

Lighting level in Neonatal Units according to environment and furniture management

Nível de iluminação em Unidades Neonatais, segundo manejo do ambiente e mobiliário
Nivel de iluminación en unidades neonatales, según el manejo del ambiente y del mobiliario

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Abstract

Objective: To identify the lighting levels in neonatal intensive care units that perform environment management or not according to types of furniture, and indicate which condition promotes the best environment for the newborn in terms of lighting.

Methods: Cross-sectional, descriptive, correlational study. The sample was composed by measuring the illuminance inside an incubator, an incubator with protection from light and an acrylic crib positioned according to proximity of natural light. Measurements with a luxmeter took place every 60 seconds for 24 uninterrupted hours per position in two neonatal intensive care units lit by natural light and artificial incandescent light, one where environment management is not performed (Institution A) and the other where environment management is performed for one-hour periods, four times a day (Institution B). The Mann Whitney, Friedman and Nemenyi tests were used for data analysis.

Results: The lighting levels showed great variation according to the period of the day and type of furniture (min=0; max=889 lux), and were higher in acrylic cribs. Positions far from the natural light source did not provide lower light levels. Protection over the incubators provided less exposure to light. The mean illuminance values in all positions considered in institution A were significantly higher compared to institution B, demonstrating the effectiveness of the environment management practice ($p < 0.05$).

Conclusion: The combination of the use of dark protection over the incubator and environment management practices provides the best lighting condition for newborns in neonatal units.

Resumo

Objetivo: Identificar os níveis de iluminação em unidades de terapia intensiva neonatais que realizam ou não períodos de manejo ambiental, segundo tipos de mobiliários, e indicar qual a condição que promove melhor ambiente ao recém-nascido, com relação à iluminação.

Métodos: Estudo transversal, descritivo e de correlação. A amostra foi composta pela mensuração da iluminância dentro de incubadora, incubadora com fotoproteção e berço de acrílico, posicionados segundo a proximidade da luz natural. As medições com luxímetro ocorreram a cada 60 segundos durante 24 horas ininterruptas por posição, em duas unidades de terapia intensiva neonatal iluminadas por luz natural e luz artificial incandescente, uma que não realiza o manejo ambiental (Instituição A) e outra que realiza por períodos de uma hora, quatro vezes ao dia (Instituição B). Para a análise dos dados foram utilizados os testes de Mann Whitney, Friedman e de Nemenyi.

Resultados: Os níveis de iluminação apresentaram grande variação conforme o período do dia e o tipo de mobiliário (min=0; max=889 lux), sendo superiores nos berços de acrílico. As posições distantes da fonte de luz natural não proporcionaram menores níveis de luz. A fotoproteção sobre as incubadoras propiciou menor

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exposição à luz. Os valores médios de iluminância em todas as posições consideradas na instituição A foram significativamente maiores, quando comparados à instituição B, demonstrando a eficácia da prática do manejo do ambiente ($p < 0,05$).

Conclusão: A combinação do uso da proteção escura sobre a incubadora e do manejo do ambiente proporciona a melhor condição de iluminação para os recém-nascidos em unidades neonatais.

Resumen

Objetivo: Identificar los niveles de iluminación en unidades de terapia intensiva neonatales que realizan o no realizan períodos de manejo ambiental, según el tipo de mobiliario, e indicar qué condición promueve mejor ambiente al recién nacido, con relación a la iluminación.

Métodos: Estudio transversal, descriptivo y de correlación. La muestra estuvo compuesta por la medida de la iluminancia dentro de la incubadora, incubadora con foto protección y cuna de acrílico, posicionados según la proximidad de la luz natural. Las mediciones con luxómetro se realizaron cada 60 segundos durante 24 horas ininterrumpidas por posición, en dos unidades de cuidados intensivos neonatales iluminadas por luz natural y luz artificial incandescente, una que no realiza el manejo ambiental (institución A) y otra que la realiza por períodos de una hora, cuatro veces al día (institución B). Para el análisis de los datos fueron utilizados las pruebas de Mann Whitney, Friedman y de Nemenyi.

