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Ergonomic Risk Analysis of Noise and its Effects on the Health of Operators in the Metal-Mechanical Sector

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Abstract: The risk of developing an occupational pathology due to exposure to noise can cause occupational clinical symptoms with short, medium or long-term health effects. The objective of the study is to identify the dysergonomic magnitude of oscillating acoustic comfort, approximately between 80 and 85 decibels, in MSMEs of the metal-mechanic sector and its effects on workers' exposure. The study population consisted of 1300 workers with a sample of 769 workers. The measurement was performed in different workstations with a sound level meter type 1, ISO 28803:2012 standard. Qualitative and quantitative data were obtained to analyze results related to occupational exposure. The sound pressure level was determined in each area of the plant during the different working days. This was done per worker according to their activity and tasks performed. In this way, it was possible to raise discussions about the improvement of the quality of life. The results of the study are satisfactory. Epidemiological surveillance programs (PVE) with an emphasis on audiometry are suggested.

Keywords: occupational pathology, noise exposure, decibels, MSMEs, acoustic comfort.

Resumen: . El riesgo de desarrollar una patología laboral debido a la exposición al ruido puede causar síntomas clínicos laborales con efectos sobre la salud a corto, medio o largo plazo. El objetivo del estudio es identificar la magnitud disergonómica del confort acústico oscilante, aproximadamente entre 80 y 85 decibelios, en las MIPYMES del sector metalmecánico y sus efectos sobre la exposición de los trabajadores. La población de estudio estaba formada por 1.300 trabajadores, con una muestra de 769 trabajadores. La medición se realizó en diferentes puestos de trabajo con un sonómetro tipo 1, norma ISO 28803:2012. Se obtuvieron datos cualitativos y cuantitativos para analizar los resultados relacionados con la exposición laboral. Se determinó el nivel de presión sonora en cada área de la planta durante las diferentes jornadas de trabajo. Esto se realizó por trabajador en función de su actividad y tareas realizadas. De este modo, fue posible plantear debates sobre la mejora de la calidad de vida. Los resultados del estudio son satisfactorios. Se sugieren programas de vigilancia epidemiológica (PVE) con énfasis en la audiometría.

Palabras clave: patología ocupacional, exposición al ruido, decibeles, MIPYMES, confort acústico.

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Introduction

Environmental ergonomics analyzes and investigates the external conditions to human beings that influence their work performance. Among these conditions are the physical environmental factors such as thermal level (cooling and heating), noise and vibration, ventilation (air and relative humidity), and lighting level; studying them will help to design and evaluate better working conditions and increase comfort, productivity, and safety [1].

Sounds are produced by the vibration of bodies or molecules. The intensity, frequency, and timbre that they produce in the ear are measured to determine the noise level in the work environment. To assess the condition of the ear, an audiometric examination is conducted (which measures the ability to distinguish sounds). Although there are controls on tools and in the work area, it is advisable to consider the best protective element and its use to safeguard your health in relation to noise exposition [2].

Noise is one of the most frequent exposures, it is any sound disturbance composed of a set of sounds that causes an unpleasant sensation, the human ear has no protection mechanism [3].

Furthermore, it represents one of the most common threats in both the workplace and the general environment and can have serious consequences for auditory health when reaching excessive levels. Specifically, in metalworking workshops, this threshold is exceeded, and without knowledge of the exposure level, it is not possible to design and implement strategies and equipment to mitigate the issue [4].

Similarly, [5] indicates that there are two types of sounds, the pure ones have a single frequency and are not present in nature and are organized artificially by man, the compounds contain several pure inflections of different frequencies. The different pure tones arrange a composite noise as frequency analysis instruments that analyze this function are the spectra or filters.

The risk factors affecting the safety and health of employees in the metal-mechanical sector are closely linked to the various forms of labor and production management [6]. Industrial metal-mechanical workshops have several machines such as lathes, drills, and polishing machines; therefore, constant exposure of workers to noise produced by them.

The high noise levels in this industrial sector hinder communication between workers to perform their tasks causing them to misinterpret the orders given by their superiors, which in many cases leads to risky situations such as accidents with injuries or death.

