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Saleema Khowaja
Aga Khan University, saleema.khowaja@aku.edu

Shabina Ariff
Aga Khan University, shabina.ariff@aku.edu

Laila Ladak
Aga Khan University, laila.ladak@aku.edu

Zainab Manan
Aga Khan University

Tazeen S. Ali
Aga Khan University, tazeen.ali@aku.edu

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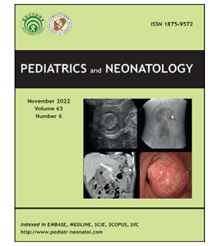

Original Article

Measurement of sound levels in a neonatal intensive care unit of a tertiary care hospital, Karachi, Pakistan

Saleema Khowaja [a], Shabina Ariff [a,*], Laila Ladak [a,b], Zainab Manan [a], Tazeen Ali [b]

[a] *Department of Paediatrics & Child Health, Aga Khan University Hospital, Karachi, Pakistan*
[b] *Aga Khan University, School of Nursing & Midwifery, Karachi, Pakistan*

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Background: High sound levels in the neonatal intensive care unit (NICU) can alter preterm newborn hemodynamics and cause long-term neuro-developmental delays and hearing loss. The study aims to collate data on sound levels in a level IV NICU of a tertiary care hospital, identify the factors associated with them, and compare them with the international standards set by the World Health Organization (WHO), Environmental Protection Agency (EPA), and American Academy of Pediatrics (AAP).
Methods: We carried out a cross-sectional study in NICU from 8th April 2019 to 30th June 2019. Sound levels were recorded for 480 h, using a portable sound meter, the Larson Davis 824. We captured sound levels on alternate days, during different shifts and shift changes and in open pods and single isolation rooms within the NICU. Additionally, we documented the total census, acuity of care, number of staff, number of procedures, and number of items of equipment used. The data was analyzed using t-test, ANOVA, and logistic regression.
Results: The average sound level (Leq) and the maximum level (Lmax) recorded were 60.66 ± 2.99 dBA and 80.19 ± 2.63 dBA, respectively, which exceeds international recommendations. The sound level gradually decreased from morning to night hours. The major increase in sound was observed during nursing shift change. Similarly, a significant increase in sound was observed in open bays compared to isolation rooms. However, no difference in sound levels was recorded during weekdays and weekends. The number of healthcare professionals and the number of procedures performed were strongly associated with an increased noise level.
Conclusion: Sound levels in NICU were beyond the safety range and international recommendations. We observed a significant sound increment during morning hours and at the time of

* Corresponding author. Deptartment of Paediatrics & Child Health, Aga Khan University Hospital, Stadium Road P.O. Box 3500, Karachi 74800, Pakistan.
E-mail address: shabina.ariff@aku.edu (S. Ariff).

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nursing shift change. High sound levels were associated with increased number of healthcare workers and bedside procedures in NICU.

1. Introduction

Prematurity is a global health problem. Pakistan ranks fourth among the top ten countries with the highest incidence of preterm births.[1] Premature neonates require intensive care and monitoring in a Neonatal Intensive Care Unit (NICU). With the advancement in technology and expertise, newborn survival has improved significantly, leading to increase burden of morbidity and an increase in disabilities and developmental delays.[2] There is a rising concern that these problems may have stemmed from an unfavorable, highly stimulating environment in the NICU.[3] High sound level is one of the major stressors in the NICU that has proved to have a negative impact on premature developing brain.[4]

The sensory system of a fetus develops in sequential order, with hearing and vision developing last; hence, these may remain underdeveloped in premature neonates.[5] The postnatal transition following birth for preterm neonates is a stressful condition. For years, it was assumed that newborns did not interact with their environment. However, recent evidence proves that neonates can respond to various environmental stimuli.[6] Exposure to high sound levels and the underdeveloped homeostatic mechanisms of premature neonates leads to physiological instability.[7] Aly and colleagues found significant neurobehavioral change along with increase in respiratory rate (RR), heart rate (HR), and blood pressure (BP), and decreased oxygen saturation among newborns exposed to noise ranging from 54 to 83 dB ($p = 0.001$).[8]