Resultados: Los niveles de iluminación presentaron gran variación conforme el período del día y el tipo de mobiliario (mín=0; máx=889 lux), superiores en las cunas de acrílico. La posición distante de la fuente de luz natural no proporcionó menores niveles de luz. La foto protección sobre las incubadoras propició una menor exposición a la luz. Los valores promedio de iluminancia en todas las posiciones consideradas en la institución A fueron significativamente más altos al compararlos con los de la institución B, lo que demuestra la eficacia de la práctica del manejo del ambiente ($p < 0,05$).

Conclusión: La combinación del uso de la protección oscura sobre la incubadora y el manejo del ambiente proporciona una mejor condición de iluminación para los recién nacidos en unidades neonatales.

Introduction

The environment of the Neonatal Intensive Care Unit (NICU) directly influences the neurodevelopment of hospitalized newborns. Exposure to light is one of the main factors that cause deleterious factors; affects sleep and activity patterns and sleep deprivation of these individuals, and interferes with clinical improvement, weight gain and diet progression.⁽¹⁻³⁾ In order to reduce these harmful effects on the environment, the Brazilian Ministry of Health recommends implementing the “*Hora do Psiu*” or “*Horário do Soninho*” (“silence time” or “nap time”), based on environment management practices of reduction of noise, light and manipulation of newborns during one-hour periods, four times a day.⁽¹⁻⁵⁾

In addition to environment management with a programmed reduction in lighting, noise and manipulation of newborns, there are other recommendations for conduct and care regarding lighting in neonatal units. For example, use of an individually adjustable lighting system for the safe development of activities by the multi-disciplinary team; positioning cribs and incubators more than 60 cm from windows given the hypothesis that natural light interferes with the level of light received by the newborn; avoid direct lighting on newborns’ eyes; use of progressive lighting to allow a gradual change from light

to dark and reduce the stress generated by the sudden change in ambient lighting.⁽⁵⁾

The implementation of a cyclic lighting schedule is recommended, i.e., that allows levels between 100 and 200 lux during the day, preferably with natural light, and artificial light below 50 lux at night with a spectral distribution similar to natural night light.⁽⁵⁾ According to the Brazilian Association of Technical Standards (Portuguese acronym: ABNT), the adequate level of illuminance in intensive care units can reach 500 lux, as long as it is glare-free for the patient. During night observation, 20 lux is considered the minimum illumination required to differentiate human face features.⁽⁶⁾

Given this environmental context and by knowing the different types of furniture where newborns are positioned during their NICU stay, such as cribs and acrylic incubators, in the present study we sought to identify the lighting levels in neonatal intensive care units that perform or not periods of environment management according to type of furniture, and to indicate which condition promotes the best environment for the newborn in terms of lighting.

Methods

Cross-sectional descriptive correlation study performed to mimic the conditions experienced by

newborns hospitalized in the NICU of two public hospitals in the city of São Paulo. One hospital does not have an institutional protocol and does not routinely reduce light, noise or manipulation of newborns; this practice is linked only to the perception of professionals working in the unit (Institution A). In the other hospital, environment management practices with reduction of noise, light and manipulation of newborns are adopted for one-hour periods, four times a day (Institution B).

The sample consisted of measuring randomly, according to a randomization list, the level of illuminance inside the incubator, in the incubator with protection from light and in the acrylic crib, all manufactured by the Fanem[®] company. The unoccupied furniture was positioned according to proximity of the natural light source, defined in two positions: close (maximum of 190 cm away from the window) and far (minimum of 430 cm away from the window) from the natural light source, by understanding that the distance changes the levels of light received, as demonstrated in the illustrative scheme in figure 1, referring to Institution B.

The randomization list distributed a position for each day of data collection, that is, the arrangement of types of furniture in positions according to proximity of natural light. Luxmeter measurements

were taken every 60 seconds throughout 24 uninterrupted hours per position in the two neonatal intensive care units. In both units, the three types of furniture, incubator without protection, incubator with protection and common crib, were arranged in two positions, near and far from the window. Thus, the total study sample consisted of twelve 24-hour periods; six in institution A (without environment management) and six in institution B (with environment management). A lux meter model HD450, brand Extech Instruments[®] was used to obtain the illuminance level (in lux) records. The sensor was positioned where the newborn's head is on the furniture, mimicking the newborn's eye level and the amount of light received. In both institutions, was observed the practice of using fabric covers over the hood of incubators in order to reduce the luminosity on newborns. Institution A used folded white sheets arranged in a non-standardized way without covering the headboards. Institution B used thicker dark blue fabrics in appropriate shape and size to cover the head of the incubator and its upper part. The types of lighting were analyzed, and they were mixed in both institutions, that is, composed of natural light and incandescent artificial light. In both institutions there was no individual lighting for each bed. In institution A, blinds were

