

# Effect of a Quality Improvement Project to **REDUCE NOISE** IN A **PEDIATRIC UNIT**



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## **Abstract**

**Purpose:** Noise levels remain high in clinical settings, which may result in stress and sleep disruption, and can lead to immunosuppression, delayed healing, confusion, disorientation, delusions, and increased length of hospital stay. The purpose of this quality improvement project was to assess effects of a multidisciplinary noise reduction program on a pediatric unit in an acute care hospital in a developing country.

**Methods:** A quality improvement project was carried out over 15 months in a pediatric unit. A three-phase study was conducted where the first phase included obtaining patient satisfaction ratings and recording sound levels, the second phase included implementing a noise reduction program and designing a noise detector machine, and the third phase included obtaining patient satisfaction data and recording noise levels over a 1-year period.

**Results:** There was a significant decrease in noise of 8 A-weighted decibels when comparing the values before and after implementing the quality improvement project at  $t = 6.44$ ,  $p < 0.000$ . There was no significant difference in patient satisfaction ratings.

**Clinical Implications:** Noise in the pediatric unit exceeded recommended guidelines; however, decreasing the levels was possible and sustainable, which can improve the psychological and physiological wellbeing of hospitalized children.

**Key words:** Environment; Noise reduction; Nursing; Pediatrics; QI project

For decades, it has been postulated that human exposure to high levels of noise produces physiological and psychological disorders; current evidence supports this premise (Falk & Woods, 1973; Guthrie et al., 2014; Kahn et al., 1998). In 1973, Falk and Woods recorded noise levels in different hospital units and concluded noise levels stimulate the hypophyseal-adrenocortical axis leading to peripheral vasoconstriction and lack of sleep. Four decades later, noise levels remain high, resulting in stress and disturbed sleep and can lead to immunosuppression, delayed healing, confusion, disorientation, delusions, and increase in hospital length of stay (LOS) (DuBose & Hadi, 2016; Hsu, Ryherd, Wayne, & Ackerman, 2012; Topf, 2000). Patients most at risk are children, elderly, the chronically ill, and those with mental illnesses (Cranmer & Davenport, 2013; Goines & Hagler, 2007; van Kamp & Davies, 2013). In 1860, Florence Nightingale wrote that noise is “that which damages the patient” (Nightingale, 1860, p. 14). A significant amount of research has documented that sound levels from medical equipment alarms, telephones, heating, air-conditioning systems, personnel, beepers, and staff talking, among other noises, are stressors that disrupt patients and affect their wellbeing (Busch-Vishniac et al., 2005; Edworthy, 2013; van Kamp & Davies). Researchers have found noise negatively affects patient sleep by release of epinephrine and norepinephrine (Basner et al., 2014; Topf; Topf, Bookman, & Arand, 1996), which impedes the recuperation process (McCarthy, Ouimet, & Daun, 1999), alters memory, and increases agitation, aggressive behavior, and delirium (Brown, Rutherford, & Crawford, 2015; Short, Short, Holdgate, Ahern, & Morris, 2011; van de Pol, van Iterson, & Maaskant, 2017), all of which increase hospital LOS, decrease patient satisfaction, and increase mortality (Bailey & Timmons, 2005; DuBose & Hadi; Hsu et al.). Noise alters concentration, and increases fatigue, irritability, and burnout among nurses (Iyendo, 2016; Joseph & Ulrich, 2007; Mahmood et al., 2011; Xie, Kang, & Mills, 2009). Despite negative consequences of noise on patients and staff, sound levels in hospital environments have increased progressively over the years with dramatic increases to a level of 57–72 dB(A) during the day and 42–60 dB(A) at night (Busch-Vishniac et al.). The World Health Organization (WHO) recommends average sound levels in hospitals should not exceed 35 (A-weighted decibels [dBA]) with a maximum of 40 dBA overnight (Berglund, Lindvall, & Schwela, 1999). These recommended levels are significantly lower than what most studies have reported (Darbyshire & Young, 2013; Hsu et al.; Luetz et al., 2016; Oliveira, Gomes, Bacelar Nicolau, Ferreira, & Ferreira, 2015).