Noise is the main source of accidents due to distractions that originate in the work environment. The incidence of accidents of operators in the exaggeratedly noisy environment increases between three and four cycles, on the other hand, in quiet areas a minimum trend of accidents is distinguished because as the noise level is reduced, the less sound effects in the workplace, the better the communication [7].

According to [8], metalworking industries are the main source of excessive noise classifying it as constant noise, intermittent noise, and impact noise. The limit of continuous noise level is a maximum permissible 85 dB for working hours of 8 hours of exposure per day and 40 dB per week, are methods that help to control the level of environmental noise provided by the Ministry of Health.

The Comprehensive Occupational Health Care Guide (GATISO) specifically mentions noise levels and exposure, classified as follows [9]:

Table 1.- Noise exposure levels

Grade	Description	Comment	Frequency of Revaluation
1	No Exposure	Doses Lower than 75 dBA	3 to 5 years
2	Low Exposure	Doses Below the Action Level, 82 dBA	From 1 to 3 years
3	Moderate Exposure	Frequent Exposure to Doses Below the Action Level (28 dBA) or infrequent exposures to doses between 82 dBA and 85 dBA	From 3 months to 1 year
4	High Exposure	Frequent exposure to doses near 85 dBA and Infrequent exposures to doses above 85 dBA	From 1 to 3 months
5	Very High Exposure	Frequent exposures to doses above 85 dBA	Continuous Assessment

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Table 1 exceeds the permissible limit values for humans, the decibels emitted by these tools could range between 86 and 100 dB [10]. According to projections provided by the World Health Organization (WHO), it is estimated that more than 5% of the global population, equivalent to approximately 430 million people, have disabling hearing loss (greater than 35 dB) and need hearing rehabilitation (432 million adults and 34 million children) [11].

Noise in the workplace presents multiple risks, such as a change in the hearing threshold and impaired speech perception [12]. In addition, several elements affect hearing ability, including genetic, biological, psychosocial, and environmental factors. These elements directly affect the ears and may result in hearing loss or, conversely, provide protection [13]. Several studies report correlations between occupational noise exposure and the risk of hypertension [14], abnormal hormone secretion [15], increased cortisol and aldosterone (stress) [16, 17], ischemic heart disease, sleep disturbance, and general discomfort [18].

Operators should be provided with adequate hearing protection in the short term until organizations adopt technical-organizational measures to control noise [19]. Companies in this sector must acquire work equipment while considering noise-related factors. This way, it is possible to choose machines that do not generate excessive noise, with the aim of safeguarding the well-being of the workers. According to [20], the elimination of excess noise in the work area is not a legal responsibility of the companies, but rather a commercial interest of the organizations. The safer and more adequate the work environment is, the lower the chances of absenteeism, accidents, and poor performance of the workers.

The objective of this study is to identify the disergonomic magnitude to which the workers of the sector are exposed and the occupational clinical picture that each of them presents due to being too exposed when performing each of their activities.

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Materials and methods

In the research, carried out within the metal-mechanical sector, the noise measurement results were obtained for each task performed by the operators in the different sectors during the working day. These results depend on the exposure. For the measurement of noise relative to each task in the company, several (six) data measurements must be taken. This allows an average result to be obtained.

According to [21], equations (1) to (8), which are explained below, are used to calculate noise levels in exposures during the working day:

$$u^2 = \sum c_i{}^2 u_i{}^2 \quad (1)$$

Where:

u: typical uncertainty.
u_i: standard deviation.
c_i: sensitivity coefficient

Combined standard uncertainty calculation: the standard combined uncertainty, u, for the daily exposure level u(LAeq,d) is calculated from the different contributions c_i u_i of the different uncertainty components [22]

$$u^2 = (\sum_{m=1}^{M} [c_{1\,a,m}{}^2 (u_{1\,a,m}{}^2 + u_{2\,,m}{}^2 + u_3{}^2) + (c_{1\,b,m} u_{1\,b,m})^{\,2}\ ]) \quad (2)$$

Calculation uncertainty U: as a measure of dispersion by measurement, it is expressed in a range of measured values, with the probability of 90%, by the uncertainty in level measurement (n) multiplied by the coverage factor [23].

$$U = 1{,}65 \times u \quad (3)$$

Calculation of sensitivity coefficients: it is simply the multiplier to be used to convert units into uncertainties of standard in sources of uncertainty between units by the output quantity, in calculating its uncertainty [24].

