

Vibroacoustic Pollution in the Neonatal Ward

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Excessive noise pollution is often a problem for neonatal nurseries. Noise pollution involves not only noise but also vibrations. The main difference between them is that noise can be heard, and vibrations are felt. The human ear cannot detect waves outside the range of 20 Hz–20 KHz. Waves from 0 Hz to 80–100 Hz should be considered vibrations. Both can be transmitted to the neonate through the incubator's operational mechanisms and other noise sources. Neonatal units' noise is well studied but very little is known about vibration. This entry focuses on the importance of vibrations reaching the inside of incubators in neonatal nurseries.

vibrations

neonates

environmental pollution

Care quality in neonatology has acquired an increasingly relevant role in the latest years for most pediatricians [1]. Noise pollution in neonatal intensive care units (NICU) is a sensitive matter to pediatric entities and doctors, being a medical study target in several articles [2][3][4][5][6][7][8][9][10][11][12][13][14][15][16]. These studies show that the measured noise levels are excessive in most cases. Their aim is to diagnose the environmental noise source as well as various remedies for that excessive noise. The World Health Organization (WHO), in some instances, may qualify it as noise pollution. Noise level studies in pediatric newborn units (NU), which are more prevalent than in NICUs, are also available and conclude the same [17][18]. Some researchers have examined noise in NICUs or nursing homes, but all these studies focus on noise and not on vibrations, with the assessment of frequencies between 100 Hz and 5000 Hz. In terms of sound analysis, in some studies, noise levels were estimated to range between 60 dB (A-weighted) and 73.5 dB (linear) [19]. Other studies set the levels at an average of 56 dB [20]. These data are above recommendations made by the American Academy of Pediatrics (AAP), remarking that the noise must not remain above 45 dB for more than one hour, to be not above 50 dB for more than 10% of the measured time, and there should not be peaks above 65 dB [16]. An optimized design could reduce the sound exposure of the newborn [21]. A difference of +8 dBA has been found when comparing the inside and outside of the incubator [16], especially when using respiratory equipment [20], these facts are supported by studies that question the quality of the isolation of the incubators, establishing high levels of reverberation above the noise at almost all frequencies [22]. Sounds produced from the inside of the incubator create a reverberation effect that amplifies in 2 to 4 dB several measured sounds such as the baby cry or opening and closing of portholes [23]. The infant's characteristics, the room, the number of medical devices, as well as visits and the level of workload also affect the amount of sound. As an example, preterm infants, although being the most fragile, are often exposed to louder exterior sounds than term-born neonates. Private rooms, low sound-level equipment, and sound-absorbing materials might contribute to the solution to this problem [16].

From the perspective of acoustic engineering, what is being assessed is the sound pressure level or airborne noise. By definition, noise pollution is “environmental vibration or noise, whatever its acoustic origin, which disturbs, endangers or damages people, their activities or property of any kind, or which has a significant negative effect on the environment,” according to environmental commissioners from EU member states [24]. A distinction must be made in the field of acoustics: airborne noise and vibrations. They are distinguished from each other by frequency. The human ear cannot detect waves outside the range of 20 Hz–20 KHz. Waves from 0 Hz to 80–100 Hz should be considered vibrations. Thus, it is undeniable that noise pollution includes both vibration and noise. The major distinction between them is that vibration is felt in the body as opposed to being heard as a noise. Generally speaking, waves with low frequencies are vibrations, and waves with medium-high frequencies are known as airborne noise. Each of their frequency spectra are clearly defined. The Spanish National Institute for Safety and Health at Work determines that, in health prevention, the vibrations that are of interest due to the effects they have on the organism are those with frequencies between 1 and 1500 Hz [25]. Some researchers are focusing on how frequencies between 20 Hz and 80 Hz are perceived, because this range has a major impact on health [26]. Only solids can produce vibrations and present a high percentage of transmission.

The International Standard ISO 2631-2: 2003 [26] issues a warning about the complexity of the physiological reaction to vibration. Regarding vibrations’ negative effects on health, it states that “biodynamic research studies, as well as epidemiological ones, showed indications of an increased risk of health deterioration caused by sustained exposure to vibration.” It also highlights the insufficient information to provide a quantifiable relation between WBV exposure in terms of the probability of the risk depending on several magnitudes and durations of exposure. A Royal Decree [27] in Spain, which approves the list of work-related illnesses covered by the Social Security System, lists among the illnesses brought on by exposure to vibration “Musculoskeletal or cerebrovascular diseases induced by mechanical vibration” or “disorders of the lumbar spine provoked by repeated whole-body vibration”. Acute health impacts from whole-body vibration exposure include pain, disruption of daily activities, changes in physiological functions, neuromuscular, cardiovascular, endocrine, and metabolic systems, as well as sensory disturbances of the central nervous system.