Ideally, the environment of the newborn should be congruent with the intrauterine environment for them to attain healthy growth and development. Noise is deemed as a health hazard causing pollution in NICUs.[9] The WHO recommends that the hourly sound level (Leq) should not exceed 35 dBA for patient areas in the hospital, with a corresponding maximum sound level (Lmax) of 40 dBA.[10] Similarly, the USEPA suggested that Leq during the day should be 45 dBA or below.[11] Furthermore, the AAP recommends that Leq in the NICU remain below 45 dBA, and that Lmax not be more than 65 dBA.[12]

Studies show high sound levels in the NICU result in short- and long-term adverse effects, including increased irritability, sleep disturbances, hearing impairment, speech delay, behavioral disorders, and intraventricular hemorrhage.[13—15] Beken showed a high incidence of hearing screening failure in NICU infants at 6 months of age compared to healthy counterparts at the same age.[16]

In high-income countries, sound levels are measured annually.[17] However, in Pakistan, no policies are at present instituted to measure sound levels in NICU. This study is novel and provides the first ever data on noise pollution in the NICU of a tertiary care hospital in the country. The purpose of this study was to measure the sound levels at different time points in the NICU and compare these with the recommended international standards.

2. Methods

A cross-sectional study was conducted in the NICU of a tertiary care hospital in Karachi, Pakistan from 8th April 2019 to 30th June 2019. This NICU is 24-bed level IV unit, well-equipped to provide invasive ventilation, therapeutic hypothermia, and isolation room facilities. The area of the NICU is approximately 7306 square feet, with vinyl floors, brick walls, and glass windows. The average occupancy rate of the NICU is 95%. The NICU have both open-bays and single isolation rooms. Fig. 1 displays the floor plan of the NICU; it consists of four large open-bays. An open-bay allows the placement of five incubators in the room; the distance between incubators is 5 feet. There are four isolation rooms: two single door isolation rooms, and two negative pressure isolation rooms; and each isolation room contains one incubator. Every incubator in the open-bay and the single isolation room has a cardiac monitor attached to monitor vital signs. Based on a newborn's condition, other equipment is also provided including ventilator, syringe and infusion pumps, and phototherapy lights.

The primary NICU team includes neonatologists, neonatal nurses, and ancillary staff. The number of healthcare professionals working in the morning, evening and night shifts are 27, 23 and 30, respectively. The nurse-to-patient ratio is usually 1:2 for non-infected, non-critical patients, and 1:1 for infected and critical patients. The NICU working hours are divided into three shifts, morning (0700—1600 h), evening (1500—2200 h), and night (2100—0800 h). There are three nursing shift changeover periods in a day: 0700—0800 h, 1500—1600 h, and 2100—2200 h. During these periods, the number of healthcare professionals almost doubles on the NICU floor and hand over by the medical and nursing team is performed in the patient area next to each incubator. Parents are allowed to visit without any time restrictions and for stable babies parents are also encouraged to participate in the routine care activities such as diaper change, feeding and kangaroo mother care.

2.1. Data collection

A portable sound meter Larson Davis 824 capable of detecting sound levels at a range of 30 dB—110 dB was used to record sound levels (Fig. 2). The sound meter was set to determine A-weighted decibel continuous values (dBA), slow time constant, and 30 dB gain.[18] The sample interval was 30 s for a 24-h data collection period.

Data were collected over a period of three months in each open-bay and isolation room. The sound variables Leq, Lmax, and Lmin were measured in all four open-bays and isolation rooms. The sound meter was pilot tested for two