$$C_{1\,b,m} = 4{,}34 \times \frac{C_{1\,a,m}}{T_m} \quad (4)$$

Calculation of $u_{1\,a,m}$:

$$u_{1\,a,m} = \sqrt{\frac{1}{I(I-1)}\left[\sum_{i=1}^{I} (L_{p,A,eqT,mi} - L_{p,A,eqT,m})^{\,2}\right]} \quad (5)$$

Calculation of $u_{1\,b,m}$:

$$u_{1\,b,m} = \sqrt{\frac{1}{J(J-1)}\left[\sum_{j=1}^{J} (T_{m,j} - T_m)^{\,2}\right]} \quad (6)$$

Routine workday measurement

Calculation of the combined standard uncertainty:

$$u^2(L_{EX,8h}) = c_1{}^2u_1{}^2 + c_2{}^2(u_2{}^2 + u_3{}^2) \quad (7)$$

Calculation of the standard uncertainty:

$$u_{1^2} = \sqrt{\frac{1}{(N-1)}\left[\sum_{n=1}^{N}\left(L_{p,A,eqT,n} - L_{p,A,eqT,}\right)^2\right]} \quad (8)$$

The instrument used to take the necessary measurements during the working day was a Type 1 sound level meter. In this way, we obtained the information regarding the dB that allowed us to evaluate the noise exposure of the workers in this metal-mechanic sector. The dB calculator provided us with the average result of the samples obtained.

In this study, carried out in several industries of the metal-mechanic sector, the calculation of the finite sample was performed with a population of 1300 workers, obtaining a sample size of 769 workers to be surveyed. This sample size corresponds to a margin of error of 2,5% and a confidence level of 90%.

Table 2 shows the procedure for obtaining the sample of exposed workers in the metal-mechanic sector [25]:

Table 2.- Statistical method to determine the finite sample of metal-mechanic sector workers

		Sample table according to Population (N)					
		1%	**2,00%**	**2,50%**	**3,00%**	**3,50%**	**4,00%**
	100	99	97	95	93	91	88
	200	197	187	181	174	166	157
	300	293	272	259	244	229	213
	400	387	352	330	307	283	259
	500	480	428	395	362	329	298
	600	571	499	455	412	370	331
N.C.	**700**	661	566	511	456	405	359
	800	749	629	562	497	437	384
	900	836	689	609	533	465	405
	1000	922	747	653	567	490	424
	1100	1,006	801	695	598	513	441
	1200	1,089	853	733	626	534	456
	1300	1,171	902	769	652	553	470

Note. The sample size is defined as 769 workers

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Results

The symptomatology reported by each of the workers was compiled. The results obtained are shown in Table 3. Based on this information, the health conditions of the workers in the metal-mechanic sector were determined. Higher stress exposure was observed with 27%, i.e., it is present in 210 workers out of the 769 interviewed.

Table 3.- Clinical occupational pathological picture

Pathologies	Evaluated	Frequency
Tachypnea	87	11%
Tinnitus	105	14%
Sensory hearing loss	70	9%
stress	210	27%
Otalgia	65	8%
Meniere syndrome	95	12%
Presbycusis	79	10%
Otitis	58	8%
Total	769	100%

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Measurements performed in different areas of the metalworking industry:

Table 4.- Measurements

Measurement Zone	Decibel		Interval
	Lower Límit	Upper Límit	
Lathe	75,7	78	2,3
Universal Milling machine	68,9	71,5	2,6
Circular saw	78,4	80,1	1,7
Welding	70,3	72,4	2,1
Polishing machine	68,8	70,2	1,4
Pedestal drill	77,9	78,3	0,4

