followed by 6:00 p.m. (115.5 lux) and 6:00 a.m. (114.0 lux). The minimum value recorded was 6 lux (at 12:00 a.m.) and the maximum was 10,804.0 lux (at 12:00 p.m.). Median heart and respiratory rates were higher at the 6:00 a.m. assessment, whereas systolic and diastolic blood pressure, SpO_2, and temperature were higher at 12:00 p.m. (Table 2).

Table 2 – Descriptive statistics of illuminance levels inside incubators, in lux, according to measurement periods. Feira de Santana, Bahia, Brazil, 2024

Variables	Minimum	Maximum	Median	1st Quartile	3rd Quartile	Interquartile Range
Illuminance level inside incubators (hours)						
6:00 a.m.	12.0	690.0	114.0	25.5	492.5	467.0
12:00 p.m.	18.0	10,804.0	662.5	214.7	1,995.0	1,780.3
6:00 p.m.	10.0	660.0	116.5	69.5	295.5	226.0
12:00 a.m.	6.0	75.0	17.0	6.2	45.2	39.0

Median heart and respiratory rates were higher at the 6:00 a.m. assessment, whereas median systolic and diastolic blood pressure, SpO_2, and body temperature values were higher at 12:00 p.m. (Table 3).

Linear regression did not identify statistically significant differences between illuminance levels during the four recording periods and the clinical parameters of the preterm newborns (Table 4).

Table 3 – Descriptive statistics of the clinical parameters of preterm newborns. Feira de Santana, Bahia, Brazil, 2024

Variables	Minimum	Maximum	Median	1st Quartile	3rd Quartile	Interquartile Range
Heart rate (hours)						
6:00 a.m.	130.0	172.0	158.0	137.7	164.0	26.3
12:00 p.m.	131.0	185.0	152.0	147.2	166.5	19.3
6:00 p.m.	130.0	183.0	151.0	143.5	163.0	19.5
12:00 a.m.	137.0	186.0	153.5	150.0	160.2	10.2
Respiratory rate (hours)						
6:00 a.m.	40.0	48.0	43.5	41.0	44.2	3.2
12:00 p.m.	40.0	49.0	42.0	40.0	45.0	5.0
6:00 p.m.	38.0	46.0	40.5	40.0	45.0	5.0
12:00 a.m.	36.0	51.0	42.0	41.7	45.7	4.0
Systolic blood pressure (hours)						
6:00 a.m.	47.0	83.0	63.0	57.7	70.5	12.8
12:00 p.m.	48.0	87.0	67.0	63.0	78.5	15.5
6:00 p.m.	53.0	81.0	63.5	58.2	70.0	11.8
12:00 a.m.	44.0	86.0	61.0	54.2	75.5	21.3
Diastolic blood pressure (hours)						
6:00 a.m.	20.0	52.0	33.5	25.0	42.0	17.0
12:00 p.m.	19.0	64.0	37.0	28.7	43.2	14.5
6:00 p.m.	20.0	47.0	34.0	28.2	40.5	12.3
12:00 a.m.	25.0	68.0	36.0	29.0	46.5	17.5
Oxygen saturation (hours)						
6:00 a.m.	94.0	100.0	98.0	96.7	99.2	2.5
12:00 p.m.	94.0	100.0	98.5	97.0	99.0	2.0
6:00 p.m.	93.0	100.0	97.5	96.0	99.0	3.0
12:00 a.m.	72.0	100.0	98.0	95.7	99.2	3.5
Body temperature (hours)						
6:00 a.m.	35.9	37.2	36.4	36.0	36.7	0.7
12:00 p.m.	35.9	37.5	36.6	36.4	37.0	0.6
6:00 p.m.	36.0	37.3	36.5	36.2	36.9	0.7
12:00 a.m.	36.0	37.0	36.4	36.0	36.7	0.7

Table 4 – Simple linear regression to estimate the relationship between illuminance levels inside incubators according to assessment time and the clinical parameters of preterm newborns. Feira de Santana, Bahia, Brazil, 2024

