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THE ASSESSMENT OF THE DEVELOPMENT OF HEARING LOSS IN A NOISY ENVIRONMENT

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Abstract: Hearing loss is one of the symptoms of ear diseases which cause a serious problem for the employee and can cause communication problems, too. Hearing loss caused by noise at work develops progressively due to excessive noise in the workplace. A workplace where the noise level exceeds 87 dB is considered risky. The presented article aims at creating a mathematical model based on the multiple regression analysis. When designing the mathematical model the author worked with 57 audiograms. The task was to determine the relationship between the total loss of hearing and hearing loss at frequencies of 500, 1000, 2000 and 4000 Hz.
Keywords: hearing loss, noise, hearing loss according to Fowler, mathematical model

1. INTRODUCTION

Throughout the 80‘s a study was carried out to assess the influence of mining machinery on hearing loss in breakers working in mines. The study sample consisted of 83 members and evaluated the percentage of hearing loss according to Fowler as well as hearing loss at frequencies 2000 and 4000 Hz. The results showed that the significant losses at the frequency of 2000 Hz could be observed in workers after 15 years of exposure to noise, at the frequency of 4000 Hz hearing loss could be observed after 5 years of exposure. With regard to age, the group of people aged between 41 and 45 years showed hearing loss at the frequency 2000 Hz and the group of people aged between 31 and 40 years showed hearing loss at the frequency 4000 Hz. The individual regression curves drawn up with regard to the exposure length and hearing loss show that hearing loss affects normal communication after about 20 years of exposure while hearing loss at 4000 Hz occurs after around six years of exposure. Noise levels during drilling reached around 100 dB [1].

2. CALCULATION OF HEARING LOSS BASED ON FOWLER METHOD

The calculation of hearing loss based on Fowler method makes use of threshold audiometry. We examined the hearing threshold at frequencies of 500, 1000, 2000 and 4000 Hz. According to the table determining the values of hearing loss at the given frequency we were able to determine hearing loss for the given ear by summing up values determined at given frequencies. Fowler‘s table has been designed to match hearing loss frequencies with the importance of the given frequency in the auditory field. The calculations were done for each ear separately and then we calculated the difference between them. Hearing loss for both ears was determined by adding the quarter of the value of the determined difference to the value determined for the better hearing ear [1].

The assessment of hearing loss and its impact on the life of those affected was addressed by Kasl [2]. According to Fowler, difficulties of patients with impaired hearing begin at 40 % hearing loss. When exceeding 45% hearing loss, patients fully experience all the consequences of hearing impairment. Fowler summarized his observations in five points:

1. According to Fowler, hearing loss under 35 % does not impair employees’ hearing in any significant way.
2. If hearing loss exceeds 30 % threshold after an employee reaches the age of 45, given that he/ she worked in the noisy environment for more than 10 years, an employee is not likely to develop any hearing impairment, mainly because of the fact that hearing loss does not exceed 45%.

3. If hearing loss exceeds 30 % threshold after an employee reaches the age between 30 and 45, an employee should be monitored at regular intervals and assigned different position if hearing loss exceeds 35%. When monitoring the progression of hearing loss, it is necessary to focus on the frequency of 2000 Hz. Deterioration of hearing loss two times in row by 5 dB is a reason for assigning a new job position.
4. If hearing loss reaches 30% during the first ten years an employee spent in a noisy environment (usually before a worker is 30 years old), an employee should be assigned a new job position due to the risk of severe hearing damage by noise in the next 15 years.
5. All employees who remained working in a noisy environment following a head injury should be medically checked at least once a year. In this case, the rule from the paragraph 3 applies.

3. OCCUPATIONAL DISEASES ARISING AS A RESULT OF EXPOSURE TO EXCESSIVE NOISE

Noise level which does not cause harm to normal healthy ears after an extended noise exposure is known as a criterion for hearing loss. It should be noted that hearing loss is the cumulative result of the impact of the sound level and time of exposure [3,7].

Occupational Exposure

Acute acoustic trauma is rare; it may occur after intense sound impulses such as a shot or explosion. Prolonged excessive noise that can cause hearing loss is the most frequent in wood processing plants, mining and mineral processing plants, oil mills, test engine test facility, airports and facilities that use saws, pneumatic tools and other noisy machinery [4].