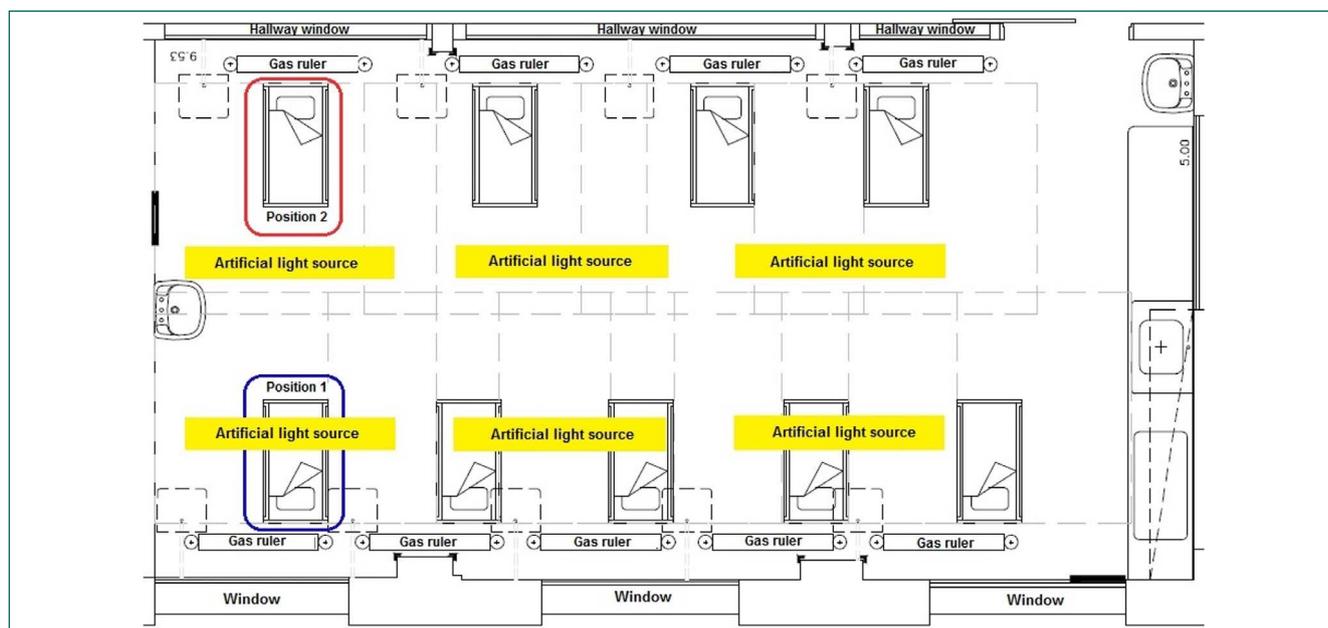


Figure 1. Illustrative diagram of the positioning of furniture according to the light source in Institution B

structured outside the window frames, allowing the incidence of more light, while in institution B, blinds were insulated between double glazing. The distances in centimeters between the sensor of the device and the natural light source (window) were measured with a measurement tape for each position of the randomization list in institutions A and B. The distances of each, position 1 - close to the natural light source and position 2- far from natural light, are shown in chart 1.

