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ORIGINAL

Characterization of hearing impairments due to exposure to industrial noise in generator set operators in Pinar del Río

Caracterización de las alteraciones auditivas por exposición al ruido industrial en operarios de grupos electrógenos en Pinar del Río

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ABSTRACT

Introduction: noise-induced sensorineural hearing loss is the consequence of multifactorial damage to the auditory structures, which is why the need for this work arose.
Objective: to characterize hearing disorders due to exposure to industrial noise in generator set operators in Pinar del Río in the period 2021-2023.
Method: a longitudinal, prospective, descriptive and observational study was carried out, which was validated using theoretical, empirical and statistical methods.
Results: a universe of (n-65) and a sample of (n-26) workers, with a predominance of the age group between 41 and 50 years, detecting 26 cases with hearing loss for 40 % of the total workers exposed to noise, with a predominance of the male sex for 100 %, the hearing impaired detected are directly exposed to noise with an intensity measured between 93 and 95 decibels. Mild hearing loss was present in 50 % of the affected (n-13). The use of individual protection equipment against the harmful effects of noise was deficient; it was found that only 26,92 % of the workers used them (n-7).
Conclusions: all the generator sets were identified as sources of high noise emissions with measured levels higher than the internationally established values. Regarding the characteristics of the audiometric curves, there was a predominance of mild and moderate hearing loss, and the partial existence of the protective equipment was found, as well as their poor use by the workers.

Keywords: Neurosensory Hearing Loss; Industrial Noise; Audiometry.

RESUMEN

Introducción: la hipoacusia neurosensorial inducida por ruidos es la consecuencia del daño multifactorial a las estructuras auditivas, por lo que surgió la necesidad del presente trabajo.
Objetivo: caracterizar las alteraciones auditivas por exposición al ruido industrial en operarios de grupos electrógenos en Pinar del Río en el período 2021-2023.
Método: se realizó un estudio longitudinal, prospectivo, descriptivo y observacional el cual se validó mediante los métodos teóricos, empíricos y estadísticos.
Resultados: un universo de (n-65) y una muestra de (n-26) trabajadores, predominando el grupo etáreo entre 41 y 50 años, detectándose 26 casos con hipoacusia para un 40 % del total de trabajadores expuestos a ruidos,

predominando el sexo masculino para un 100 %, los hipoacúsicos detectados están expuestos directamente al ruido con una intensidad medida entre 93 y 95 decibeles. La intensidad ligera de la hipoacusia estuvo presente en el 50 % de los afectados (n-13). La utilización de los medios de protección individual contra la acción nociva del ruido fue deficiente, se pudo comprobar que solo el 26,92 % de los operarios los utilizan (n-7). **Conclusiones**: todos los grupos electrógenos fueron identificados como fuentes de alta emisión de ruidos con niveles medidos superiores a los valores establecidos internacionalmente, en cuanto a las características de las curvas audiométricas hubo un predominio en la de intensidad ligera y moderada de hipoacusia, y se comprobó la existencia parcial de los medios de protección, así como su pobre uso por los trabajadores.

Palabras claves: Hipoacusia Neurosensorial; Ruido Industrial; Audiometría.

INTRODUCTION

Noise-induced sensorineural hearing loss results from multifactorial damage to auditory structures secondary to exposure to occupational, environmental, or recreational noise as sources of intense sounds. Noise has been recognized as a contributing factor to hearing loss, and after rigorous interpretation of collected data, sophisticated analyses and careful experiments have demonstrated the need for protective measures, standards, and regulations to protect people against the harmful effects of noise.[1,2] Recent research mentions that due to high noise levels, 75 % of the inhabitants in industrialized cities have some hearing impairment. Yet, there is a lack of awareness of this problem.[3] Hearing loss due to occupational noise exposure is a major occupational health problem. Cases of hearing loss in miners exposed to the noise of hammers on metal have been reported since the 18th century. An estimated 1,3 billion people have hearing loss due to noise exposure. Occupational noise is widely responsible for 16 % of people in the adult hearing-impaired environment. This indicates that noise-induced sensorineural hearing loss is not a cause of premature mortality but substantial disability.[4] Although earplugs were patented in 1864, hearing protection devices are mentioned in ancient mythology. Sensorineural hearing loss was recognized as a medical condition in the United States during the Industrial Revolution, first called boilermaker's deafness, as a reference to the hearing loss suffered by workers who built powerful engines for transportation and production. Historical data in the United States reveals that women factory workers during the First and Second World Wars suffered devastating health effects, including hearing loss.[1,2,5]

Noted physicists and Nobel Prize winners such as Robert Koch predicted in 1910 that man would struggle mightily against noise one day. After this prediction and long-standing knowledge of the adverse effects of noise on hearing and extensive research in the modern era, hearing loss remains among the top occupational diseases in the world.[1,2,5]

The high exposure to occupational and urban noise in developing nations increases the risk of sensorineural hearing loss, and limited access to health care and screening tests may leave many cases undiagnosed, in addition to the lack of programs and legislation to limit noise and the absence of public education measures to encourage the use of hearing protection. This can be seen in data on the prevalence of occupationally caused sensorineural hearing loss across nations within the same geographical region. Approximately 16 % of adults with hearing impairment internationally are attributed to occupational noise.[6,7,8]

Noise is a negative factor in work environments; it is considered an occupational hazard that should be minimized as much as possible using appropriate protection. Its harmful effect causes hearing impairment. On the other hand, it has been reported that regular audiometric controls are carried out on workers to know the degree of exposure they have in their working environment, then to make the respective recommendations to the respective professional so that they can take the relevant actions. On the other hand, noise includes a subjective and an objective component. The former is the perception of the noise by the person, i.e., the psychosocial component; the latter is the sound pressure levels obtained by measurement in the contaminated or uncontaminated area.[9]

The highest permissible level of noise exposure in the workplace recommended by the WHO is 80 dB for a maximum of 8 hours daily.[10,11,12]

Safe exposure to sound depends on its intensity or volume, as well as its duration and frequency. Exposure to loud sounds can lead to temporary hearing loss or tinnitus (ringing in the ears). When deafening sounds are involved, or exposure occurs regularly or prolonged, the inner ear's sensory cells can be permanently damaged, resulting in irreversible hearing loss.[13]

To discuss noise as an aetiological agent, it is essential to differentiate between sound and noise. Sound is any simple to complex vibration whose intensity exceeds the threshold without causing pain and provides a pleasant or at least tolerable sensation for any accustomed ear. Complex or straightforward sounds immediately unpleasant, annoying, or harmful in the long run because of their disharmony or high intensity should be

classified as noise.