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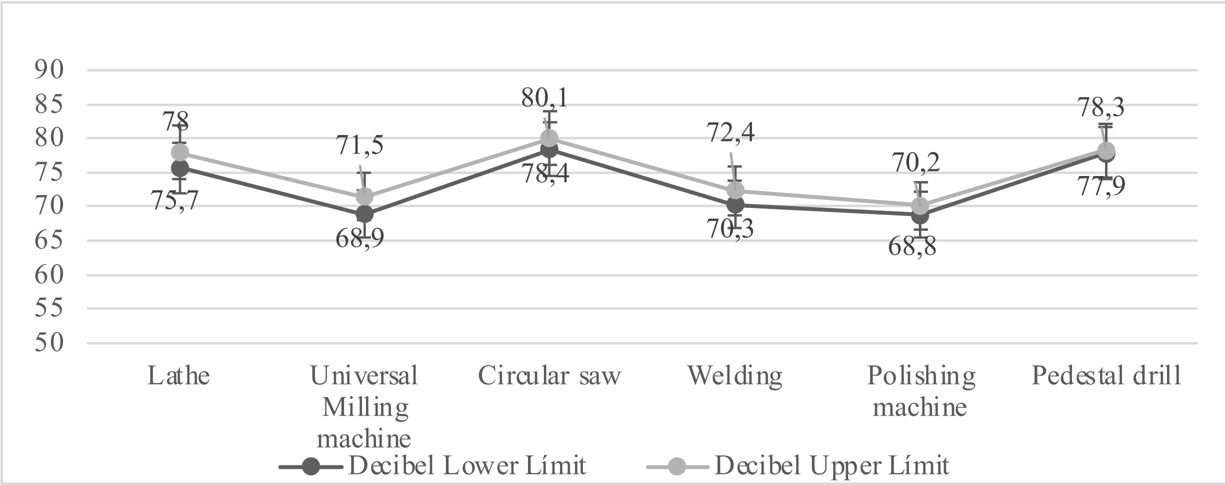
Exposure Intervals

Illustration 1 shows the universal milling machine zone with the widest interval in decibels (2,6 dB). The shortest range is in the pedestal drill area (0,4 dB).

Illustration 1.- Exposure Intervals



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LAeq, T dB(A) Values and Exposure Times Used:

The equivalent daily exposure level (LAeq,d) 1: There are significant gaps between the exposure times, being the highest in the welding zone at 120 minutes and the lowest in circular saw and pedestal drill at 30 minutes; the highest LAeq, T dB (A) value corresponds to the circular saw zone with 79,25 dB and the lowest in the polishing machine zone with 69,5 dB.

[1]LAeq,d: The level-decibels A, by expression: where T is the time of noise exposure, in hours per day.

Table 5.- Values and exposure times

Measurement zone	LAeq, value, T dB(A)	Exposure time
Lathe	76,85	45
Universal Milling machine	70,2	60
Circular saw	79,25	30
Welding	71,35	120
Polishing machine	69,5	45
Pedestal drill	78,1	30

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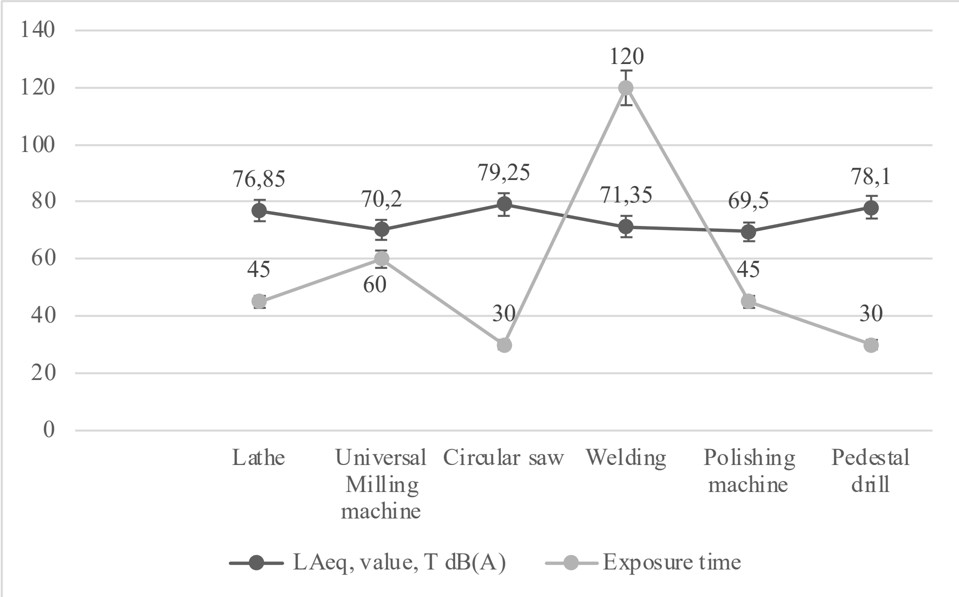
Illustration 2.- LAeq, TdB (A) values and exposure time



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Measurement of daily noise dose

During the study period, in the work cycles, it was found that workers were exposed to a dose of less than 0,5 (indicating a low risk) in all areas evaluated. Noise levels in the work areas did not exceed 85 dB(A). In addition, maximum noise levels remained reasonably low.