Chart 1. Distance between luxmeter and light sources by position 1 or 2 according to type of furniture and institution

Positioning and type of furniture	Distance between natural light and the sensor (cm)	Distance between artificial light and the sensor (cm)
Institution A		
Incubator position 1	70	72
Incubator position 2	450	90
Acrylic crib position 1	190	3
Acrylic crib position 2	450	90
Institution B		
Incubator position 1	75	20
Incubator position 2	430	110
Acrylic crib position 1	75	20
Acrylic crib position 2	430	110

The mean distance between the natural light source and the sensor, considering position 1, was 110 (± 69.28) cm, and between the artificial source and the sensor was 49 (± 39.83) cm. As positions 2 were measured in the same place, measurements were the same in the three items of randomization, both for distances from the natural source and from the artificial source, with no differentiation between the common acrylic crib and the incubator. In institution B, all distances coincided considering positions 1 and 2, regardless of the type of furniture (incubator with and without protection and acrylic crib) (Chart 1). Data collection began after approval by the participating institutions and took place between October 2019 and January 2020. Since this was not a study with humans, approval of the Research Ethics Committee was not needed. The captured data saved in the luxmeter datalogger were transferred to the computer through the software of the equipment made available by the manufacturer. This software automatically saved and stored data in Excel spreadsheets where they were organized and sent for data analysis performed with software

R, version 4.0.1 and Rstudio, version 1.3.959. The data obtained are presented by calculating the median, minimum and maximum values. In order to compare the lighting levels according to the different positions and types of furniture, the Mann-Whitney and Friedman tests were used since data did not present a normal distribution according to the Shapiro-Wilk test. The Nemenyi test was used for multiple comparisons 2 by 2 when the Friedman test was significant, considering a significance level of 5%.

Results

During 24 hours, 1,441 lighting measurements of the conditions, furniture and institutions studied were performed. The lighting levels showed great variation according to the period of the day and type of furniture (min=0; max=889 lux), and were higher in evaluations of acrylic cribs, regardless of the position in the unit, if close (position 1) or far from natural light (position 2). The illuminance captured in the different positions is presented in figures for demonstration of the variability of levels in lux during the 24-hour collection period. Figure 2 shows the illuminance levels in institution A, according to positions close (position 1) or far (position 2) from the natural light source and type of furniture, incubator with protection, incubator without protection and acrylic crib.

In figure 2, the highest levels of lighting are observed in acrylic cribs, regardless of the position. The condition with the lowest levels of illumination was the incubator with protection in position 2. Note that the comparison of tracings with horizontal lines represents the levels of illuminance that vary according to each figure. The highest horizontal line in the incubator with protection in position 1 represents 500 lux, although the highest line of the same furniture in the opposite position represents 250 lux. Thus, it is possible to visualize the variation of measurements over 24-hour periods, that is, involving morning and evening periods. Figure 3 shows the illuminance levels in institution B according to positions close or far from light sources and the types of furniture.