More research is needed to document the negative consequences of noise in hospitalized children.

Several studies have described interventions to reduce noise. These include, but are not limited to, changes in hospital design (Luetz et al., 2016) behavior modification (Li, Wang, Vivienne, Liang, & Tung, 2011; Monsén & Edéll-Gustafsson, 2005), staff education (Olson, Borel, Laskowitz, Moore, & McConnell, 2001), and strategies to decrease environmental noise levels (Luetz et al.). Few studies, however, have assessed the combined effects of different strategies on reduction of noise over time (Chawla et al., 2017). No published studies were found that included a researcher-designed instrument to alert people to high noise levels. This is especially important as commercially available instruments are costly and may not be affordable to many hospitals in the developing world. The purpose of this quality improvement (QI) project was to assess effects of a multidisciplinary noise reduction program on a pediatric unit in an acute care hospital in a developing country over a 15-month period. The time frame was chosen to allow adequate time to assess sustainability of the multiple interventions over time. The QI project was based on patient and family complaints that the pediatric unit was *too noisy* and that noise was disturbing their children's sleep.

## Methods

**Design:** A quality improvement project was conducted.

### Setting

The study took place in the pediatric unit at the American University of Beirut Medical Center in Beirut, Lebanon. The hospital is a 350-bed tertiary care center providing a variety of inpatient and outpatient services to the people of Lebanon and the Middle East. It has Joint Commission International accreditation and is Magnet-designated. The pediatric unit has 27 beds with 5 to 10 admissions per day. Flooring is made with a 3 mm thick vinyl sheet; walls of hollow concrete blocks (10 and 15 cm) with 2 cm thick plastering on both sides, and painted with colored paintings. The nurse station is constructed of wooden panels and is in the middle of the unit. There are 29 registered nurses, 10 practical nurses, and 1 nurse aid. There are two medical interns, one resident physician, one chief resident physician, and three medical students. No overhead speakers or public announcements are used on the unit.

### Procedure

This three-phase study that took place between February 2016 and February 2017 was exempted for institutional review board approval as it was considered a QI project. In the first phase, a taskforce representing all stakeholders (nurses, attending physicians, the patient



## A quality improvement project can be effective at reducing noise levels in a pediatric unit.

affairs department, house staff physicians, plant engineers, housekeepers, and security personnel) was formed to review the literature and develop action plans. Baseline patient and family satisfaction responses (both objective and subjective) were obtained on 25 participants (72% response rate) for 3 months prior to implementation of the program based on the Patient Satisfaction Survey-Middle-East (PSS-ME) (Kouatly et al., 2015). The PSSME is a 22-item Likert survey adopted to our culture from the Hospital Consumer Assessment of Healthcare Providers and Systems survey. It was tested on sample of 1,339 randomly selected patients with a reported cronbach's alpha coefficient of  $r = 0.87$  and adequate construct and predictive validity (Kouatly et al., 2015). Sound levels were recorded for 3 consecutive weekdays using the sound meter (Lutron SL-4023SD), which is a time data recorder but does not display any visual light to high noise levels. One of the study members walked around the unit at different times of the day and week and recorded sound levels every 10 seconds to determine location of the noisiest areas. Highest noises were next to the nurses' station where the sound meter was permanently installed in the hallway facing the nurse's station. The sound meter recorded noise levels for 3 consecutive 24-hour days, which was preceded every morning by calibration by a plant engineer.

Phase two consisted of implementing the noise reduction program, which included an education component and an action plan was designed by the engineering department at the Medical Center. (Table 1). In phase two, a noise detector machine was designed by the engineering department at the university. This was done based on the pilot status of the project and the cost (~\$1,200 each) of commercial sound ears from outside the country. The noise detector designed by our engineering department is ear shaped and made of plexiglass with an electronic circuit and timer that records noise levels and displays a yellow light when noise levels exceed 40 dBA to 65 dBA and a red light when noise levels exceed 65 dBA. The noise detector measures sound using an electric condenser microphone with an accuracy

of alarm threshold at  $\pm 3$  dB. It was calibrated using the SL-4023SD.