Table 6.- Daily dose

Measuring zone	LAeq, value, T dB(A)	Exposure time (h)	Time allowed (h)	Dose	Risk
Lathe	76,85	0,75	52,59	0,01	Low
Universal Milling machine	70,20	1,00	244,44	0,00	Low
Circular saw	79,25	0,50	30,20	0,02	Low
Welding	71,35	2,00	187,40	0,01	Low
Polishing machine	69,50	0,75	287,35	0,00	Low
Pedestal drill	78,10	0,50	39,40	0,01	Low

Determination of Sound Pressure Levels

The sum of the noise level in the plant is equal to 83,62 dB, therefore, it complies with ISO 28803:20112 by not exceeding 85 dB. However, it is in the critical zone of 80 dB to 85 dB, corrective actions and appropriate safety equipment should always be applied and evaluated frequently.

$$NPS = 10 \times \log (10^{7.685} + 10^{7.02} + 10^{7.925} + 10^{7.135} + 10^{6.95} + 10^{7.81}$$

$$NPS = 83.62\ dB$$

Discussion

Noise is not only limited to causing hearing impairment but also influences the cardiovascular system, mental well-being, and other physiological alterations. Noise exposure can lead to several symptoms and diseases, including hearing loss, tinnitus, tachypnea, and Ménière's syndrome. Tinnitus is characterized by the conscious perception of an auditory sensation, such as a ringing or buzzing in the ears, in the absence of a corresponding external stimulus [26].

At moderate levels, noise does not represent a significant risk to hearing function, although it can generate negative effects in other areas unrelated to hearing such as stress, anxiety, arterial hypertension, tachycardia, increased respiratory rate (tachypnea), and depression [27, 28]. Among other disorders, Ménière's disease is prevalent, characterized by intermittent episodes of vertigo, fluctuating sensorineural hearing loss, tinnitus, and hearing pressure [29].

The pathologies with the highest risk of exposure were determined with a sample of 769 workers in the metal-mechanical sector; they are stressed 27%, tinnitus 14%, tachypnea 11%, and Ménière's syndrome 12%. On the other hand, [30] has identified a higher prevalence of headaches, stress, hearing loss, and cardiovascular problems among workers in a metal-mechanical company.

Noise tests recorded in different areas do not exceed 80 dB and the sound pressure level is equal to 83,62 dB(A) [31], observed that the average noise exposure level in a metallurgical industry was 96.2±4 dB(A), with a maximum noise level of 108 dB(A) in the area of cutters and welders. Similarly, they reported the prevalence of hearing impairment, in 20,5% of the workers.

The results indicated that all the sectors evaluated presented a low exposure risk. However, [30] determined that the welding, lathe, sawing, and polishing processes maintained high-risk levels (dose greater than 2) with sound pressure levels greater than 85 dB(A). While the pedestal drill process maintained a high risk (dose of 1 to 2).

Conclusions

Workers in the metal-mechanical sector operate machines that produce a significant level of noise. As they are positioned in the same physical area, they expose the workers to high health risks.

Through the ISO 28803:2012 standard, it was possible to determine the sound pressure level to which the workers in this study are exposed. The evaluated noise level is 83,62 dB and does not exceed the maximum decibels established by the standard; thus, the workers are in a work environment characterized by acoustic discomfort.

When workers are exposed to acoustic discomfort for several hours, they experience various discomforts such as fatigue, headaches, difficulty communicating, and sleep disturbance, which leads to poor performance in their daily tasks and thus to losses for the organization.

MSMEs do not have adequate planning to reduce noise exposure. The implementation of this type of planning is important because it would help to protect the health of workers and avoid unnecessary costs and compensation.

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