Clinical Aspects

Acoustic trauma includes the feeling of buzzing in ears, pressure and pain in ears and subjective tinnitus. Symptoms may last from a few minutes to days, and then the state usually normalizes. Tinnitus (buzzing or ringing in the ears) may be permanent. Hearing loss caused by noise usually happens due to the excessive exposure to noise. Hearing loss develops in the course of a few years and at the beginning a person does not realize its effects since it starts at high frequencies which are not important for regular communication. Progressive hearing loss is usually noticed at frequencies which are vital for understanding speech.

Diagnostics

Occupational hearing loss diagnosis is based on:

» work history and demonstration of long-term exposure to excessive noise,
» typical clinical presentation of the disease confirmed by otorhinolaryngological and repeated audiometric testing. In more complicated cases it is normal to use the method of objective audiometry [5].

Preventive Medical Examinations

The usual outcome of threshold tests is symmetric perception disorder which exceeds the allowed threshold set by Fowler (with regard to age and exposure). Such a diagnosis should take into account the development of hearing loss and the causal link with working in a noisy environment. It is not always easy to prove that hearing loss is really caused by one's occupation and not a two-sided perception disorder caused by other factors. The properly assessed hearing loss is crucial for workers because if hearing loss is really caused by their occupation, they are entitled to compensation. Therefore, tests have to be carried out properly and results of audiometric testing are to be kept for future reference.

If the result of preventive examination shows that an employee is affected by disabling hearing loss caused by work performed, the employer shall:

» re-examine the existing risk assessment,
» review the measures that have been taken or are taken to eliminate or reduce risks from exposure to noise,
» take into account the recommendations of the physician responsible for medical surveillance and health protection authority when implementing measures to eliminate or reduce risks including assigning employees to other job position where there is no risk of similar noise exposure,
» provide health surveillance and evaluation of the health of other employees who have been exposed to similar noise levels.

An employee working in the noisy environment shall be assign a different job position provided:

» an employee is under the age of 30, any of the limits of the dynamics of hearing loss has been exceeded after reaching 20% loss of hearing according to Fowler.
» an employee has taken the job position in the noisy environment later in life (after he/ she reached 30 years of age) and hearing loss was not serious at the beginning but due to external and internal

factors the employee's state have deteriorated. The short-term dynamics of hearing loss is so great that it would exceed the limits of hearing loss during employee's working age [1,6].

4. COLLECTION AND PROCESSING OF INPUT DATA

The research sample consisted of eight employees who during the reported period have underwent a number of audiological assessments regarding their hearing loss (n=57). The available audiogram provided hearing curves for frequencies of 500, 1000, 2000 and 4000 Hz in the human auditory field ranging between 10 and 95 dB. Data have been summarized in the tables featuring hearing loss values for the right and left ear (in %) and the total loss of hearing. These values were then listed for each employee separately in chronological order. Of the total number (n=57) of available audiograms 17 were incorrectly read. These values were checked and corrected using tables for the calculation of hearing loss (Fowler's method) in Microsoft Excel. The corrected values were then used for further evaluation.

Based on the International Classification of Hearing Impairment (degrees of hearing loss) proposed by WHO in 1980 it was found that two employees suffer from moderate hearing loss (56-70 dB), four employees suffer from severe hearing loss (71-90 dB) and two employees suffer from the total hearing loss (more than 91 dB). It is necessary to note that audiometric examination is an objective-subjective examination and therefore it is necessary to take into account several examinations or average hearing loss.