In phase three, the noise detector machine was installed in the unit next to Lutron SL-4023SD sound meter also facing the nurses' station and became clearly visible to staff, parents, and patients. Thresholds for the noise were set to 40 dBA based on the American Academy of Pediatrics (AAP) guidelines that recommend noise levels to be less than 45 dBA (AAP, 1997). Posters reminding people and visitors to be quiet were hung in the hallways. Similar to phase one, sound levels were continuously recorded for 9 months using the same sound meter (Lutron SL-4023SD). Patient satisfaction data were obtained from 38 participants (74% response rate) as required by our institution using the PPSME (Kouatly et al., 2015).

**Table 1.** Environmental Changes to Decrease Noise Levels

New beepers were purchased to replace using the intercom.
Wheels of the linen and housekeeping carriages were changed to rubber.
Door knobs were oiled.
Time for using the floor cleaning machine was adjusted so that it does not interfere with sleep periods.
Adjusting the telephone sound levels to below 45 dBA.
Allocation of a special room for nurses and physicians to discuss patient-related issues. (This initiative was not implemented.)
Patients were provided with earplugs if they so required.
Adjusting the intercom sound level to below 45 dBA.
Establishing a second nursing station to relieve the congested primary nursing station.
Distribution of reminder pins to all unit staff and house staff.
Distribution of noise stickers at the main entrance of the unit to reinforce the noise reduction campaign.

## Intervention

The intervention had three components 1) educational sessions, 2) behavioral modifications, and 3) environmental changes based on current research (Luetz et al., 2016; Taylor-Ford, Catlin, LaPlante, & Weinke, 2008). Educational sessions were 60-minute Powerpoint presentations conducted by two of the investigators and modified for each group of employees based on their specific needs. All nurses, physicians, housekeepers, plant engineers, and food service personnel were required to attend ( $N = 395$ ). Presentations involved results of sound levels obtained in phase one as well as the sources of noise, and compared them with the recommended values by the WHO (Berglund et al., 1999). The negative impact of noise on health, for both children and professionals, was also discussed. Behavioral changes implemented included instructing the medical and nursing team not to use the cell phone in patient's room or in the hallway, to switch the cell phone to the silent or vibrating mode, to have their conversations in a special room, and to lower their voices when talking. Environmental changes included working with the physical plant engineers to come up with cost-effective ideas that would decrease noise as noted in Table 1.

## Data Analysis

Sound level data were transferred to a laptop computer, summarized and transferred to an SPSS 24 file for management (IBM SPSS, version 24.0, Armonk, NY). To quantify changes in noise levels before and after the education and noise reduction strategies, sound levels were summarized and averaged for the 3 consecutive days before the intervention (phase one) and compared with the

summarized and averaged data for 9 months after the intervention (phase three) using a paired-samples T-test. Paired T-tests were also used to compare patient satisfaction scores before and after the intervention on question 16 pertaining to noise on the PSSME.

## Results

Sources of noise identified in phase one of the study that were measured using the Lutron SL-4023SD were mostly from people; healthcare professionals and visitors, followed by environmental noises such as opening and closing doors and by equipment such as ringing phones and beepers. Most of the subjective comments of patients were related to the loud voices of staff and visitors, for example; *Nurses should change their way in speaking and speak quieter*. The highest noise level recorded was 119.5 dBA as seen in Figure 1, which provides an example of a 24-hour recording of noise levels in dBA with the highest and lowest noises.