Noise characteristics.

The degree of injury caused by noise depends on its characteristics and the nature of the subject exposed. The variables concerning noise are:

Frequency

High frequencies are more traumatic than low frequencies, especially those between 2000 to 3000 cycles per second, causing greater hearing impairment than others. Industrial sounds are composed of a high-frequency range, but most are high-pitched, as with turbines and other machinery. Noises are not pure tones but sounds composed of different frequencies. Low frequencies and ground-borne vibrations have been found to make the receptor organ more susceptible to noise or increase the hearing deficit.[14]

Intensity

A louder sound will produce more injury than a weaker sound.

Noises below 80 dB do not irreversibly damage the ear, as they can produce temporary threshold shifts that return to normal. From 90 degrees onwards, the sound becomes traumatic for the cochlea, as the ear has sufficient protection mechanisms up to these intensities.

Duration

The longer the exposure time of the cochlea to a sound stimulus, the greater the damage.

The noise rhythm

In equal intensity, frequency, and exposure time, discontinuous or intermittent noises are more harmful, provided the pause without noise is brief. However, if noise exposure is interrupted by sufficiently long silent recovery times, its tolerance for the total sound energy received is better.[14]

Noise or noise pollution is sound exceeding the estimated 50 decibels (dB) limit. Any sound above this limit is considered noise, causes adverse health consequences, and can be classified as a pollutant. In simple terms, noise is an 'unwanted sound' that affects health and well-being. The highest intensity the human ear can safely tolerate is around 80 db.[12] Noise pollution has a direct relationship with the expansion and development of cities. This is because, in cities, there are polluting factors that are the leading cause of health disorders and damage, such as high population concentration, transport, damaged vehicle exhaust silencers, fire or ambulance sirens, industrial activities, public or building constructions, commerce, social habits, and household dynamics.[11] The highest permissible level of noise exposure in the workplace recommended by the WHO is 80 dB for a maximum of 8 h per day.[12]

Many patrons of nightclubs, bars, and sporting events are often exposed to even higher noise levels and should, therefore, reduce the duration of exposure considerably. For example, exposure to noise levels of 100 dB, which is normal in such places, is only safe for 15 minutes. Governments also have an important role in protecting people from noise pollution. Enact and enforce stringent legislation on noise from recreational activities. Raise awareness through public information campaigns of the risks of noise that can cause hearing loss.[12,15,16]

International standards for safe listening in entertainment venues and events outline recommendations to mitigate the risk of hearing loss while maintaining high sound quality and a pleasant experience.[14] The maximum average sound level should be 100 dB, and sound levels should be constantly monitored and recorded using calibrated equipment by qualified personnel.

The new standard developed in the framework of the World Health Organisation's (WHO) 'Safe Listening' initiative aims to improve listening practices, especially among young people, using technological advances and the support of governments, industry, consumers, WHO experts, and civil society. In Cuba, measures have been developed in line with WHO stipulations, where a policy led by the Ministry of Science and Technological Innovation and Environment (CITMA) has been established.[12,14]

Today, noise pollution is something we deal with daily. Every day, we receive thousands of sounds of great magnitude and frequency without perceiving the damage it causes, which can be irreversible. It is recommended that when the noise source cannot be controlled, it should be moved away or shielded to reduce the risk of illness. Still, ideally, comprehensive, inter-sectoral, and interdisciplinary action plans that are sustainable and appropriate to local realities should be developed.[17]

Some research shows that the prevalence of occupational hearing loss in Latin America is 17 % [13,14,15] and that the magnitude of hearing damage is directly related to the frequency and intensity of noise exposure, among other factors.[18,19]

Numerous experimental and epidemiological studies highlight the health effects of noise, with some even

indicating that Europeans lose up to 1,6 million years of healthy life, taking into account premature deaths and deterioration in quality of life.[17]

In addition to hearing loss, there is an increased risk of cardiovascular disease, psychological problems, insomnia, and slower cognitive development in children. The WHO warns of dangers every year with the intention that governments develop directives to protect public health from noise, which is the second leading cause of illness due to environmental reasons.[11,16]

In our country, due to a severe crisis in the Cuban energy system, a series of measures were taken, including the widespread introduction of generators throughout the country. Most of this equipment was connected to the national grid to support the thermoelectric power stations. Although they are a guarantee for the generation of electrical energy, they also cause a nuisance in society and hurt the environment. Their noise affects both the environment and the workers who operate them. It is estimated that the sound pressure level generated by generating sets ranges between 83 and 95 Db at distances of between one and 10 meters, which implies high-risk health and work hygiene values, mainly if several pieces of equipment are operating simultaneously.[20]

Considering these aspects, the Generator Set Complex was identified as one of the industrial centers emitting noise in our province's municipality of Pinar del Río. The lack of research on the clinical-epidemiological characterization of the subject makes it necessary and pertinent to carry out this research. The new knowledge to be obtained through the clinical-epidemiological characterization of hyperacusis caused by noise pollution will constitute the theoretical contribution of the study, making it an impact and a novelty. The practical contribution will be determined by the design and application of intervention actions with a focus on risk to prevent and control the harmful effects of noise on workers' health in this noise-emitting industry.