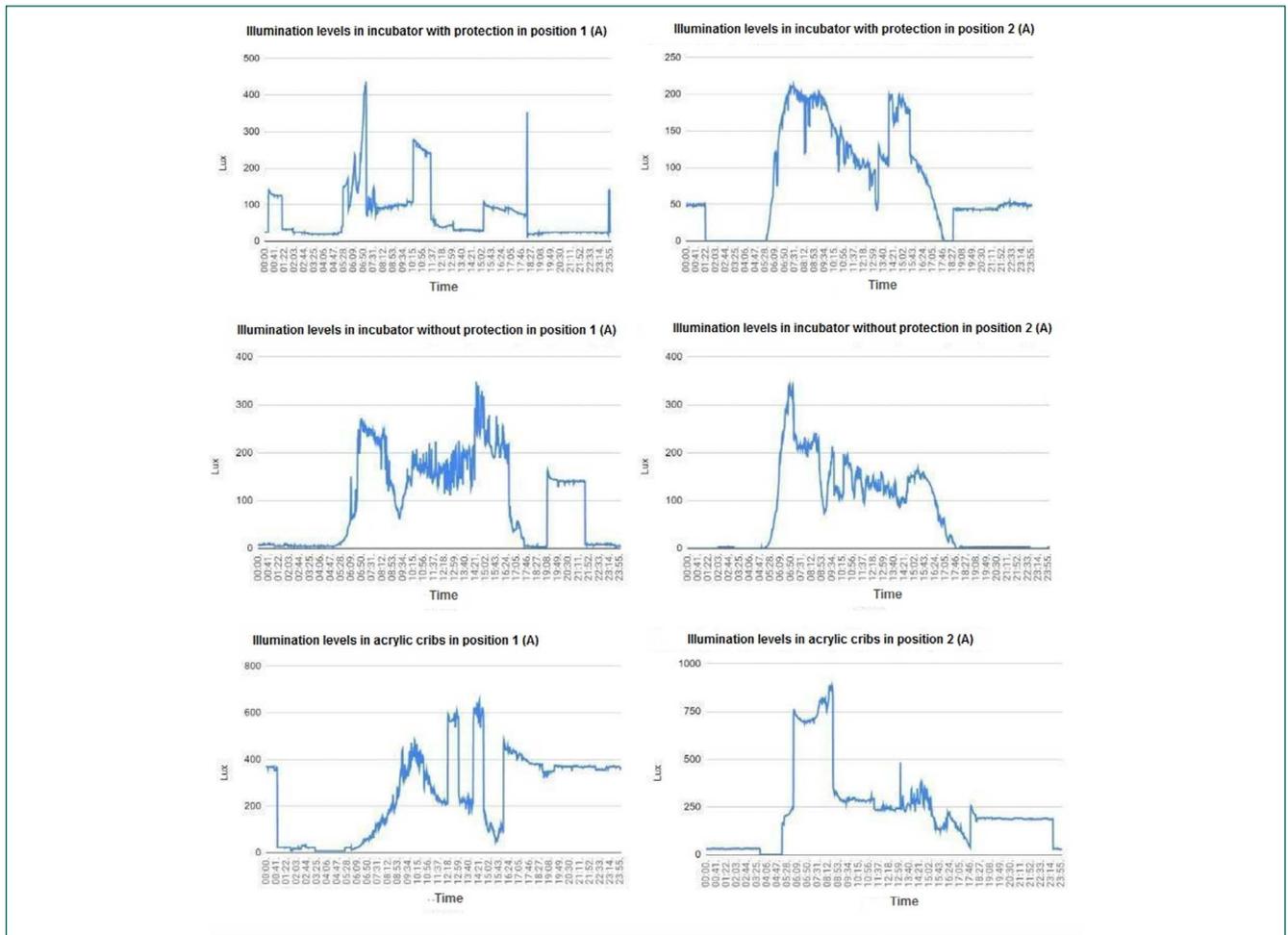


Figure 2. Illuminance levels in institution A, according to furniture and positioning (position 1- close to source of natural light; position 2- far from source of natural light)

Contrary to the hypothesis stipulated at the beginning of this study, keeping the furniture far from the window did not provide lower lux levels in all cases, as it depends on the type of furniture and the incubator protection model adopted by the NICU. In addition, the use of protection over the incubators provided less exposure to light in most positions, especially when adopted in conjunction with environment management practices. Therefore, the combination of the use of the incubator with protection and the implementation of environment management practices provided the best lighting condition for newborns hospitalized in neonatal units. Table 1 presents the minimum and maximum values and the median of illuminance obtained under conditions studied in both institutions in 24-hour periods.

A significant difference in the distribution of illuminance levels in lux between institutions A and

B was identified for all positions. The maximum illuminance values in a common acrylic crib both in position 1 and in position 2 exceeded 500 lux. As in institution A, the crib in position 1 received the highest levels of lighting, followed by the incubator without protection in this same position, the mean lighting values in all positions considered in institution A were significantly higher compared to institution B, mainly in acrylic crib, which demonstrates the effectiveness of the environment management practice. During data matching of this same relationship in both institutions, there was a statistically significant difference ($p < 0.001$) by the Mann Whitney test.

When protection is used without environment management, the newborn still receives higher levels of illuminance. It can be summarized that all positions in institution A compared to each other showed a significant difference according to the