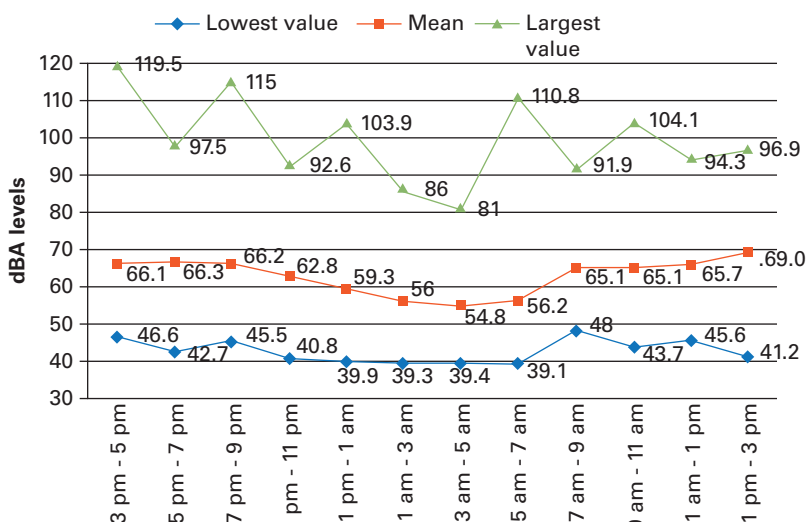
There was a significant decrease in noise levels before and after implementing the project as noted in Figure 2. Before the program, average dBA values in 3 days ranged between 39.45 and 94.75 with a mean of  $62.54 \pm 11.43$ . After the program, the ranges in the 12-month period were between 27.45 and 56.27 with a mean of  $54.24 \pm 5.94$  ( $t = 6.44, p < 0.000$ ). There was no significant difference in patient satisfaction related to noise (one item on the survey), mean was  $4.25 \pm 1.14$  for the 25 participants before the intervention and  $4.13 \pm 2.15$  for the 38 participants after.

## Discussion

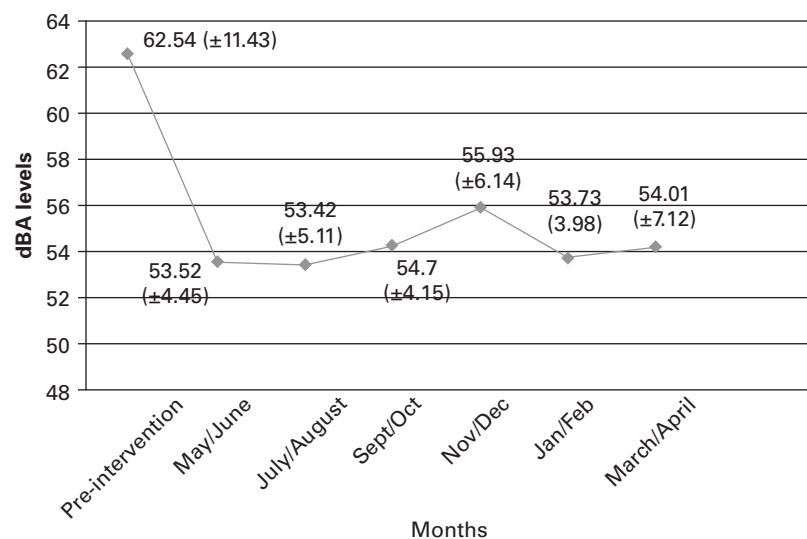
This QI project aimed at identifying noise levels and sources of noise in a pediatric unit and assessing effectiveness of an educational, behavioral, and environmental intervention. Sources of noise reported in this study are similar to those mentioned in other published reports that include noise from conversations of healthcare workers, followed by ringing telephones, and equipment (Broom, Capek, Carachi, Akeroyd, & Hilditch, 2011; Campbell, Arfanis, & Smith, 2012). Likewise, a multicenter study in Spain (Marqués, Calvo, Mompert, Arias, & Quiroga, 2012) noted that the most annoying noises in a hospital setting were people who talk loudly. This may be more pronounced in a Middle Eastern county such as Lebanon where patient rooms and hallways are crowded with visitors (Hajj et al., 2017).