In the municipality of Pinar del Río, the emission of industrial noise above the established levels has been detected in the complex of generators in the territory, constituting a health problem. Workers exposed to industrial noise have not yet been studied and treated for the detection of possible hearing impairments that they could present, so we propose as an objective to characterize hearing impairments due to exposure to industrial noise in generator set operators in Pinar del Río in the period 2021-2023, to develop intervention actions that contribute to preventing and controlling the problem.

METHOD

A longitudinal, prospective, descriptive, and observational study was carried out on the workers of the generator set complex in the municipality of Pinar del Río, a source of noise in the province, from January 2021 to March 2023 to determine the presence and evolution of auditory alterations due to industrial noise.

Definition of the study universe.

The universe consists of the 65 workers at the center above who are directly or indirectly exposed to industrial noise.

The sample consisted of 26 cases with a diagnosis of hearing impairment linked to exposure to noise and was selected by non-probabilistic sampling.

The clinical epidemiological method with a risk approach was used to carry out the research. Empirical methods such as the survey, theoretical methods such as analysis and synthesis, and methodological triangulation were also necessary.

The information was obtained by means of the empirical survey method after an interview and physical examination with a questionnaire prepared for this purpose, which made it possible to obtain the data necessary for the research's development. The descriptive statistical method was used, using absolute and relative percentage frequencies, and the tests were carried out with 95 % certainty.

Groups were established according to the degree of hearing impairment obtained by audiometry and classified by sex, age group, and years of direct or indirect exposure to noise. The data obtained were recorded in each personal survey, which made it possible to establish the clinical and epidemiological characteristics of hearing impairment caused by noise and the existence and use of individual means of protection against the harmful action of noise.

The implementation and effectiveness of the intervention actions designed to prevent and comprehensively care for hearing disorders caused by industrial noise were verified.

Ethical aspects

This research followed the principles and recommendations adopted by the 18th World Medical Assembly in Helsinki in 1964 and by the last one ratified in the 41st World Assembly held in Hong Kong in 1991. It complied with fundamental ethical principles such as respect for persons and their autonomy, beneficence and non-maleficence, and the principle of justice. For each patient, or failing that, the primary guardian of each patient who underwent the intervention was given specific explanations until their understanding and informed consent were obtained. The data obtained were used for strictly scientific purposes and will only be disclosed

at scientific events.

RESULTS

Table 1. Workers affected by hearing loss by age group and gender.

Age (years)	Male operators	%	Hearing impaired	%
18 to 30 to	9	13,8	2	22,2
31 to 40 years	12	18,4	3	33,3
41 to 50 years	21	32,3	8	30,09
51 to 60 years	15	23,07	7	46,6
Over 60 years old	8	12,3	6	56,25
Total	65	100	26	40,0

Hearing loss was present in 40 % of the workers exposed to noise in the generator set complex, with 100 % of the cases being male because all the workers in the center area of this biological sex (see table 1).

100 % of the workers were directly exposed to the source of the high-intensity noise generated by the generators for 12 continuous hours at a distance of between one and ten meters. The intensity in decibels was very high and above the internationally permitted levels, as seen in the same way as the noise exposure time, as seen in table 2.

Table 2. Noise sources identified, decibels measured, time of direct or indirect worker exposure to noise and distance of the operator from the noise source.

Noise emitting sources, measured intensity, distance from the source and hours of noise exposure.	No. of operators with direct exposure	%	No. of workers with indirect exposure	%	Total	%
Twelve Generating sets	26	100	0	0	26	100
Noise intensity in decibels between 93 and 95	26	100	0	0	26	100
Db measured on three occasions with a noise exposure time of 12 hours	26	100	0	0	26	100
Distance between operator and source from 0 to three metres	26	100	0	0	0	0
Total	26	100	-	-	26	100

Different degrees of hearing loss intensity and the presence of typical noise exposure trauma curves were detected as shown in the following table and graphs.

Table 3. Intensity of hearing loss and presence of curves typical of acoustic trauma

Intensity of hearing loss	No.	%	Presence of acoustic trauma	%
Slight	13	50,0	3	11,53
Moderate	6	23,07	4	15,8
Severe	4	15,38		
Profound	3	11,53	-	-
Total	26	100	7	26,92

The frequency of hyperacusis was high due to the harmful effect of the noise, and the predominance of the slight intensity of hyperacusis was present in 50 % of those affected, as shown in table 3. Only 26,92 % (7 workers) presented a typical curve of acoustic trauma, as shown in the table, of which 11,53 % corresponded to slight hyperacusis and 15,38 % to moderate hyperacusis (table 3).

In the cases investigated in the generator sets, there is a direct relationship between noise-induced hearing loss and the years of noise exposure, as seen in table 4.

50 % of the workers with less than five years of exposure to noise had mild hearing loss because these cases had been working for fewer years than the others. As the years of exposure increased, the intensity of the hearing loss increased, as shown in table 4.

As shown in table 4, most cases of hearing loss and vertigo occurred in workers with less than five years of noise exposure.

Table 4. Relationship between hearing loss intensity and years of exposure to industrial noise

Degree of hearing loss	Less than 5 years	%	Between 5 and 10 years	%	More than 10 years	%	Total	%
Slight	13	50,0	-	-	-	-	13	50
Moderate	2	7,69	4	15,38	-	-	6	23,07
Severe	-	-	1	3,84	3	11,53	4	15,38
Profound	-	-	-	-	3	11,53	3	11,53
Total	15	57,69	5	19,23	6	23,07	26	100

Table 5 shows the relative frequencies of other auditory manifestations that appeared in the workers with hearing loss due to exposure to the intense noise of the generator sets. Tinnitus appeared in a relative frequency of 73,07 % in cases with less than five years of noise exposure, and both tinnitus and vertigo occurred entirely in those with less than five years of noise exposure.