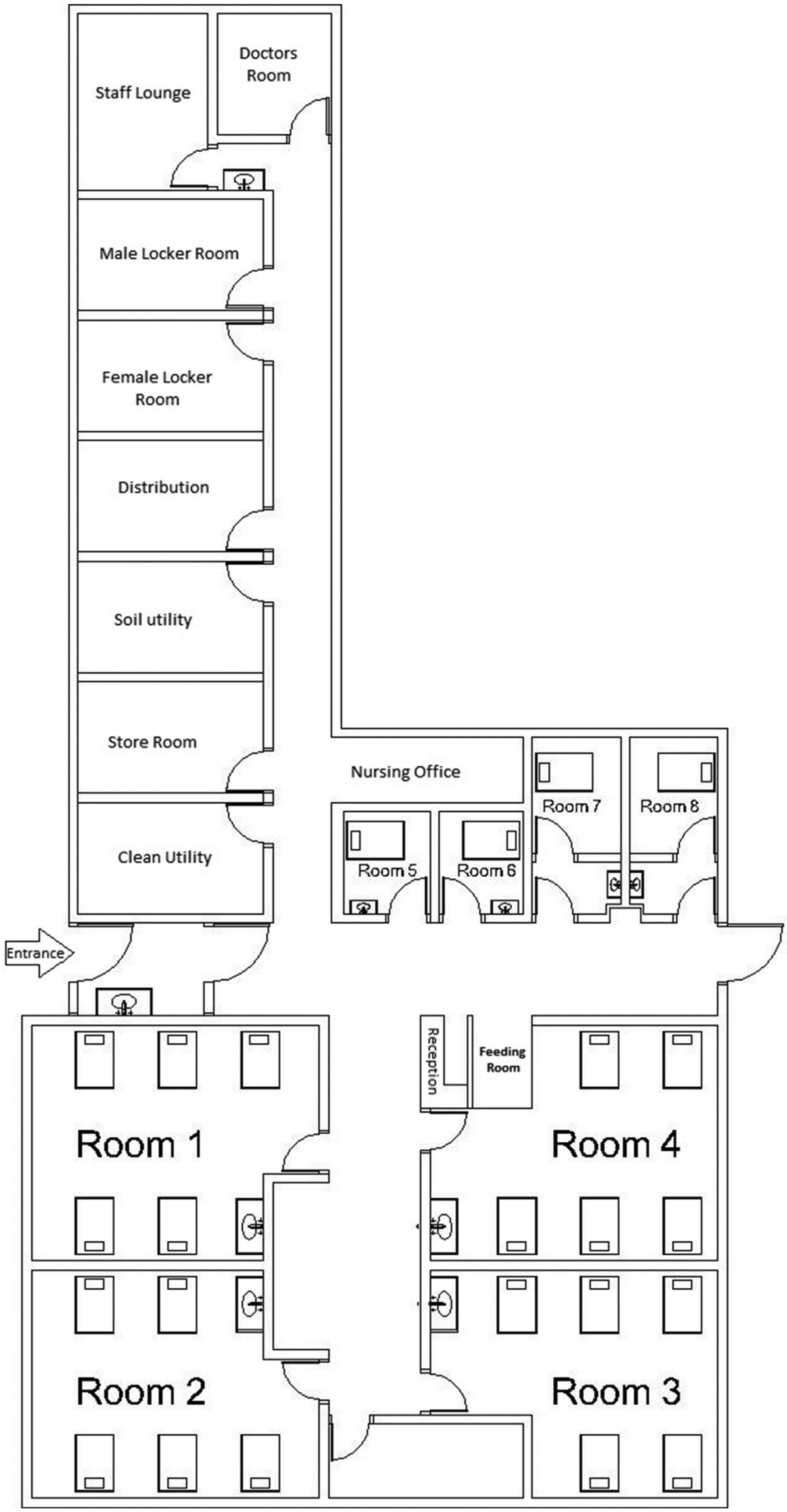

Figure 1 NICU floor plan.

Figure 2 Larson Davis 824 sound meter.

weeks in the NICU. The body of the device was wrapped in an A4-sized brown envelope, with just the microphone hanging out. The sound level meter was placed 80 cm below the ceiling and 32 cm from the wall at an angle of 90° to the incubators. In consideration that healthcare professionals might change their behavior because of the presence of the device, desensitization was carried out for two weeks. During this phase, the sound meter was placed in a similar position and rotated in different locations to minimize the Hawthorne effect.

Out of the total recordings, 480 h were analyzed. Recordings of pilot testing and the desensitization week were not included in the data analysis. The sound recordings of the initial 30 min, and 30 min at the end of each shift were discarded to avoid the possibility of false noise production while positioning the device. We also documented unit census, the healthcare professionals on the floor, invasive and non-invasive procedures performed, and number of equipment items functioning in the clinical area where the device was placed. Records of these activities were extracted daily from the patient file and unit logbook.

The data analysis was performed using the Statistical Package for Social Sciences (SPSS) version 20.0. For descriptive analysis frequencies, percentages, means, and Standard Deviation (S.D) were calculated. The inferential analysis included t-test, ANOVA, and univariate and multivariate logistic regression.