Sound levels recorded in this study exceeded the WHO international standards (Berglund et al., 1999) for noise levels in hospitals

**Figure 1.** Example of Highest and Lowest Mean Noise Levels in dBA in 24 Hours in Pediatric Unit Measured by the Lutron SL-4023SD



**Figure 2.** Noise Levels Over a 12-Month Period



before and after the intervention. Although there was a significant decrease as a result of the intervention, the sound level remained high and warrants further interventions and long-term assessments especially for children who need more hours of sleep during the night than adults. The WHO (Berglund et al.) recommends that for a good sleep, sound levels should not exceed 30 dB(A) for continuous background noise and 45 dB(A) for an individual noise event. Therefore, we can assume that in our institution where noise levels are high, children are not getting a good sleep especially rapid eye movement sleep, which is necessary for their recovery as well as their growth (Zaharna & Guilleminault, 2010).

The intervention, which included several facets, was effective in reducing noise levels albeit, not in changing the satisfaction of patients, probably due to the small sample size of patients surveyed. It is possible that it takes a longer period of time to change opinions of pa-

### Suggested Clinical Implications

- Nurses working in pediatric units should make consistent efforts to reduce noise levels as they have been shown to be harmful for children.
- Nurses can work with a multidisciplinary team to promote practices to reduce noise.
- Engaging parents, family, and other visitors to reduce noise has been shown to be effective.
- Hospitals with limited budgets may design their own methods to decrease noise levels.

tients and families. It is also worth noting that in general Middle Eastern people speak with higher tones and volumes (Rababa'h & Abd Alkareem Malkawi, 2012), which makes adhering to the 45 dBA sound level even more difficult. Several researchers in the West have also found that it is close to impossible to adhere to 45 dBA noise levels (Chawla et al., 2017; Oliveira et al., 2015) thus, in a region where higher tones and volumes are the norm, should the WHO standards be adjusted? It is likely that ongoing education and support of staff is necessary before behavioral change is quantified.

### Limitations

Although the intervention was successful in reducing noise levels in this study, and the fabrication of a locally designed instrument at a low

cost was strength of this project, several limitations are worth noting. Assessing noise levels for a longer period of time preintervention may have provided richer and more representative data. Using spectral analysis would also have enhanced data quality and provided frequencies of sound some of which are more disruptive to patients. We did not assess staff satisfaction that would have added further information. We collected data over 12 months, which may be insufficient to detect changes in patient satisfaction scores related to noise. Further studies are recommended to reduce noise levels in hospitals and to document patient satisfaction, experiences, and outcomes (Elliott, McKinley, & Eager, 2010).

### Clinical Implications

Controlling noise levels in hospitals is possible and sustainable, which can improve the psychological and physiological wellbeing of hospitalized children. It has been well documented that noise is an environmental stressor that has negative consequences especially for children who are vulnerable. The focus of future research and QI projects should be to implement a variety of interventions to reduce noise levels and to assess the impact of such interventions on both the short- and long-term outcomes of patients as well as staff. ❖