Variables	β Coefficient	p-value	R^{2}*	95% CI†
Heart rate (hours)				
6:00 a.m.	-0.570	0.053	0.325	137.43 – 169.53
12:00 p.m.	-0.508	0.092	0.258	147.50 – 163.86
6:00 p.m.	0.081	0.783	0.007	140.30 – 164.46
12:00 a.m.	-0.228	0.477	0.052	145.83 – 173.54
Respiratory rate (hours)				
6:00 a.m.	-0.065	0.842	0.004	41.01 – 45.61
12:00 p.m.	0.050	0.878	0.002	40.28 – 44.40
6:00 p.m.	0.431	0.124	0.186	38.74 – 42.78
12:00 a.m.	0.342	0.227	0.117	38.48 – 45.00
Systolic blood pressure (hours)				
6:00 a.m.	0.437	0.155	0.191	51.40 – 70.28
12:00 p.m.	0.351	0.264	0.123	58.46 – 76.28
6:00 p.m.	0.177	0.545	0.031	56.30 – 69.68
12:00 a.m.	0.208	0.517	0.043	46.41 – 74.16
Diastolic blood pressure (hours)				
6:00 a.m.	0.141	0.662	0.020	22.82 – 41.86
12:00 p.m.	0.257	0.420	0.066	27.42 – 45.21
6:00 p.m.	0.187	0.523	0.035	26.11 – 38.86
12:00 a.m.	-0.181	0.573	0.033	30.06 – 58.09
Oxygen saturation (hours)				
6:00 a.m.	-0.388	0.213	0.151	96.76 – 100.12
12:00 p.m.	0.178	0.581	0.032	96.63 – 99.20
6:00 p.m.	0.113	0.700	0.013	95.20 – 98.76
12:00 a.m.	0.386	0.215	0.149	84.97 – 99.55
Body temperature (hours)				
6:00 a.m.	-0.283	0.373	0.080	36.18 – 37.00
12:00 p.m.	-0.034	0.917	0.001	36.27 – 37.03
6:00 p.m.	-0.021	0.944	0.000	36.21 – 36.94
12:00 a.m.	0.011	0.972	0.000	36.07 – 36.86

*R^2: Coefficient of determination; †CI: Confidence interval

Discussion

In this study, high illuminance levels were identified inside the incubators over the 24-hour period, exceeding the recommended values[5]. The highest median illuminance values were recorded between 6:00 a.m. and 6:00 p.m., with the highest value observed at 12:00 p.m., demonstrating that environmental rhythms vary throughout the 24 hours[16] of care provided to preterm newborns in the three NICUs investigated, and confirming findings from the literature indicating that the greatest exposure to lighting occurs during the morning period[6,16].

It was found that 80% of the measurements ranged between 10 and 50 lux, whereas 20% showed values above 50 lux[8]. Light exposure was generally low, with illuminance rarely exceeding 75 lux[16]. One factor that may have contributed to these findings was the use of covers on the incubators, especially those located near natural light sources, which maintains illuminance between 32.5 and 51 lux. When the incubator is not protected from light exposure, illuminance levels may reach up to 108 lux, and if this device is positioned farther from the natural light source, illuminance values range between 200 and 250 lux[6] due to ambient lighting. These conditions were observed in the units investigated.

Another environmental condition that interferes with the internal and external illuminance of incubators in a neonatal unit is the single-room physical structure. In these environments, daytime ambient lighting levels may reach 3,630 lux, while inside the incubators illuminance can remain below 50 lux through the use of covers and cycled lighting[16].

When comparing light levels before and after an architectural redesign of an open-plan NICU with 34 beds to a 40-bed unit composed of single-family rooms, light levels were significantly higher in the single-family room unit. This finding was associated with the number and configuration of windows in the new unit, which allowed greater daylight exposure compared with the open-plan NICU[20].

In open-plan units, such as the NICUs investigated, controlling ambient illuminance and illuminance inside incubators is difficult in order to meet the developmental needs of each preterm newborn, requiring the staff to use covers over the hood of this device. The three NICUs investigated in the present study are open-plan units exposed to natural light in addition to artificial light sources. However, as a strategy to reduce lighting levels, blankets are placed over the incubator hood, along with the environmental management provided by the quiet time. This management strategy may have influenced the absence of a statistical association between illuminance levels and the clinical parameters of the preterm newborns included in the study.