Table 1. Audiological assessment of hearing loss

Serial A	Serial E	AE	AC	Audio-RE					Audio-LE					THL
				500	1000	2000	4000	HLRE	500	1000	2000	4000	HLLE	
1	1	38	3	50	45	35	65	43.2	30	35	35	55	29.8	33.2
2		41	4	50	50	40	75	50.7	35	40	40	65	39.3	42.2
3		43	4	50	40	55	60	55	40	45	40	65	43.3	46.2
4		43	4	50	50	45	70	54.4	40	45	50	65	52.8	53.2
5		44	4	45	45	55	65	57.5	35	50	55	70	58.6	57.8
6		44	4	60	60	68	71	76.5	50	50	65	70	67.3	69.6
7	2	45	4	15	20	30	60	21	15	20	30	60	21	21
8		46	5	30	40	40	60	36.9	25	30	50	55	39.3	37.5
9		52	5	25	40	50	70	37	25	30	45	65	47.9	39.7
10		53	5	20	40	45	70	42.1	20	35	45	70	39.6	40.2
11		54	5	30	30	50	55	40.1	20	40	60	60	50.5	42.7
12		57	5	30	40	50	70	48.7	20	30	50	70	42.4	44
30	5	46	4	35	45	35	45	32.9	35	55	50	50	53.1	38
31		51	5	50	60	50	50	71.3	55	65	55	65	59.8	62.7
32		51	5	45	60	50	60	61.4	55	65	60	60	72.3	64.1
33		52	5	40	60	55	55	61.8	50	60	65	60	70.8	64.1
34		52	5	45	55	55	65	63.5	50	60	60	60	68.6	64.7
35		52	5	55	65	55	60	70	50	65	60	60	70.6	70.1
36		52	5	45	70	55	60	68.7	55	70	60	60	74.3	70.1
52	8	43	4	10	20	25	25	8.9	15	35	40	50	29.1	14
53		45	4	15	15	60	85	44.2	20	30	65	70	50.2	45.7
54		46	4	25	25	65	80	52.2	20	30	70	75	49.6	50.2
55		47	4	25	30	70	80	54	20	25	70	80	51.5	52.1
56		48	4	40	35	45	60	41.1	80	70	80	90	91	53.6
57		50	5	60	60	70	70	78.5	55	45	50	70	58.5	63.5
58		54	5	50	40	55	70	57.3	70	70	85	90	91.7	65.9

Notes: Serial A: serial no. of audiogram / Serial E: serial no. of an employee / AE: age of an employee at which he/she underwent the audiological assessment / AC: age category / Audio-RE: hearing loss according to Fowler read from the hearing curves for frequencies at 500-1000-2000-4000 Hz for the right ear / Audio-LE: hearing loss according to Fowler read from the hearing curves for frequencies at 500-1000-2000-4000 Hz for the left ear / HLRE: hearing loss (in %) for the right ear / HLLE: hearing loss (in %) for the left ear / THL: total hearing loss (in %)

5. THE PROPOSAL OF THE MATHEMATICAL MODEL

In this part of the study the author's aim was to create a mathematical model using the multiple regression analysis. The task was to determine the relationship between the total loss of hearing and hearing loss at frequencies of 500, 1000, 2000 and 4000 Hz. Firstly, it was necessary to determine how

different frequencies influence the total loss of hearing. From the above it can be seen that the largest impact on the total hearing loss had frequencies 1000 and 2000 Hz.

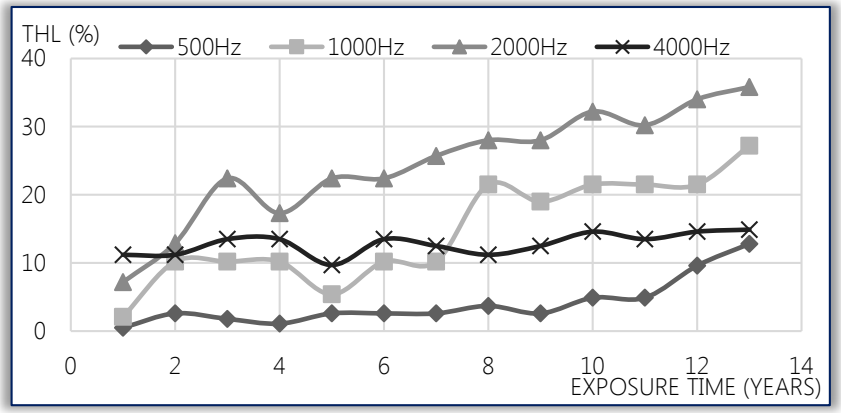

Figure 1. The impact of frequencies on total hearing loss (in %)

The relationship between the dependent variables Y and k and the independent variables can be expressed by a linear regression mathematical model as follows:

$$Y = B_0 + B_1 \cdot X_1 + B_k \cdot X_k + E$$

where B_0 is an absolute term and values from B_1 to B_k are regression model parameters.