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## References

- American Academy of Pediatrics Committee on Environmental Health. (1997). Noise: A hazard for the fetus and newborn. *Pediatrics*, 100(4), 724-727.
- Bailey, E., & Timmons, S. (2005). Noise levels in PICU: An evaluative study. *Pediatric Nursing*, 17(10), 22-26.
- Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. *Lancet*, 383(9925), 1325-1332. doi:10.1016/S0140-6736(13)61613-X
- Berglund, B., Lindvall, T., & Schwela, D. H. (1999). *Guidelines for community noise Geneva: World Health Organization*. Retrieved from <http://whqlibdoc.who.int/hq/1999/a68672>. Accessed January 2017.
- Broom, M. A., Capek, A. L., Carachi, P., Akeroyd, M. A., & Hilditch, G. (2011). Critical phase distractions in anaesthesia and the sterile cockpit concept. *Anaesthesia*, 66(3), 175-179. doi:10.1111/j.1365-2044.2011.06623.x
- Brown, B., Rutherford, P., & Crawford, P. (2015). The role of noise in clinical environments with particular reference to mental health care: A narrative review. *International Journal of Nursing Studies*, 52(9), 1514-1524. doi:10.1016/j.ijnurstu.2015.04.020
- Busch-Vishniac, I. J., West, J. E., Barnhill, C., Hunter, T., Orellana, D., & Chivukula, R. (2005). Noise levels in Johns Hopkins hospital. *The Journal of the Acoustical Society of America*, 118(6), 3629-3645.
- Campbell, G., Arfanis, K., & Smith, A. F. (2012). Distraction and interruption in anaesthetic practice. *British Journal of Anaesthesia*, 109(5), 707-715. doi:10.1093/bja/aes219
- Chawla, S., Barach, P., Dwaihy, M., Kamat, D., Shankaran, S., Panaitescu, B., ..., Natarajan, G. (2017). A targeted noise reduction observational study for reducing noise in a neonatal intensive unit. *Journal of Perinatology*, 37(9), 1060-1064. doi:10.1038/jp.2017.93
- Cranmer & Davenport (2013). Quiet time in a pediatric medical/surgical setting. *J Pediatr Nurs*, 28(4):400-5. doi: 10.1016/j.pedn
- Darbyshire, J. L., & Young, J. D. (2013). An investigation of sound levels on intensive care units with reference to the WHO guidelines. *Critical Care*, 17(5), R187. doi:10.1186/cc12870
- DuBose, J. R., & Hadi, K. (2016). Improving inpatient environments to support patient sleep. *International Journal of Quality Health Care*, 28(5), 540-553. <https://doi.org/10.1093/intqhc/mzw079>
- Edworthy, J. (2013). Medical audible alarms: A review. *Journal of the American Medical Informatics Association*, 20(3), 584-589. doi:10.1136/amiajnl-2012-001061
- Elliott, R. M., McKinley, S. M., & Eager, D. (2010). A pilot study of sound levels in an Australian adult general intensive care unit. *Noise and Health*, 12(46), 26-36.
- Falk, S. A., & Woods, N. F. (1973). Hospital noise—levels and potential health hazards. *The New England Journal of Medicine*, 289(15), 774-781.
- Goines L & Hagler L (2007). Noise pollution: a modern plague. *Southern Medical Journal*. 100:287-294.
- Guthrie, O.W., H. Xu, B.A. Wong, S.M., Mclturf, J.E. Reboulet, P.A. Ortiz and D.R. Mattie (2014). Exposure to low levels of jet propulsion fuels