2.2. Ethical considerations

Approval was obtained from the Ethics review committee (ERC) of the Aga Khan University Hospital (AKUH), 2019-0886-2359.

3. Results

During the 3-month data collection period, there were a total of 306 admissions. The average length of stay of neonates at the NICU was 12 days. Most neonates were late pre-terms: 134/306 (43.8%) and 113/306 (36.8%) weighed more than 1500 g. Moreover, a total of 59 procedures were performed during the study period. Intubation (33.90%) was the most frequently performed procedure.

3.1. Comparison of the recorded sound levels with international guidelines

The results reveal that the mean hourly sound level (Leq) in the NICU was 60.66 $\pm$ 2.99 dBA. The mean Lmax recorded was 80.19 $\pm$ 2.63 dBA. All recorded values exceeded the recommended international values ($p < 0.001$) (Fig. 3).

The hourly sound levels in open-bays exceeded those in the single isolation rooms, in terms of Lmin (49.16 $\pm$ 0.95 dBA; $p < 0.001$), Lmax (81.86 $\pm$ 2.54 dBA; $p < 0.002$), and Leq (63.34 $\pm$ 1.55 dBA; $p < 0.001$). Similarly, the sound level during nursing shift change period (64.79 $\pm$ 4.49 dBA) was significantly different ($p < 0.001$) from that during working hours (58.25 $\pm$ 2.40 dBA). It was found that sound variables Leq, Lmax, and Lmin of the nursing shift changeover hours were higher compared to those during working hours.

Working hours were further subdivided into three shifts: morning, evening, and night. The mean scores of sound variables showed statistically significant results in all three shifts as presented in Table 1. On the post hoc Tukey's test, the mean hourly sound level of the night shift was lowest compared with the morning and evening shifts (p-value < 0.001 and 0.028, respectively); however, it was still significantly higher than the international recommendations.

On comparison of mean sound levels on weekdays (61.24 $\pm$ 3.41 dBA) and weekends (59.59 $\pm$ 1.73 dbA), similar ranges of mean with insignificant statistical difference ($p = 0.17$) were observed, so sound levels did not differ between weekdays and weekends.

3.2. Association of various activities with sound level in NICU

Activities at NICU that were significantly associated with sound level, at a p-value of $\leq$0.20, on univariate logistic regression were considered for multivariant analysis. We used the Hosmer and Lemeshow test to achieve goodness of fit in the model, and it showed a p-value of 0.264, making the model the best fit. The final model, shown in Table 2, illustrates that the number of healthcare professionals and number of procedures had a significant relationship with sound level, at a p-value of $\leq$0.05. After adjusting for other variables, odds of having a sound level above 56.4 dBA increased 2.08 times and

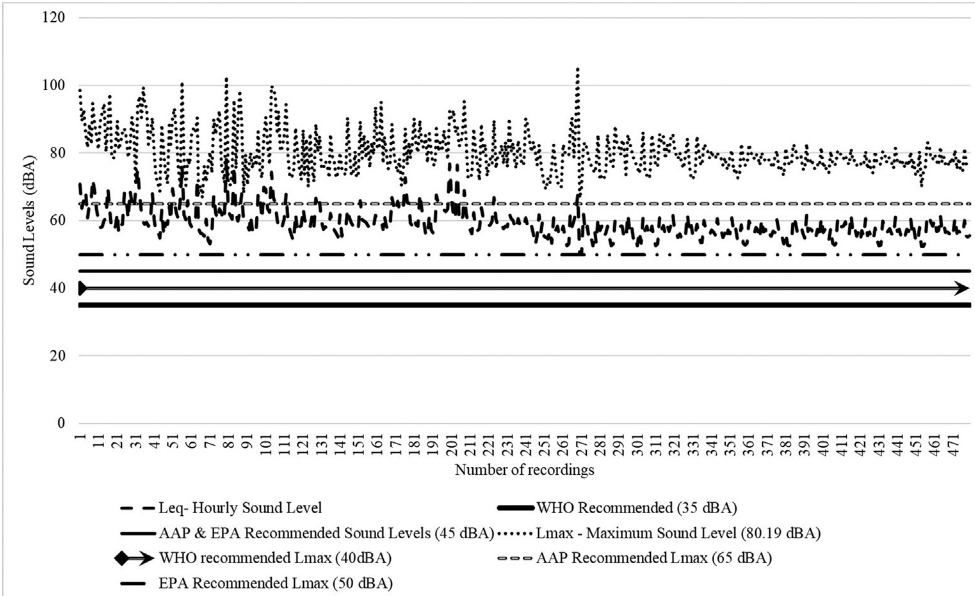

Figure 3 Comparison of recorded sound level and recommended international values.