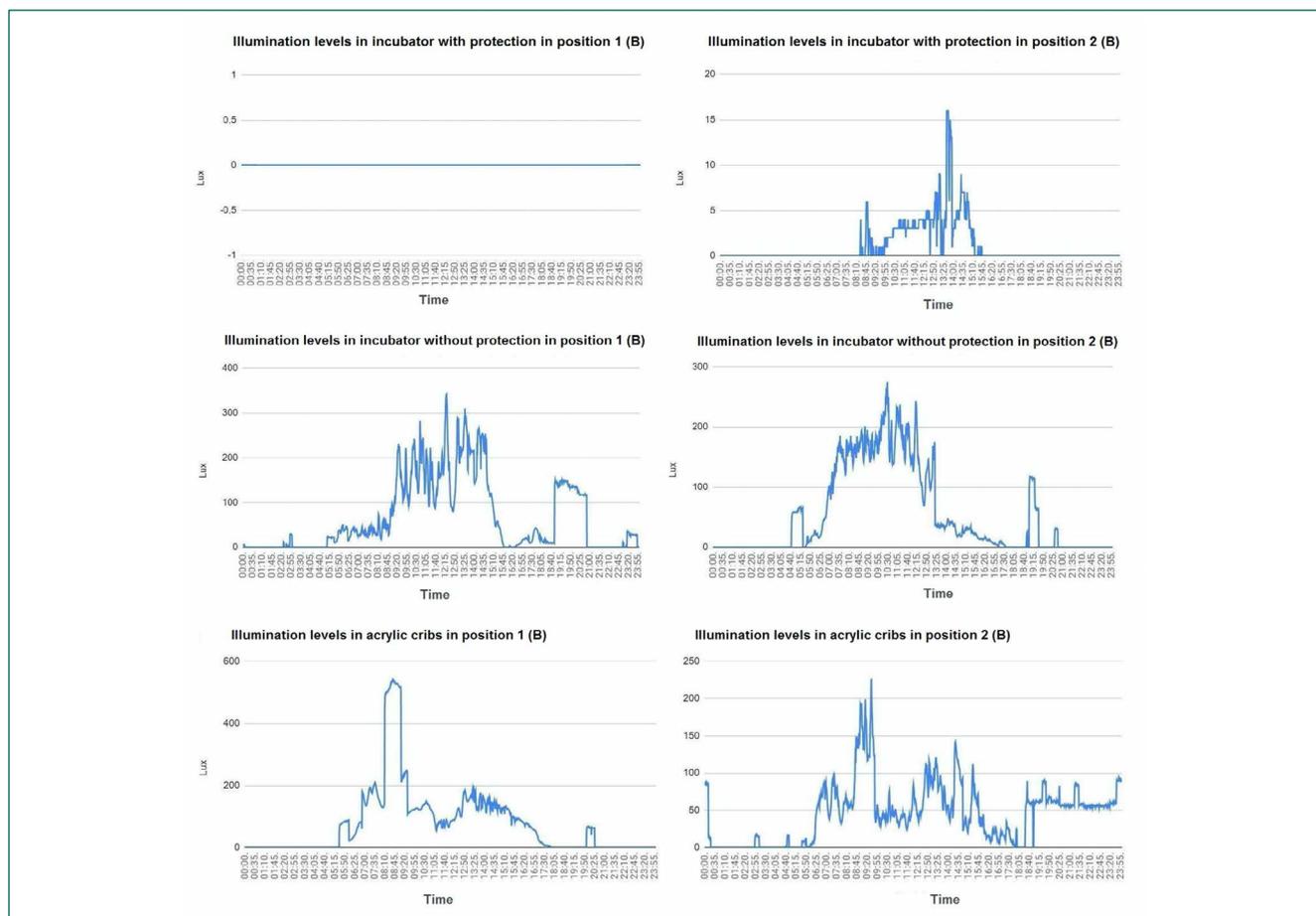


Figure 3. Illuminance levels in institution B according to furniture and positioning (position 1- close to the source of natural light; position 2- far from the source of natural light)

Table 1. Illuminance values in lux according to type and position of furniture in institutions A and B

Furniture and position	Institution A			Institution B			A/B
	Median	Min	Max	Median	Min	Max	p-value*
Incubator with protection position 1	32.5	9.1	437.1	0	0	0	<0.001
Incubator without protection position 1	108	0	349	28	0	341	<0.001
Incubator with protection position 2	51	0	212	0	0	40	<0.001
Incubator without protection position 2	17	0	342	14	0	275	<0.001
Acrylic crib position 1	313	6	654	25	0	540	<0.001
Acrylic crib position 2	191	0	889	48	0	227	<0.001

*Mann-Whitney test

Mann Whitney test, except for incubator with protection in position 1 compared to incubator without protection in position 1 (p=0.393).