The dependence of the variable THL (total hearing loss) on the independent variables hearing loss in the right / left ear at frequencies up 500 to 4000 Hz was examined in (n=57) audiograms (total number).

In order to simplify the model, we excluded the parameters B_0, B_1, B_5, B_6 and B_8, since they far exceed the desired level of $\alpha = 0.05$.

The equation of the simplified regression model:

$$THL = -11{,}2492 + 0{,}482897 \cdot R_{1000} + 0{,}364188 \cdot R_{2000} + 0{,}137913 \cdot L_{500} + 0{,}318291 \cdot L_{2000}$$

Multiple coefficient of determination $R^2 = 0.9834$ suggests that 98.34% of THL 'variability could be explained by the combined impact of the variables R1000, R2000, L500 and L2000.

The point estimate of a linear regression model is the regression function as follows:

$$THL = B_0 + B_1 \cdot R_{500} + B_2 \cdot R_{1000} + B_3 \cdot R_{2000} + B_4 \cdot R_{4000} + B_5 \cdot L_{500} + B_6 \cdot L_{1000} + B_7 \cdot L_{2000} + B_8 \cdot L_{4000}$$

Individual parameters of the regression model were calculated using the statistical program STATHGRAPHICS.

Table 2. The results of the analysis

	Estimate	Error of the mean value	p-value
B_0	-12.02	2.859	0.0001
B_1	0.03225	0.05539	0.5631
B_2	0.4467	0.05064	0.0000
B_3	0.3511	0.06271	0.0000
B_4	0.02841	0.05231	0.5896
B_5	0.09747	0.05845	0.1019
B_6	0.06471	0.06871	0.3511
B_7	0.3121	0.05848	0.0000
B_8	-0.01661	0.05861	0.7780
R^2	0.9838		
F	365.19		
p-value	0.0000		

Table 3. The results of the analysis – the simplified model

	Estimate	Error of the mean value	p-value
B_0	-11,2492	1.45913	0.0000
B_1 - R1000	0.482897	0.0339853	0.0000
B_2 - R2000	0.364188	0.051699	0.0000
B_3 - L500	0.137913	0.026332	0.0000
B_4 - L2000	0.318291	0.0414354	0.0000
R^2	0.9834		
F	771.52		
p-value	0.0000		

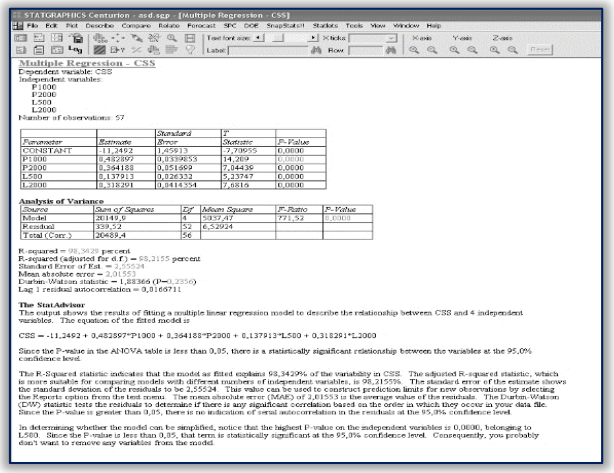

Figure 2. The program STATHGRAPHICS

6. CONCLUSION

Healthy work environment enables employees to be useful parts of the company. Any excessive load is harmful to their physical and mental state. Therefore a comprehensive approach to disease prevention and health promotion, including the assessment of occupational risks is needed.

As input data we used medical records of patients with the main focus on employees who are exposed/ used to be exposed to excessive noise.

Based on the results of audiological records and subsequent experimental assessment it can be concluded that the proposed multiple regression model is statistically significant.

It is important to note that this issue is complicated and therefore there exist many relevant ways to handle it.

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