Table 5. Relationship between the presence of other hearing impairments and years of exposure to industrial noise

Years of noise exposure	Tinnitus	%	Hearing loss	%	Dizziness	%
Less than 5 years	19	73,07	2	7,69	4	15,38
Between 5 and 10 years	4	15,38	-	-	-	-
More than 10 years	3	11,53	-	-	-	-
Total	26	100	2	7,69	4	15,38

The non-use or improper use of noise protection devices may be directly related to the occurrence and intensity of sensorineural hearing loss. The use of personal protective equipment against the harmful effects of noise was deficient; it was found that only 26,92 % of the workers used it, as shown in table 6.

Table 6. Relationship between degree of hearing loss and use of personal protective equipment

Degree of hearing loss and No. of cases.	Use of personal protective equipment			
	yes	%	No	%
Slight	4	15,38	9	34,61
Moderate	3	11,53	3	11,53
Severe	0	-	4	15,38
Profound	0	-	3	11,53
Total	7	26,92	19	73,07

DISCUSSION

This was not due to any law prohibiting women from carrying out this type of work but because none had requested it.

Recognition of work-related diseases is problematic in countries with workers' compensation schemes. In a study conducted between 2010 and 2017, 53,7 % were confirmed to have some occupational disease; among them, hearing loss (29,4 %) ranked fourth.[21,22]

Millions of people have some form of hearing impairment, making hearing loss the fourth leading cause of disability worldwide. World Health Organisation estimates show that more than 466 million people have disabling hearing loss, 22 % more than in the previous decade.[20]

Other results show frequencies much higher than those obtained in the study in the generator sets in Pinar del Río, as stated by Márquez Ibáñez and collaborators in their study where state that the relative frequency of hearing loss cases is lower than other studies that state that noise produces adverse effects on 75 % of the inhabitants in industrialized cities who have some hearing impairment. However, there is no awareness of this problem, and Márquez's work was present in only 46,9 %.[23,24]

The origin of hearing impairment can be diverse, and knowledge of its causes and associated risk factors is essential for early diagnosis and timely treatment. The incidence and prevalence of hearing loss are expected to increase significantly in the coming years due to the demographic transition phenomenon being experienced worldwide. It is essential that the treatment and approach for these patients not only focus on

aural rehabilitation but also on counseling and education for adherence and good outcomes.[25]

Research has shown that the cases most affected by noise are men between 50 and 65. Those with the most damage are those most frequently exposed to machines such as saws, grinders, sanders, motors, turbines, and looms, and, in general, factory work that generates intense and persistent noise.[26,27]

A study of patients with noise-induced hearing damage found that the greatest likelihood of harm is in middle age. The mechanisms and structures damaged by noise differ in young adults and older people.[26]

According to the World Health Organisation (WHO), around 1,5 billion people are living with hearing loss worldwide, which is estimated to reach 2,5 billion by 2050. The consequences of hearing loss are significant and numerous and can lead to communication problems, but also to fatigue, anxiety, social isolation, psychological distress, and depression. Hearing loss is associated with cognitive decline.[27,28,29]

All the cases with hearing loss were directly exposed to noise with a measured intensity between 93 and 95 decibels, measured on three occasions, which is considerably above the internationally accepted figure since the highest permissible level of noise exposure in the workplace recommended by the World Health Organisation is 80 dB for a maximum of 8 hours a day. There are a total of twelve generating sets causing intense noise pollution. Here, it was found that they are continuously exposed to noise for 12 hours, which exceeds the maximum 8 hours established by CITMA.[12]

It is estimated that the generator's sound pressure level ranges between 83 and 95 Db at distances of between one and 10 meters, which implies high-risk values for health and work hygiene, especially if we consider that several pieces of equipment are working simultaneously.[20]

Others state that in a work environment, the type of exposure to this physical air pollutant was generally related to high sound intensities and was regulated by the worker's exposure for short periods. Subsequent studies showed that exposure to high noise intensities for brief periods produced health effects, and prolonged exposures to lower sound intensities had a similar impact. In this way, pathologies identical to those previously described for the work environment began to be related to people who, although not exposed to high noise levels, were exposed for a more extended period.[30]

Noise destroys the hair cells of the organ of Corti. While the average person is born with approximately 16,000 hair cells, as many as 30,50 % may be damaged or destroyed before any appreciable level of hearing loss is detected. Hearing loss related to inner ear hair cell destruction is not reversible and cannot normally be restored.[31]

This hearing impairment increases with exposure time and can also occur in populations of different ages in the vicinity of sources of environmental noise pollution. As stated in several publications,[32] the consequences of this hearing loss can sometimes cause a disability that leads to the use of hearing aids and different ear surgeries to compensate for the hearing loss.

The frequency of hearing loss was high due to the harmful effect of noise. The intensity of the hearing loss was predominantly light, presenting a typical curve of acoustic trauma in a group of these workers, with moderate hearing loss predominating more in them, followed by light hearing loss; this happens in three ways: the case may have presented a sensorineural hearing loss of another etiology that was increased by the noise, or because they have been exposed to noise for many years and generally without any individual protection, which causes severe destruction of the sensory elements of the organ of Corti, which is very sensitive to this type of environmental pollutant. There are also phenomena associated with presbycusis in third place because the operators are older, and the noise increases the intensity of the hearing loss.