Although elevated, the illuminance levels inside the investigated incubators did not statistically affect the clinical parameters (heart and respiratory rates, systolic and diastolic blood pressure, SpO_2, and body temperature) of the preterm newborns included in the study sample.

These results are important because they indicate a lack of statistically significant association[21], which must be interpreted with caution given the small number of preterm newborns included in the study, since the absence of statistical significance may be related to lower statistical power. The precision of the confidence intervals obtained for each investigated association should also be emphasized, as this may add value to the study findings.

Results of this nature are important for the advancement of science because, as more relevant studies confirm these findings, the phenomenon begins to be investigated from another perspective or may eventually indicate the absence of an effect of the exposure of interest on the investigated outcomes, no longer requiring further studies for its consolidation.

The clinical parameters investigated showed slight changes according to the increase in illuminance levels inside the incubator; however, they remained stable. These findings were similar to those of a randomized clinical trial that investigated possible differences in the vital signs of preterm newborns between 28 and 32 weeks of gestation hospitalized in a NICU in Turkey and exposed to a light-dark cycle, in which no

statistically significant differences in vital signs were found between the intervention and control groups[22].

According to the results of a study conducted in Turkey, with repeated measurements in two distinct groups (incubator cover and absence of this intervention) and involving 91 newborns hospitalized in NICUs (44 full-term and 47 preterm), there was no significant difference between the median heart and respiratory rates of full-term and preterm newborns in the measurements performed without and with an incubator cover. In the first measurement, the median SpO_2 values of full-term and preterm newborns in incubators with covers were significantly higher than those of full-term and preterm newborns in incubators without covers[23].

When the variation in lighting exceeds 50 lux, heart rate increases by 3.8 beats per minute, respiratory rate by six breaths per minute, and regional cerebral oxygen saturation by 1.1%. Respiratory rate significantly decreased by 8.4 breaths per minute when the variation in lighting was equal to or less than 50 lux. Thus, higher illuminance levels increase the reactivity of preterm newborns. Moderate light changes between 10 and 50 lux increase respiratory and heart rates and decrease SpO_2 and cerebral oxygenation during more intense variations (>50 lux)[12].

There are reports indicating that exposing preterm newborns to light-dark cycles promotes earlier discharge from the NICU when compared with the absence of this intervention[22].

The aforementioned data may be explained by the fact that preterm birth affects the circadian cycle because maternal hormonal signals no longer synchronize this system, which may affect the newborn[11]. Controlling lighting in the NICU environment is a major challenge, since the position of incubators in relation to windows is generally fixed, and care activities require bright lighting at any time of the day. In addition, there are many factors that lack strict rhythmicity or disrupt the physiological rhythmicity of these newborns in the NICU, including the absence of a clear day/night rhythm in exposure to ambient lighting[16].

In most preterm newborns born between 24 and 29 weeks of gestation, circadian rhythmicity in skin temperature and heart rate was not observed until they reached 34 weeks of gestational age[16], which may be associated with the effect of conventional artificial lighting on neuropsin, a light-sensitive G protein-coupled receptor that is not activated and, therefore, does not adequately regulate the newborn's body temperature[24].

When protection against light inside the incubator is insufficient, preterm newborns may be awakened by variations in lighting, which can affect their sleep patterns. The more time the brain spends sleeping during early development and later in life, especially through consistent and uninterrupted sleep, the greater its capacity for brain maturation[25].

Therefore, reducing ambient lighting in the NICU plays a critical role in minimizing oxidative stress in preterm newborns, which may affect their immediate health and long-term neurodevelopment[26]. Light-dark cycles may be more appropriately introduced in preterm newborns between 26 and 32 weeks of gestational age[22,27], when the eyes begin to perceive light[27].

The benefits of this type of lighting are more pronounced between 32 and 34 weeks of gestational age, with light levels ranging from 10 to 600 lux[28]. These cycles may not be fully effective for preterm newborns with gestational age below 30 weeks, as they do not respond adequately to light because their visual photoreceptors are still immature and do not function effectively. Circadian rhythmicity in these newborns placed in incubators may be developed through the stimulation of nonvisual senses, such as touch and hearing[27].