- impairs brainstem encoding of stimulus intensity. *J. Toxicol. Environ. Health*, 77(5) 261-280
- Hajj, M., Gulgulian, T., Haydar, L., Saab, A., Dirany, F., & Badr, L. K. (2017). The satisfaction of families in the care of their loved ones in CCUs in Lebanon. *Nursing in Critical Care*, 22(4), 203-211. doi:10.1111/nicc.12195
- Hsu, T., Ryherd, E., Wayne, K. P., & Ackerman, J. (2012). Noise pollution in hospitals: Impact on patients. *Journal of Clinical Outcomes Management*, 19(7), 301-309.
- Iyendo, T. O. (2016). Exploring the effect of sound and music on health in hospital settings: A narrative review. *International Journal of Nursing Studies*, 63, 82-100. doi:10.1016/j.ijnurstu.2016.08.008
- Joseph A & Ulrich R (2007) Sound Control for Improved Outcomes in Healthcare Settings, Issue Paper #4. The Center for Health Design, Concord, CA.
- Kahn, D. M., Cook, T. E., Carlisle, C. C., Nelson, D. L., Kramer, N. R., & Millman, R. P. (1998). Identification and modification of environmental noise in an ICU setting. *Chest*, 114(2), 535-540.
- Kouatly, I. A., Hassan, M. M., Yazbik-Doumit, N., Soubra, M., Malak, S., & Badr, L. K. (2015). Psychometric testing of a comprehensive patient satisfaction survey in Arabic. *Journal of Nursing Measurement*, 23(2), 204-223. doi:10.1891/1061-3749.23.2.204
- Li, S. Y., Wang, T. J., Vivienne, Wu, S. F., Liang, S. Y., & Tung, H. H. (2011). Efficacy of controlling night-time noise and activities to improve patients' sleep quality in a surgical intensive care unit. *Journal of Clinical Nursing*, 20(3-4), 396-407. doi:10.1111/j.1365-2702.2010.03507.x
- Luetz, A., Weiss, B., Penzel, T., Fietze, I., Glos, M., Wernecke, K. D., ..., Spies, C. (2016). Feasibility of noise reduction by a modification in ICU environment. *Physiological Measurement*, 37(7), 1041-1055.
- Mahmood, A., Chaudhury, H., Valente, M. (2011). Nurses' perceptions of how physical environment affects medication errors in acute care settings. *Appl. Nurs. Res.* 22(4), 229-237.
- Marqués, P., Calvo, D., Mompert, M. P., Arias, N., & Quiroga, E. (2012). Multi-center study of noise in patients from hospitals in Spain: A questionnaire survey. *Noise and Health*, 14(57), 83-85.
- McCarthy, D. O., Ouimet, M. E., & Daun, J. M. (1999). Shades of Florence Nightingale: Potential impact of noise stress on wound healing. *Holistic Nursing Practice*, 5(4), 39-48.
- Monsén, M. G., & Edéll-Gustafsson, U. M. (2005). Noise and sleep disturbance factors before and after implementation of a behavioural modification programme. *Intensive & Critical Care Nursing*, 21(4), 208-219.
- Nightingale, F. (1860). *Notes on nursing: What it is and what it is not* (Commemorative ed.). Philadelphia, PA: J. B. Lippincott.
- Oliveira, L., Gomes, C., Bacelar Nicolau, L., Ferreira, L., & Ferreira, R. (2015). Environment in pediatric wards: Light, sound, and temperature. *Sleep Medicine*, 16(9), 1041-1048. doi:10.1016/j.sleep.2015.03.015
- Olson, D. M., Borel, C. O., Laskowitz, D.T., Moore, D.T., & McConnell, E. S. (2001). Quiet time: A nursing intervention to promote sleep in neuro-critical care units. *American Journal of Critical Care*, 10(2), 74-78.
- Rababa'h, M., & Abd Alkareem Malkawi, N. (2012). The linguistic etiquette of greeting and leave-taking in Jordanian Arabic. *European Scientific Journal*, 8(18), 14-28.
- Short, A. E., Short, K. T., Holdgate, A., Ahern, N., & Morris, J. (2011). Noise levels in an Australian emergency department. *Australian Emergency Nursing Journal*, 14(1), 26-31. doi:10.1016/j.aenj.2010.10.005
- Taylor-Ford, R., Catlin, A., LaPlante, M., & Weinke, C. (2008). Effect of a noise reduction program on a medical-surgical unit. *Clinical Nursing Research*, 17(2), 74-88. doi:10.1177/1054773807312769
- Topf, M. (2000). Hospital noise pollution: An environmental stress model to guide research and clinical interventions. *Journal of Advanced Nursing*, 31, 520-528. doi:10.1046/j.1365-2648.2000.01307.x
- Topf, M., Bookman, M., & Arand, D. (1996). Effects of critical care unit noise on the subjective quality of sleep. *Journal of Advanced Nursing*, 24(3), 545-551. doi:10.1046/j.1365-2648.1996.22315.x
- van Kamp, I., & Davies, H. (2013). Noise and health in vulnerable groups: A review. *Noise and Health*, 15(64), 153-159.
- van de Pol, I., van Iterson, M., & Maaskant, J. (2017). Effect of nocturnal sound reduction on the incidence of delirium in intensive care unit patients: An interrupted time series analysis. *Intensive & Critical Care Nursing*, 41, 18-25. doi:10.1016/j.iccn.2017.01.008
- Xie, H., Kang, J., & Mills, G. H. (2009). Clinical review: The impact of noise on patients' sleep and the effectiveness of noise reduction strategies in intensive care units. *Critical Care*, 13(2), 208. doi:10.1186/cc7154
- Zaharna, M., & Guilleminault, C. (2010). Sleep, noise and health: Review. *Noise & Health*, 12(47), 64-69. doi:10.4103/1463-1741.63205