Hearing loss due to exposure to noisy environments has increased worldwide in recent years.[16,33] It is classified by the World Health Organisation (WHO) according to its intensity as mild hearing loss (loss between 21-40 decibels (dB), moderate (between 41-60 dB), severe (between 61-80 dB) or profound (a loss greater than 81 dB). Depending on the affected site, it can be conductive hearing loss, sensorineural hearing loss, and mixed hearing loss when both pathways are affected.[16,34]

Noise-induced sensorineural hearing loss has a fairly typical audiometric pattern, with initial changes usually seen at 4000 Hz. Still, it is not unusual for the maximum peak to be between 3000 and 6000 Hz. It is estimated that in the first 10 years, the scotoma deepens and then stops while the defect extends into the nearer frequencies. If the stimulus does not cease, the notch becomes more evident in the lower frequencies, and the curve takes on a 'bucket' appearance that disappears as the threshold for the higher frequencies increases.[9,34]

Multiple studies have found that specific genetic and epigenetic characteristics increase the sensitivity to acoustic trauma in animals with hearing loss. Transgenic mice express genes related to hearing loss, such as Ahl1(Cdh23 735AQ-G) in C57BL/6J, which are more susceptible to hearing impairment caused by noise.[35,36]

In our country, there is research related to the causes of sensorineural hearing loss and its intensity; in descending order, presbycusis (50,0 %), noise-induced hearing loss (26,0 %), and vascular causes (11,0 %) stand out, the latter being associated with a moderate intensity loss.[37]

Studies indicate that the prevalence of noise-induced sensorineural hearing loss is increased by duration of exposure time, noise energy levels, gender, and age. Each type of work has an average noise exposure.

The high prevalence of high-frequency sensorineural hearing loss in manufacturing workers is associated with gender, age, duration of noise exposure, noise intensity, and temporal exposure to this environmental pollutant, affecting speech frequencies and increasing with age. The degree of concentration loss in the hearing curve is related to loss in the high frequencies. The temporal influence of noise should be considered in the early diagnosis and prevention of occupational complex noise deafness.[38,39,40]

Aging significantly affects hearing loss. Likewise, there is a relationship between the different causes of hearing loss and moderate levels of hearing loss, and risk factors such as arterial hypertension, exposure to noise, and vascular causes worsen the disease, which has become a health problem in Cuba and worldwide.[37]

It is estimated that after the age of 60, hearing decreases by an average of 1 dB per year, with a greater loss observed in men than in women. If the harmful action of noise is added to this, the situation worsens.[24,36]

Those affected by hearing loss may also have other significant repercussions, such as frustrating experiences due to communication difficulties caused by hearing loss and increased feelings of burden associated with the role as a contributor that they must assume and because of their age and hearing loss are no longer able to do so. It is therefore necessary to review the guidelines and protocols for action created in this regard to avoid or mitigate these situations.[36,37]

Any person repeatedly exposed to noise can develop progressive hearing loss. Over the years, the hearing loss begins in the extra-conversational zone and is therefore not perceived by the patient. Often, the initial symptom is tinnitus, which usually occurs at the end of the working day.[9,41]

Noise-induced cochlear damage can be acute or chronic, as there is also an individual susceptibility to sound, which makes some people more prone to hearing loss than others. When we feel ringing in our ears after being exposed to loud noise, it means there has been damage, which may be transient, but if we are exposed frequently and long enough to these high noise levels without adequate protection, the damage will be permanent.[3,42]

Hearing disorders are a significant public health problem due to their increasing prevalence worldwide and the economic impact they have on healthcare systems and the economy in general. They have been studied in various regions of the world.[43]

Tinnitus appeared in cases with less than five years of noise exposure, and as the years of exposure increased, tinnitus was also present. Both algiacusis and vertigo were entirely present in those with less than five years of noise exposure.

It was considered that this phenomenon, which is so annoying for the affected person, occurs because those exposed to noise for the first time lose a considerable number of hair cells of the organ of Corti in the inner ear. This destruction is increased by high noise intensities and by periods of exposure of more than eight hours. After more than five years of exposure, the number of destroyed cells of the organ of Corti almost completely disappears and may be the reason for the absence of hearing loss and dizziness when exposure lasts more than five to 10 years or, as the patients have become accustomed to them, they do not even mention them, or they disappear.

Up to 18 % of the general population in industrialized countries are mildly affected by chronic tinnitus and 0,5 % report that tinnitus severely affects their ability to lead an everyday life. Tinnitus, often described as 'ringing in the ears,' is a serious problem affecting a significant proportion of the population today. It is most common in people over 65 (approximately 30 % of this group report tinnitus). Specific occupational populations are at high risk of developing tinnitus.[44,45]

Tinnitus is the most common consequence of noise-induced hearing loss. In current studies, it is an independent predictor of increased hearing threshold among steelworkers with this type of hearing loss. Tinnitus has a significant impact on quality of life and is responsible for stress itself. In studies, occupational deafness was shown to be associated with tinnitus from high-intensity sounds. However, the volume of tinnitus has not been reported in these studies.[46]

Comorbidities such as vertigo and tinnitus coexist and are considered burdens for people with sensorineural hearing loss. Vertigo may be present in 30 to 60 % of cases. Vertigo from the onset of sensorineural hearing loss can often be seen in the most severe cases and is frequently associated with a poor prognosis for hearing recovery.[47]

Tinnitus is universally close to sensorineural hearing loss and remains constant and annoying. It has an economic significance and psychological burden. Recovery of hearing after sensorineural hearing loss is often accompanied by concomitant improvement of tinnitus. Residual tinnitus may exacerbate or replace the physiological and functional burden of hearing loss in recovered sensorineural hearing loss.[48]

Noise overexposure can also damage the peripheral vestibular system. Based on pre-clinical work in different animal models, it has been shown that depending on the noise characteristics or overexposure to noise often leads to cellular damage of the peripheral vestibular system with well-characterized effects on the response of organs called otoliths.[5,33]

The use of personal protective equipment against the harmful effects of noise was deficient, and it was

found that few workers use it, which increases the risk of hearing loss, as was the case in the affected cases.