Regarding acoustic zoning, quality goals, and acoustic emissions, one must consider the restrictions set out by Law 37/2003 on 17 November 2003, as well as Royal Decree 1367/2007 [27][28]. The introduction of this act intends to stop, track, and lower the country’s levels of vibroacoustic pollution. The following restriction values are suggested [28][29] in order to meet the European aim of reducing noise pollution.

According to **Table 1**, legislation requires recorded Law index levels in the health sector to be less than 72 dB with a 5 dB safety buffer. This Law index is useful to estimate the maximum vibration values during the assessment of the interior of buildings.

Table 1. Vibration sound quality objectives applicable to indoor living space of residential, sanitary, educational, and cultural use adapted from [28].

Use of the Building	Vibration Index, Law (dB)
Residential	75
Sanitary	72
Cultural or educative	72

exposure might result in significant differences across people. The lumbar spine and its surrounding nerve system are frequently impacted by this exposure. Peripheral veins, the cochleo-vestibular system, the gastrointestinal system, female reproductive organs, and the neck-shoulder region have all been emphasized in other studies [30] [31] [32]. The effects are difficult to assess and mainly rely on the vibration's amplitude, frequency, duration, direction, and body part affected. Most of these studies focus on workers who are subjected to prolonged vibration from the equipment and the vehicles used at work, and all have come to the same conclusion: exposure can induce loss of balance, fatigue, discomfort, lack of attention, and even health hazards, including potential damage to some organs when subjected to certain frequencies or amplitudes. In the case of newborns, whole-body vibration is also related to reduced heart rate variability, a marker of sympathetic regulation and high levels of stress [33]. Vibrations might alter the development of hearing and language, also generating disorders in blood pressure, oxygenation, respiratory rate, and sleep. Preterm infants, which are still in earlier stages of development, might be more affected by these disorders [16]. There is a lot of research to be done about the impact of vibrations on a neonate, because most of the research focuses on the detection of vibrations in buildings or workplaces, and there is very little accessible information about the vibrations detected in pediatric contexts [34] [35].

Regarding the research on vibrations in the pediatric area, there are studies on vibrations during pregnancy [30], but there is a knowledge gap in neonatal patients. Limited studies have concentrated on the amount of vibration experienced during the transportation of neonatal patients, both by ground (ambulance) and air (helicopter) [36] [37] [38] [39] [40], as a cause of morbidity [36] [39] [41], most concluded that noise exposure during neonatal transport exceeds the published recommendations and neonates are subjected to vibration levels that are higher than acceptable norms for adults. Moreover, some reports have shown an increased rate of death and morbidity after the transportation of preterm neonates [40]. The possible link between brain damage in preterm infants and neonatal transport raises the issue of potential risks from environmental exposure, including vibrations, the translational forces, and rotational moments of inertia during transport, but the exposure to vibration of neonates during hospitalization has been seldom studied. Although the functional auditory and vestibular systems of a newborn are functional at the 28th gestational week, the mechanisms that adapt and habituate the child to sensory stimuli are not completely developed. Therefore, the newborn is unable to adapt to changes in sensory input. Additionally, until 32 to 34 weeks postmenstrual age, preterm newborns are less able to coordinate their autonomic and self-regulatory responses to deal with the stress brought on by external disruptions. Unfortunately, there are no specific legal limitations for any pediatric age.

Both the atmosphere of the room, such as central air conditioning, and the NU room's typical equipment, such as alarms, infusion pumps, or pulse oximeters have not been developed considering the patients' well-being. Behavioral modification for noise reduction would also be profitable to avoid the negative impact of vibration on neonates. It should include avoidance of careless opening and closing, as well as bumping of the incubator, and

avoidance of loud volume conversation or teaching activities inside the room. Also, and to a lesser degree, tearing plastic or paper bags near the incubators, adequate placement of aseptic gauze in the containers, carefully opening and closing trash containers, and appropriate maintenance of cartwheels should be considered. It was found that around 20 peak noises occurred every hour and were mostly distributed during the daytime and without any difference between weekdays and weekends. In-depth study of the sources of these peaks could be a potential advance in this topic [42]. As Del Rey et al. demonstrated during the analysis of ambient airborne noise in the neonatal nursery [17], certain airborne noise frequencies are amplified by the geometrical shape of the isolette closure and the mechanism of fixing the alarms to the incubators. This study shows that in some airborne noise evaluation circumstances, the level within the incubator is higher than the level outside the incubator. However, it is important to keep in mind that both inside and outside registered noise levels are above the recommended values according to other investigations [43]. It is necessary to extend the study's frequency range to evaluate low-frequency activity and it is essential to ascertain whether there is a transmission channel within the incubator that is empowering the spread of those frequencies that raise vibration levels. Some studies [44] demonstrate that, under certain conditions, vibration values are higher than the values allowed by current legislation for hospital environments. In every observed scenario, a peak is found on acceleration levels at the band of 16–20 Hz. This is basic in order to analyze the global value and the effect of vibration on humans. The incubator's motor has the highest impact on vibrations, with other potential vibration sources such as the room's central air conditioning having a smaller impact. It is noteworthy that vibrations due to the air-conditioning in addition to those produced by the engine are recorded. If the air conditioning and the incubator engine are activated, the limit values are exceeded (77 dB), while if only the air conditioning is on, it is close to reaching them (72 dB). The engine has the highest impact on vibrations. In fact, with the motor on, the sound inside is louder than outside at bands of <250 Hz [21], as low-frequency sounds arise from the motor [20]. Newborns can perceive noises from 113 Hz, where they are affected by high spectral sound sources at low frequencies, which are numerous in a NICU, such as the incubator itself or an air fan [45].