There is growing evidence that the introduction of light-dark cycles in the NICU has beneficial effects on clinical outcomes in preterm newborns when compared with those exposed to constant light or near-constant darkness[11]. Maintaining preterm newborns in near-complete darkness until the 32nd week of gestational age is recommended to promote sleep[28], which could contribute to other long-term clinical outcomes in the preterm newborns included in this study, even though the sample size was small.

In the units investigated, continuous and in-

tense lighting is used in the environment. Data from a recent systematic review with meta-analysis of ten randomized clinical trials demonstrated that the use of cyclic daytime and/or nighttime lighting reduces the length of hospitalization by 7.52 days when compared with intense or dim lighting[29].

Evidence remains uncertain regarding the effect of cycled lighting compared with dim light or near-darkness on the likelihood of developing retinopathy of prematurity at any stage. There are no reports of severe neurodevelopmental impairments. Cycled lighting, compared with dim light or near-darkness, may have little or no effect on the duration of initial hospitalization, although the evidence is highly uncertain. Intermittent lighting, compared with continuous bright lighting, may reduce the duration of initial hospitalization, but the evidence is also highly uncertain[4].

However, the biological basis for these effects and their relationship with the functional and anatomical development of the circadian system in preterm newborns are not yet fully understood[11], which requires further scientific investigation.

Although no statistically significant effects were found between illuminance levels inside the incubator and the investigated clinical parameters, the results obtained provide scientific knowledge through a post hoc analysis and may contribute to supporting the optimization of the NICU clinical environment and its adaptation to the sensory needs and capacities of preterm newborns, with potential improvements in their neurodevelopment[8].

Study limitations

This study has some limitations. The association between illuminance levels and clinical parameters was estimated secondarily through a post hoc analysis, and this type of study design carries a greater risk of selection bias. To minimize this bias, it was decided to include data from all newborns in the control group. The absence of statistical significance for the investigated association may be related to the small sample size, convenience sampling, as well as the environmental measures adopted in the three investigated units (reduction of ambient lighting and the use of a blanket over the incubator hood).

The association intended in the present study was not considered in the sample size calculation of the randomized clinical trial, which may have influenced the statistical results. The limited publication of knowledge related to the research object addressed in this scientific study made it difficult to compare the findings of this research in order to publicly refute or confirm them.

The assessment of vital signs during four periods of the day may have limited and obscured variations that occurred before or after the collection of clinical signs. The lack of standardization regarding the location of lamps within the units and the positioning of incubators hindered the precise evaluation of the effects of illuminance inside these devices on the clinical parameters of preterm newborns, which may be considered in future studies.

Contributions to practice

The data are relevant to clinical practice insofar as the illuminance values recorded in this study were elevated during the three main periods of handling preterm newborns in the NICU, which requires greater visibility and the use of ambient lighting. These findings may also indicate the need for interventions aimed at reducing illuminance levels in order to mitigate other potential clinical effects in these newborns.

Conclusion

High illuminance levels were recorded inside incubators containing preterm newborns in neonatal intensive care units. However, although descriptive changes were identified in the clinical parameters of heart and respiratory rates, systolic and diastolic blood pressure, oxygen saturation, and body temperature during the periods of greatest peak illuminance (6:00 a.m., 12:00 p.m., and 6:00 p.m.), these differences were not statistically significant.

Acknowledgments

The *Universidade Estadual de Feira de Santana* (FINAPESQ 2024 Call), the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) – Universal Call CNPq/MCTI/FNDCT No. 18/2021, Process No. 407771/2021-2, and the *Fundação de Amparo à Pesquisa do Estado da Bahia* through Scientific and Technological Initiation scholarships.

Author contributions

Conceptualization and design or analysis and interpretation of data: **Carmo MDJ, Santos LM, Silva BSM, Marcatto JO, Pereira JS, Camargo MC**. Manuscript writing or critical review of the intellectual content: **Carmo MDJ, Santos LM, Mascarenhas LTS**. Final approval of the version to be published: **Santos LM, Silva BSM, Marcatto JO, Camargo MC**. Agreement to be accountable for all aspects of the manuscript related to the accuracy or integrity of any part of the work and to ensure that any issues are appropriately investigated and resolved: **Carmo MDJ, Santos LM, Silva BSM, Marcatto JO, Mascarenhas LTS, Pereira JS, Camargo MC**.

Data availability

The authors declare that the data are fully available within the body of the article.

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