For this reason, hearing protection devices, earplugs, and earmuffs are insisted upon. The evidence shows that, regarding the immediate effects of hearing protection, giving instructions for the correct insertion of earplugs in the ear canal has a relevant and significant impact on noise attenuation.[41]

It is necessary for the administrations of noise-emitting industries to update and unify the permitted limits of sound levels in the working environment according to the daily hourly workload and to determine the periodic audiometric controls according to the daily exposure time.[41]

Occupational Sensorineural Hearing Loss is a pathology that will affect those who suffer from it for the rest of their lives; therefore, its early detection, treatment, and decisions by the company are fundamental for employees' quality of life. Thus, the Ibero-American Social Security Organisation proposes the implementation of norms and laws for the control of occupational risk where noise and vibration pollution levels emitted by the use of machines that are part of work activities are addressed to ensure the quality of life of the workers.[49]

Hearing loss affects 5,3 % of the world's population, which represents 360 million people, 56 % of whom are men. These people have been exposed for several years to high levels of vibrations and noise during their working hours without having the appropriate safety equipment to reduce or avoid this type of risk. Ecuador has only generalized data on occupational accidents and diseases.[50]

CONCLUSIONS

The predominant age group was between 41 and 50 years of age, of which approximately half of the workers had hyperacusis, and all of them were male. All the generators were identified as sources of high noise emission with measured levels above the internationally established values. The characteristics of the audiometric curves were delineated, with a predominance of mild and moderate intensity of hearing loss, coinciding with the typical characteristics of the acoustic trauma curve in a quarter of the operators affected by hearing loss. The relative frequency of hearing loss was higher in workers with less than five years of noise exposure, with light and moderate intensities predominating. The partial existence of the means of protection was verified, and their poor use by the workers at the beginning of the research was resolved after the intervention was carried out. Intervention actions for preventing and comprehensive care of noise-induced hearing loss in exposed workers were validated.

REFERENCES

1. Natarajan N, Batts S, Stankovic KM. Noise-Induced Hearing Loss. J. Clin. Med. [Internet].2023 [Consultado 15 oct 2023];12:2347. Disponible en: https://doi.org/10.3390/jcm12062347. https://www.mdpi.com/journal/jcm

2. Shield, B.; Hearing Loss: Numbers and Costs. Evaluation of the Social and Economic Costs of Hearing Impairment. A Report for Hear-It AISBL. [Internet].2021 [Consultado 15 oct 2023].

3. García Ortiz MJ y col. Audiometría de altas frecuencias en adolescentes expuestos a ruidos. Revista Cubana de Pediatría. [Internet].2021 [Consultado 15 oct 2023];93(1):e1468. Disponible en: https://creativecommons.org/licenses/b

4. Kou-Huang C. Shih-Bin S, Kow-Tong C. Chenet al. Environmental Health and Preventive Medicine [Internet].2020 [Consultado 15 oct 2023]. Disponible en: https://doi.org/10.1186/s12199-020-00906-0

5. Stewart, C.E.; Holt, A.G.; Altschuler, R.A.; Cacace, A.T.; Hall, C.D.; Murnane, O.D.; King, W.M.; Akin, F.W. Effects of noise exposure on the vestibular system: A systematic review. Front. Neurol. 2020, 11: 593919.

6. Schwela, D. Environmental noise challenges and policies in low- and middle- income countries. SFJH 2021, 2: 26–45.

7. Kalisa, E.; Irankunda, E.; Rugengamanzi, E.; Amani, M. Noise levels associated with urban land use types in Kigali, Rwanda. Heliyon 2022, 8: e10653.

8. King, E.A. Here, there, and everywhere: How the SDGs must include noise pollution in their development challenges. Environ. Sci. Policy 2022, 64:17–32.

9. Delgado Armijos E, Plúa Quiroz J, López Mantuan C, Macías Montalván, A..Contaminación acústica y su relación con las alteraciones auditivas. Revista Sinapsis. [Internet].2019 [Consultado 15 oct 2023];15(2): 1390 – 9770. Disponible en: https://www.itsup.edu.ec/sinapsis

10. Delgado Juan I, Rodríguez Regalado LA .El ruido es uno de los más ignorados riesgos para la salud .Revista Cubana de Otorrinolaringología y Cirugía de Cabeza y Cuello [Internet]. 2023 [Consultado 15 oct 2023];7(1):e395. Disponible en: https://creativecom mons.org/licenses/

11. Organización Mundial de la Salud. Nueva norma para hacer frente a la creciente amenaza de la pérdida de audición. OPS. PAHO. Madrid. [Internet].2022 [Consultado 15 oct 2023]. Disponible en: https://www.paho.org/es/noticias/2-3-2022.

12. Ministerio de Ciencia innovación tecnológica y medio ambiente. Cuba. Programa nacional de educación ambiental para el desarrollo sostenible [Internet]. 2016 [Consultado 15 oct 2023]. Disponible en: https://repositorio.geotech.cu/jspui/bitstream/1234/2727/1/

13. Maya G, Correa M, Gómez M. Gestión para la prevención y mitigación del ruido urbano. Rev. P+L. [Internet].2010 [Consultado 15 oct 2023];5(1):75-94. Disponible en: http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S1909-04552010000100005

14. Barreras Rivera D, Peña Casal CL, Arnold Alfonso ML, Alfonso Rodríguez J, Llerena Suárez JA. Impacto bio-psico-social del uso indiscriminado de dispositivos de audio. Rev Méd Electrón. [Internet]. 2016 [Consultado 15 oct 2023]; [38(5).Disponible en: http://www.revmedicaelectronica.sld.cu/index.php/rme/article/view/1638/31

15. Norma cubana. Ruidos en zonas habitables- Requisitos higiénicos sanitarios. Oficina Nacional de Normalización de Cuba, secretario del subcomité de RUIDO (CTN 98 / SC 1) [Internet].2012 [Consultado 15 oct 2023]. Disponible en: http://noisecontrol.radicalmanagement.com/2012/05/