Table 1 Sound variables during different shifts in the NICU.

Sound Variables	Mean ± SD			P-Value
	Morning	Evening	Night	
Minimum Sound Level (Lmin)	49.04 ± 3.43	47.20 ± 2.90	44.59 ± 1.55	<0.001*
Maximum Sound Level (Lmax)	81.85 ± 2.89	81.10 ± 4.70	77.19 ± 2.53	<0.001*
Equivalent A-weighted Sound Level (Leq)	61.32 ± 3.67	59.23 ± 2.79	56.86 ± 1.65	<0.001*

Table 2 Multivariable logistic regression model of activities associated with sound level.

Variables	Crude OR	95% Confidence Interval		P-value	Adjusted OR	P-value
		Lower	Upper			
Number of Healthcare professionals	2.242	1.836	2.737	<0.001*	2.083	<0.001*
Occupancy of the room	2.084	1.741	2.494	<0.001*	–	–
Equipment in the room	1.458	1.322	1.609	<0.001*	–	–
Procedures	2.196	1.631	2.955	<0.001*	1.549	0.028*
Census of the unit	1.066	0.981	1.158	0.130*	–	–

*Statistically significant results at p-value ≤ 0.05.

1.54 times, with every increase in the number of healthcare professionals and number of procedures, respectively.

4. Discussion

Noise pollution is prevalent in several busy LMIC NICUs and we recorded similar average sound levels in our study.[17,19] Although the study NICU was designed to meet international standards, it did not incorporate any mechanism for measuring sound levels in the unit. This study identified a very critical gap in patient safety and quality of care for the vulnerable pre-terms already at risk of complications. Research has demonstrated that noise pollution has immediate physiological changes and long-term impact on the growing brain including deafness, sleep disturbances, cognitive impairment, language disorders, learning difficulties, and behavioral disorders in neonates.[20]

This study showed that sound levels varied at different time points and locations within the unit. The sound levels were high mainly during morning shifts. High sound levels in the morning shift are attributed to clinical and patient monitoring activities that occur predominantly during morning hours. These include physical examination of the baby, clinical discussion in close proximity to the incubator, faculty rounds, administrative activities, parents' counselling, elective admissions, elective and emergency procedures, central line insertion or removal, portable radiographic devices/equipment and family visits. Other studies conducted in India, Iraq, Colombia, and Portugal report similar findings with peak sound levels in morning shifts.[9,21–23]

We observed high sound levels in open-bays compared to single isolation rooms. Similar findings have been reported from hospitals in the America and Taiwan, underscoring the need to ensure adequate distancing between incubator and appropriate traffic to minimize sound exposure.[24,25] In the present study, the high sound level in open-bays could be attributed to open doors that allow hallway traffic sounds to flow in, whereas single isolation room doors remain shut, reducing sound exposure. Additionally, there are more healthcare team members and items of equipment in an open-bay compared an isolation room.

We did not find any variation in sound decibels during weekdays and weekends as shown by Aljawadi and colleagues, who ascribed decreased sound on weekends to less crowding and fewer procedures planned for those days.[22] However, the study NICU had a similar routine on weekends and weekdays as regards number of healthcare professionals and visiting hours.

The nursing shift change period was the noisiest period of the day with a sound level of 6.5 dBA higher than mean sound level of the rest of the day. The increment in sound decibels was associated with an increase in the number of healthcare professionals on floor during this time. More importantly, the handovers take place at patient bedside, increasing the intensity of sound. In most high-income countries, the maximum sound level is reported during physician clinical rounds in comparison to nursing handovers. This is probably due to the practice of having a separate nursing station located away from the patient area, thus limiting sound exposure.[24,25]

Our observations on the major sources of sound are consistent with other studies. The principal sources of noise reported in the NICU are staff conversations, functioning equipment and alarms, placing of objects on top of the incubator, telephone rings, crying of newborns, and ambient sounds from the physical environment, such as the opening and closing of doors, objects falling, running faucets, and the moving of equipment.[15,26,27] In the present study, from the activities analyzed, the effect of medical procedures and the presence of a large number of healthcare professionals in the clinical area were associated with increased noise levels, which can be modified by simple interventions.