Regarding vibrations, a comfort rating system is described in ISO 2631 [26], which also provides extensive procedures for whole-body vibration monitoring and an assessment of the exposure's intensity. In terms of vibration, neonates' feet reach higher vibration levels than their heads [19]. According to an analysis conducted by Mc Calling [33], it is evident that incubators can cause harm as an unintended result of their design, as they generate vibrations that can be harmful to the infant. According to studies regarding in-hospital transport of neonatal incubators, the vibrations found were all classified as "extremely uncomfortable" in the maximum level set by the ISO previously mentioned [46]. Although there are laws governing workplaces, there are no restrictions on how much vibration newborns can be exposed to. The amount of published information on exposure to vibrations in incubators during transport and "in situ" in the hospital environment is rather scarce. Most previous transport studies have drawbacks regarding sample size, the use of neonates as opposed to dummies, and type of transportation, however, according to ISO 2631, the top end of the comfort scale categorization is reached or exceeded by the vibration emission detected and published to date. Studies [33] conducted during in-hospital management to date also indicate that, in the great majority of instances, in incubators for newborns, the exposure

to body vibrations exceeds the limits. With the unit's equipment, the alerts it implies, and the neonate's customary care, things might be worse.

The question at hand is whether or not this vibration is hazardous (although it is assumed that any ambient contamination is harmful, especially for an immature organism). Vibrations in adults negatively affect cardiorespiratory function, as well as the central and peripheral nervous systems. The metabolic and endocrine function, the electroencephalographic activity, the gastrointestinal system, and body temperature may also be damaged according to research by the International Organization for Standardization. For sitting adults, this organization has published guidelines regarding body vibration. However, no guidelines have been set for those who are standing or lying down [35]. There are guidelines for how much noise a baby in an incubator can tolerate, but there is no guideline or criteria for how much vibration is safe or how destructive it is.

Different studies have shown that whole-body vibration (WBV) may be positive in diverse conditions. One of them [47] demonstrated that WBV with a specific protocol generates several benefits for patients with bone mineral density (BMD) and functional capacity in cases of thalassemia at pediatric ages. Another study [48] concludes that WBV is more effective than suit therapy in children who suffer from cerebral palsy of spastic diplegia. Also [49], WBV and focal muscle vibration (FMV) are beneficial for reducing spasticity and improving motor function in patients who have suffered a stroke. WBV together with conventional physiotherapy improve the motor system of hemiparetic cerebral palsy pediatric patients, inhibiting spasticity [50].

Vibrational stimulation has been shown to reduce pain in pediatric and newborn populations, according to several publications [40]. Despite the paucity of research on neonates, vibrating chairs and swings are frequently used to relax babies. Infants with colic may potentially benefit from mechanical vibration therapy. Some studies found that higher average whole-body vibration was related to a lower heart rate, suggesting a calming effect on the baby, while high sound levels raised the heart rate as an indicator of stress [51].

A complex biological system, such as the human body, becomes more sensitive when a small amount of random vibration is applied, according to the fundamental idea of stochastic resonance. It is possible that in some circumstances, gently applying vibrations to newborns might be useful to treat apnea. It was found that a decrease in the apnea rate resulted after sensory stimulation of preterm infants in comparison with a control group [52]. In preterm infants who are currently receiving caffeine or respiratory support devices, stochastic resonance may also be helpful in reducing apnea episodes. Using a specialized mattress and stochastic resonance stimulation, a clinical experiment shows that preterm neonates with apnea, bradycardia, and oxygen desaturation may be successfully treated. The stimulation supplied by the mattress was based on a subtle massage-like vibration. Apnea was reduced by 50%, as was bradycardia intensity (20%). Oxygen desaturation also dropped by 20–35% [53][54]. To prevent harm to the infant's still-developing brain, care was taken to minimize vibrations near the baby's head. There are no other studies addressing the head's area so there is a lack of information about the possible usefulness of vibrations in neonates that must be cleared in terms of area, time, or intensity.

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