16. Hernández Peña O, Hernández Montero G, López Rodríguez E. Ruido y salud. Rev Cub Med Mil. [Internet].2019 [Consultado 15 oct 2023];48(4):e431. Disponible en: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0138-65572019000400019&lng=es

17. Ortiz Rodríguez ÁG. Estudio transversal: pérdida auditiva causada por ruido en el personal de la aviación militar ecuatoriana. Rev. Ciencia y Poder Aéreo. [Internet].2021 [Consultado 15 oct 2023];16(1):139-48. Disponible en: https://doi.org/10.18667/cienciaypoderaereo.688

18. Tezel M, Sari D, Ozkurt N, Keskin S. Combined NOx and noise pollution from road traffic in Trabzon, Turkey. Science of The Total Environment. [Internet].2019 [Consultado 15 oct 2023] ;27(9). Disponible en: https://doi.org/10.1016/j.scitotenv.2019.134044

19. Wen X, Lu G, kai LV, Jin M, Shi X, Lu F, Zhao D. Impacts of traffic noise on roadside secondary schools in a prototype large Chinese city. Applied Acoustics [Internet].2019 [Consultado 15 oct 2023];153-63. Disponible en: https://doi.org/10.1016/j.apacoust.2019.02.024

20. Albizu, E. J., Goncalves, C. G. O., de Lacerda, A. B. M., Zeigelboim, B. S. y Marques, J. M. Noise exposure and effects on hearing in Brazilian fishermen. Work, 2020. 65: 881–889.

21. García Rey T. ¿Cómo prevenir la pérdida auditiva por la exposición al ruido? REF: Acta Colombiana de Otorrinolaringología y Cirugía de Cabeza y Cuello [Internet]. 2020 [citado 2023 Sep 15];48(3):131-2. Disponible en: https://revista.acorl.org.co/index.php/acorl/article/view/568

22. High-Frequency Audiometry in Women with and without Exposure to Workplace No ise. Int J Environ Res Public Health [Internet]. 2021[citado 2023 Sep 15];18(12):64 -9. Disponible en: https://10.3390/ijerph18126463

23. Toledo Valdés C, Pacheco Macías AR, Pérez García T, Contreras Álvarez PJ, Armstrong L. Características clínico-epidemiológicas de pacientes ancianos con Hipoacusia atendidos en el Hospital Calixto García. Rev. hab. Cienc. Med [Internet]. 2018 [citado 2023 Sep 15] ;(3):427-39. Disponible en: www.revhabanera.sld.cu/index.php/rhab/article/view/2152

24. Hernández Sánchez H. Hipoacusia inducida por ruidos. Revista Otorrinolaringología. Trabajo de revisión para el diplomado de gestión de información en salud [Internet]. Mayo 1-2016 [citado 2023 Sep 15] . Disponible en: http://articulos.sld.cu/otorrino/?cat=78

25. Hotton M, Prud'Homme V et al.Impacts and Identification of Hearing Aid Refurbishing Programs for People with Hearing Loss: A Scoping Review .Audiol. Res [Internet]. 2023 [Consultado 05/04/2023]; 13: 326–340. Disponible en: https://doi.org/10.3390/audiolres13030028.

26. Gómez Cayambe JE. El ruido y los efectos en la audición, Quito. Ecuador. Tesis de grado. [Internet]. 2020 [Consultado 05/04/2023]. Disponible en: http://www.dspace.uce.edu.ec/handle/25000/22455

27. World Health Organization. World Report on Hearing; World Health Organization: Geneva, Switzerland, 2021.

28. Hernández Ríos LA. Diagnóstico predictivo de la hipoacusia inducida por ruido utilizando las otoemisiones acústicas .Revista Cubana de Otorrinolaringología [Internet].2019 [Consultado 05/04/2023];20(3):e109. Disponible en: https://creativecommons.org/licenses/by-nc/4.0/deed.es_ES

29. Lawrence, B.J.; Jayakody, D.M.P.; Bennett, R.J.; Eikelboom, R.H.; Gasson, N.; Friedland, P.L. Hearing Loss and Depression in Older Adults: A Systematic Review and Meta-analysis. Gerontologist 2020, 60, e137–e154.

30. Fanzo González P, Cornetero Mendoza D R, Ponce Linares R A, Peña-Sánchez E R. Frecuencia de hipoacusia y características audiométricas en pacientes con diabetes de un hospital de la ciudad de Chiclayo, Perú, 2015. Rev. argent. endocrinol. metab. [Internet]. 2016 Dic [Consultado 05/04/2023]; 53(4):157-162. Disponible en: http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1851-30342016000400006&lng=es

31. Kakuki T , Miyata R et al.The Effects of Utilizing Cartilage Conduction Hearing Aids among Patients with Conductive Hearing Loss .Audiol. Res. [Internet]. 2023 [Consultado 05/04/2023]; 13: 408–417. Disponible en: https://doi.org/10.3390/audiolres13030036 . https://www.mdpi.com/journal/audiolres

32. Flores Pilco DA. Daño auditivo en trabajadores por exposición a ruido laboral. INICIO .52 ARCUIVOS. [Internet]. 2021 [Consultado 05/04/2023]; S2 (13). Disponible en: http://orcid.org/0000-0002-8759-6024-3594

33. Sofia Waissbluth A. Hipoacusia: Tamizaje, Rehabilitar, Comunicar. Revista Chilena Otorrinolaringología y Cirugía de Cabeza y Cuello. [Internet]. 2021[Consultado 05/04/2023];81(1). Disponible en: http://dx.doi.org/10.4067/S0718-48162021000100007

34. Hernández Frometa RE, García Ortiz MJ. 1 .Hipoacusia inducida por ruido en edad pediátrica. Revista Cubana de Otorrinolaringología y Cirugía de Cabeza y Cuello. 2022;6(1):e341.