In figure 3, there is a single position in which all measurements have a value of zero; the incubator with protection in position 1 in institution B. This finding is in line with the incubator protection model. This argument was justified during data collection, when it was observed that the protection adopted also covered the head of the incubator and did not allow the entry of natural light from the window. When comparing

this same furniture in the opposite position, position 2, there was greater lighting during the 24-hour period, given the greater light incidence in the incubator through the bottom, where newborns' feet are located. Note that this discrepant difference between the two positions is statistically confirmed by the Mann Whitney test (p<0.001). Thus, it is proven that position 2, far from the window, does not always provide lower levels of lux. This will depend on the type of furniture and the model of protection from light of incubators used at the NICU.

When performing the general cross-referencing of data between institutions using the Mann Whitney test, there was no significant difference ($p=0.065$) between an incubator without protection in position 2 in institution A and the same furniture in position 1 in institution B. Therefore, on this occasion there was no impact from environment management practices and the positioning in relation to the source of natural light. In the institution without environment management practices, the lux measurement in the incubator with protection far from the window generated a median greater than in the same position without protection, in disagreement with the predicted, although the maximum value and standard deviation were higher when the incubator was without protection. In addition to this one, other crossings confirm the same finding. For example, if the crib is far from the window and if it is in a NICU without environmental management, it tends to receive more light than a newborn in a crib near the window in a NICU with environmental management. The analysis of data of acrylic cribs at institution A clearly demonstrates that they receive more lux than any other position and other furniture, presenting higher levels. Position 1 had a greater median than that of position 2, as expected. Even though according to the Mann Whitney test all crosses involving a common acrylic crib in institution A showed a significant difference ($p<0.001$), in institution B, three crosses with a value of $p>0.05$ were identified. Among these, the ratio between common crib in position 1 and in position 2 ($p=0.297$) stands out and was also identified in the Nemenyi test ($p=0.059$). In institution A, even the common crib far from the window still receives a higher amount of lux than the measurement in an incubator without protection near the window. However, in the presence of environment management, the opposite was evidenced. In the NICU with environment management, the crib does not necessarily receive more light than the incubator, as it depends on the position. This issue was confirmed when comparing measurements in an unprotected incubator and in a common crib, identifying that in position 1 the crib receives more light than the incubator, but in position 2 the opposite happens. By considering measurements as a block and positions as

a treatment, the Friedman test showed a difference in lux measurements between all positions of the types of furniture. The Nemenyi test revealed eight cases of similarity between lux distributions of positioning between multiple comparisons 2 by 2. Among these, only two crossings coincided with cases of non-difference of the Mann Whitney test, incubator without protection in position 1 with crib in position 2 of institution B, and crib in position 2 with crib in position 1, both in institution B ($p>0.05$). Among the other eight cases of indifference, four included a common crib in position 1. Note that in the institution with environment management, there is no difference between positioning the newborn in the crib or in the incubator without protection if both are close to the window. Another relationship predicted only in the Nemenyi test ($p=0.118$) was the indifference between an incubator with protection close to the window and an incubator with protection far from the window in both institutions, that is, if the incubator has protection, there is no difference with respect to distance from the window.

Discussion

The institution with environment management practices had lower lux levels for all evaluated positions compared to the institution without management. Therefore, we understand that management of the NICU environment provides better environmental conditions regarding lighting for hospitalized newborns.

Furthermore, the comparison of lux levels in incubators with and without protection allowed us to identify that the protection over incubators positively interferes with the amount of light received. However, the characteristic of the cover can exert influence. The cover that obtained the best results was thicker, had darker color and appropriate size to also cover the head of the incubator.