Many studies have been successful in reducing sound hazards by behavior modification strategies and by instituting an awareness program in the unit for healthcare professionals and families. Biabanakigoortani achieved a reduction in sound levels at the infant bedside from 68.2 to 48.50 dB with health education on noise impact on the newborn outcome.[27] Hence, noise pollution and its detrimental effects on neonate should be introduced in the in-service curriculum for healthcare professionals. A refresher course should be conducted for all new fellows, nurses, and medical students to alert and sensitize them to noise before they begin their rotation.

Reductions in sound levels can also be achieved by placing gentle reminders ("Quiet, Please" posters) around the NICU and by creating sound control champions across units. It is also important to implement a protocol for the periodic monitoring of sound levels in the NICU and to screen all NICU graduates for hearing impairment before hospital discharge.[28] Proven interventions, such as defined quiet times, as a standard care practice can be incorporated in NICU to improve neurodevelopment outcomes.[29] Pugliesi and colleagues achieved a 26% reduction in sound levels during quiet time, which was associated with improved sleep in infants.[30] Additionally, the installation of a noise sensor light alarm could also effectively reduce sound levels. This study underscores a critical yet ignored aspect of neonatal care in the country. This evidence should be utilized to carry out quality initiatives and develop cost-effective interventions to reduce noise pollution in NICU.

Our study had few limitations. We could not record sound inside the incubator, which could reduce the accuracy of the sound exposure to newborn. As we only had one item of equipment that was used to measure sound levels for each area, we were unable to capture sound dynamics simultaneously in open and closed bays. Furthermore, this study could not capture live bedside data due to financial limitations and hence only those factors were considered that were extracted from an indirect source. Although precautions were taken to reduce bias, healthcare providers could have possibly changed their behavior causing "halo bias".

5. Conclusion

The sound level recorded in the NICU exceeded the safe limits established by international bodies. We identified the highest noise levels during nursing shift change times and during morning hours. The majority of activities related to high sound levels can be amended. A holistic approach encompassing health education on sound hazards, installation of sound monitoring and modification of NICU practices can serve to reduce noise pollution in the Neonatal intensive care units.

Declaration of competing interest

The authors do not have any conflicts of interest to report.

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References

1. Chawanpaiboon S, Vogel JP, Moller AB, Lumbiganon P, Petzold M, Hogan D, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health* 2019;**7**:e37—46.
2. Blencowe H, Lee AC, Cousens S, Bahalim A, Narwal R, Zhong N, et al. Preterm birth-associated neurodevelopmental impairment estimates at regional and global levels for 2010. *Pediatr Res* 2013;**74**(Suppl 1):17—34.