35.Borkoski BS, Falcón JC, Corujo C, Osorio Á, Ramos A. Detección temprana de la hipoacusia con emisiones acústicas. Rev. Otorrinolaringol. Cir. Cabeza Cuello [Internet]. 2017 Jun [citado 2023 Sep 15];77(2): 135-143. Disponible en https://scielo.conicyt.cl/scielo.php?script=sci_arttext&pid=S0718-48162017000200003&lng=es.

36. Izquierdo Domínguez Y, Hernández Montero G, Alfonso Muñoz. E. Caracterización epidemiológica de la hipoacusia neurosensorial en adultos mayores de 60 años. Revista Cubana de Otorrinolaringología [Internet]. 2020 [citado 2023 Sep 15] ;21(3):e177. https://creativecommons.org/licenses/by- nc/4.0/deed.es_ES

37. Zhou et al. Epidemiological characteristics of hearing loss associated with noise temporal structure among manufacturing workers. Frontiers in Integrative Neuroscience [Internet]. 2022[citado 2023 Sep 15]. Disponible en: https://doi.org/10.3389/fnint.2022.978213

38. Chen, K. H., Su, S. B., and Chen, K. T. An overview of occupational noiseinduced hearing loss among workers: epidemiology, pathogenesis and preventive measures. Environ. Health Prev. Med. [Internet]. 2020 [citado 2023 Sep 15];25:65. Disponible en: https://doi.org/10.1186/s12199-020-00906-0

39. Zhou, J., Shi, Z., Zhou, L., Hu, Y., and Zhang, M.. Occupational noiseinduced hearing loss in China: a systematic review and meta-analysis. BMJ Open [Internet]. 2020 [citado 2023 Sep 15];10:e039576. Disponible en: https://doi.org/10.1136/bmjopen-2020-039576

40. Zhou, L. F., Xie, H. W., Zou, H., and Zhang, M. B.. [Investigation on noise exposure characteristics of workers in wooden furniture manufacturing industry and textile industry]. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 39 [Internet]. 2021 [citado 2023 Sep 15]; 507–510. Disponible en: https://doi.org/10.3760/

cma.j.cn121094-20200511-00250

41. Escobar-Castro et al. Síntomas de hipoacusia y exposición al ruido recreativo en jóvenes universitarios, Barranquilla, Colombia.CoDAS [Internet]. 2022 [citado 2023 Sep 15];34(1):e20200379. Disponible en: https://doi.org/10.1590/2317-1782/20212020379

42. Snapp HA, Schaefer Solle N, Millet B et al. Hearing Deficits in Noise-Exposed Firefighters.Int. J. Environ. Res. Public Health [Internet]. 2022[citado 2023 Sep 15]; 19:11028. Disponible en: https://doi.org/10.3390/ijerph191711028

43. Serrano-Andrade R, Mena-Canata C et al. .Infiltración transtimpánica de corticoides para el tratamiento de los ac úfenos subjetivos en pacientes del Hospital de Clínicas de Julio-Agosto 2021. Med. clín. soc. [Internet]. 2022 [citado 2023 Sep 15];6(2):53-56. Disponible en: https://doi.org/10.52379/mcs.v6i2.250

44. Yener M, Sarı E, Aslan M, Yollu U, Gözen ED, İnci E. The Efficacy of Intratympanic Steroid Injection in Tinnitus Cases Unresponsive to Medical Treatment. J Int Adv Otol. [Internet]. 2020 [citado 2023 Sep 15];16(2):197-200. Disponible en: https://doi.org/10.5152/iao.2020.7588

45. Elshaer N, Meleis D, Mohamed A. .Prevalence and correlates of occupational noise-induced hearing loss among workers in the steel industry. Elshaer et al. Journal of the Egyptian Public Health Association [Internet]. 2023 [citado 2023 Sep 15]; 98:11. Disponible en: https://doi.org/10.1186/s42506-023-00135-7

46. Ralli M, Balla MP, Greco A, Altissimi G, Ricci P, Turchetta R, et al. Workrelated noise exposure in a cohort of patients with chronic tinnitus: analysis of demographic and audiological characteristics. Int J Environ Res Public Health. [Internet]. 2017 [citado 2023 Sep 15];14(9):1035. Disponible en: https://doi.org/10.3390/ijerph14091035

47. Chandrasekhar S S.Clinical Practice Guideline: Sudden Hearing Loss.Otolaryngology– Head and Neck Surgery [Internet]. 2019 [citado 2023 Sep 15]; 1S (161). Disponible en: https:// doi.org/10.1177/0194599819859885 , http://otojournal.org

48. Stewart, C.E.; Kanicki, A.C.; Bauer, D.S.; Altschuler, R.A.; King, W.M. Exposure to Intense Noise Causes Vestibular Loss. Mil. Med. 2020, 185 (Suppl. S1), 454–461.

49. OISS.Riesgo de exposición laboral a ruido y vibraciones mecánicas. Obtenido de Organización Iberoamericana de Seguridad Social OISS: [Internet]. 2019 [citado 2023 Sep 15]. Disponible en: https://oiss.org/wp-content/uploads/2019/06/MT19-Riesgo-de- exposicionlaboral-a-vibraciones-mecanicas.pdf

50. Moreira- Macias, M. F. (2019). Incidencia de Accidentes de Trabajo declarados en el Ecuador periodo 2014 - 2015. EUMED. Universidad Estatal de Milagro -Ecuador, [Internet]. 2019 [citado 2023 Sep 15]. Disponible en: https://www.eumed.net/rev/cccss/2019/02/accidentes-trabajo - ecuador.html

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The authors declare that there is no conflict of interest.

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