Note that in the incubator with protection near the window, all measurements were kept at 0 lux during the 24-hour period, although these data were only found in the institution with environment management. This occurred because the type

of protection adopted covered the head of the incubator, not allowing light incidence through the window. Studies show that exposure to a completely dark environment, that is an environment with a measurement of zero lux for 24 hours, is not beneficial for newborns. They need light and dark cycles to synchronize the circadian rhythm, since the continuous penumbra does not provide the circadian information to stimulate the biological clock. Therefore, this study also warns about the harmful impact of the constant absence of light.⁽⁵⁻¹²⁾

According to research, light strikes the eye through the pupil, is transformed into an electrical impulse by the photoreceptors and then transmitted to the brain. As these photoreceptors develop and migrate at 28 weeks of gestation, a light/dark cycle is recommended for newborns older than 28 weeks.^(12,13) In addition, the circadian rhythm of the fetus starts approximately from 25 weeks of gestation, synchronizing with the maternal biological clock, but at birth the baby must synchronize the rhythm autonomously, and periodic and low-intensity light is essential to this end.⁽¹²⁾

According to analyzed data, it appears that in NICUs without environment management practices, in an incubator near the window, there is no significant difference in lux levels if it is with or without protection. Hence the conclusion that the use of protection in this position does not significantly interfere with the amount of light received by the newborn if there is no environment management. This finding is extremely important, as it serves as a support for a possible redefinition of recommendations for the environment in NICUs. Environment management practices are more effective than the use of protection over the incubator, since this same relationship in institution B (with environment management) showed a significant difference.⁽¹⁴⁻¹⁶⁾

The constitution of windows and blinds may also influence the discrepancy of illuminance levels, as the unit with blinds inside double glazing received less light.

Regarding positioning in relation to the natural light source, position 2 showed lower light levels for most positions analyzed.

In this study, the standard of lighting levels stipulated by ABNT were adopted as a reference,

with a measurement unit in lux, while in other studies ampere was used as the measurement unit. Most studies^(7,8) that presented lighting data in the NICU used the levels stipulated by the American Association of Pediatrics as a reference standard. Their recommendation is 650 lux as maximum illumination for observation, 1,080 lux for external procedures, and in other situations, adjustable levels between 10 and 600 lux with the introduction of day and night cycles.

Thus, most measurements evaluated in this study are in line with the recommendation. In one of these studies⁽⁸⁾, higher levels of lighting in cribs (referred to as open beds) were found in comparison to incubators, as observed in the results of this study.

There are few studies presenting the levels of illuminance in NICUs, making it difficult to argue and debate this topic. A study identified in the literature⁽⁹⁾ addressed the environment management practice and its impact on noise minimization. However, few studies offer this perspective for lighting and recommendations for conduct, and they do not present measurements of lighting levels.⁽⁵⁾

In a study, the total sleep time of hospitalized newborns was observed in neonatal units with and without environment management, and the highest total sleep time (mean of 696.4 minutes) was found in the presence of “nap time”. Therefore, the reduction of environmental stimuli, which includes the minimization of lighting, as well as the practice of covering the incubators, was important to characterize longer time and quality of sleep for newborns.⁽¹⁰⁾

In another study, the environmental effects on sleep time, wakefulness, and sleep stages of newborns in incubators was observed and the influence of high light levels on sleep, including increased wakefulness was also found. In this same study, noise levels, manipulation and humidity inside the incubator were correlated, but only light significantly influenced the sleep of newborns. Furthermore, the authors recommend that nurses create strategies to reduce the exposure of newborns to high levels of light.⁽¹¹⁾

This study identified the need for further studies on lighting in NICUs with measurement of illumi-

nance levels, as well as notes on the positioning of beds within the unit and the amount of light received, considering the variability of characteristics of the physical environment in NICUs and the measures instituted by professionals without reliable scientific evidence. The importance of “nap time” is highlighted for the reduction of light incidence on newborns and, consequently, for their recovery.

Conclusion

The best lighting conditions for newborns hospitalized in NICUs were achieved in incubators with dark protection, positioned close to or far from natural light and in conjunction with the environment management practice. Measures with an awareness-raising approach for NICU professionals, such as the use of protection over incubators and the effective implementation of environment management practices are in fact essential to reduce lighting levels. However, adapting characteristics of the physical environment, such as the incorporation of gradual and individualized lighting, and construction with a structural focus, aiming at a better arrangement of beds, could further minimize light overexposure and its harmful consequences for newborns.

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Collaborations

Oh RS, Orsi KCSC, Pinheiro EM, Santos LM and Avelar AFM contributed to the study design, data analysis and interpretation, article writing, relevant critical review of the intellectual content and approval of the final version to be published.

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