3. Santos J, Pearce SE, Stroustrup A. Impact of hospital-based environmental exposures on neurodevelopmental outcomes of preterm infants. *Curr Opin Pediatr* 2015;**27**:254—60.
4. Aijaz N, Huda N, Kausar S. Disease burden of NICU, at a tertiary care hospital, Karachi. *Journal of the Dow University of Health Sciences (JDUHS)* 2012;**6**:32—5.
5. Neille J, George K, Khoza-Shangase K. A study investigating sound sources and noise levels in neonatal intensive care units. *South African Journal of Child Health* 2014;**8**:6—10.
6. Venkataraman R, Kamaluddeen M, Amin H, Lodha A. Is less noise, light and parental/caregiver stress in the neonatal intensive care unit better for neonates? *Indian Pediatr* 2018;**55**:17—21.
7. Ahamed MF, Campbell D, Horan S, Rosen O. Noise reduction in the neonatal intensive care unit: a quality improvement initiative. *Am J Med Qual* 2018;**33**:177—84.
8. Aly HA, Ahmed A. Effect of noise on neonatal vital data and behavior in NICU. *Clin Med Diagn* 2016;**6**:1—6.
9. Manuel Sá M, Azevedo R, Neves J, Machado O, Tavares J. Noise in an intensive care nursery/newborn unit. *J Health Educ Res Dev* 2018;**6**:1000265.
10. Berglund B, Lindvall T, Schwela D. *World Health Organization Occupational and Environmental Health Team*. Guidelines for Community Noise; 1999.
11. Control USOoNA. *Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety*. US Government Printing Office; 1974.
12. Noise: a hazard for the fetus and newborn. American Academy of Pediatrics. Committee on Environmental Health. *Pediatrics* 1997;**100**:724—7.
13. Almadhoob A, Ohlsson A. Sound reduction management in the neonatal intensive care unit for preterm or very low birth weight infants. *Cochrane Database Syst Rev* 2020;**1**:CD010333.
14. Xyrichis A, Wynne J, Mackrill J, Rafferty AM, Carlyle A. Noise pollution in hospitals. *BMJ* 2018;**363**:k4808.
15. Jordão MM, Costa R, Santos SV, Locks MOH, Assuiti LFC, de Lima MM. Noise in the Neonatal Intensive unit: identifying the problem and proposing solutions. *Cogitare Enferm* 2017;**22**:e51137.
16. Beken S, Önal E, Gündüz B, Çakir U, Karagöz İ, Kemaloğlu YK. Negative effects of noise on NICU graduates' cochlear functions. *Fetal Pediatr Pathol* 2021;**40**:295—304.
17. Valizadeh S, Bagher Hosseini M, Alavi N, Asadollahi M, Kashefimehr S. Assessment of sound levels in a neonatal intensive care unit in Tabriz, Iran. *J Caring Sci* 2013;**2**:19—26.
18. White RD. Recommended standards for newborn ICU design, 9th edition. *J Perinatol* 2020;**40**(Suppl 1):2—4.
19. Parra J, de Suremain A, Berne Audeoud F, Ego A, Debillon T. Sound levels in a neonatal intensive care unit significantly exceeded recommendations, especially inside incubators. *Acta Paediatr* 2017;**106**:1909—14.
20. Smith SW, Ortmann AJ, Clark WW. Noise in the neonatal intensive care unit: a new approach to examining acoustic events. *Noise Health* 2018;**20**:121—30.
21. Joshi G, Tada N. Analysis of noise level in neonatal intensive care unit and post natal ward of a tertiary care hospital in an urban city. *Int J Contemp Pediatr* 2016;**3**:1358—61.
22. Aljawadi HFM, Al-Muhsen Ali EA, Mahmood MH. Noise level at neonatal care unit of Al-Sader teaching hospital in Misan province, Iraq. *Kerbala Journal of Medicine* 2017;**10**:2740—6.
23. Garrido Galindo AP, Camargo Caicedo Y, Vélez-Pereira AM. Noise level in a neonatal intensive care unit in Santa Marta-Colombia. *Colomb Med (Cali)* 2017;**48**:120—5.
24. Domanico R, Davis DK, Coleman F, Davis BO. Documenting the NICU design dilemma: comparative patient progress in open-ward and single family room units. *J Perinatol* 2011;**31**:281—8.
25. Liu WF. Comparing sound measurements in the single-family room with open-unit design neonatal intensive care unit: the impact of equipment noise. *J Perinatol* 2012;**32**:368—73.
26. Laubach V, Wilhelm P, Carter K. Shhh... I'm growing: noise in the NICU. *Nurs Clin North Am* 2014;**49**:329—44.
27. Daniele D, Pinheiro EM, Kakehashi TY, Balieiro MM. Workers' knowledge and perception regarding noise in the neonatal unit. *Rev Esc Enferm USP* 2012;**46**:1041—8. [Article in Portuguese]
28. Abdeyazdan Z, Ghasemi S, Marofi M, Berjis N. Motor responses and weight gaining in neonates through use of two methods of earmuff and receiving silence in NICU. *ScientificWorldJournal* 2014;**2014**:864780.
29. Zauche LH, Zauche MS, Williams BL. Influence of quiet time on the auditory environment of infants in the NICU. *J Obstet Gynecol Neonatal Nurs* 2021;**50**:68—77.
30. Pugliesi RR, Campillos MS, Calado Orsi KCS, Avena MJ, Pradella-Hallinan MLC, Tsunemi MH, et al. Correlation of premature infant sleep/wakefulness and noise levels in the presence or absence of "quiet time". *Adv Neonatal Care* 2018;**18**:393—9.