American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Hearing Impairment Caused by Noise at the Workplace

Zerina Zahirovic[a*], Ago Omerbasic[b], Ermina Sitnic- Milanovic[c], Edina Lazovic-Salcin[d]

[a]*Family Medicine, Primary Health Care Center Zenica, 72000 Zenica, Bosnia and Herzegovina*

[b]*Department of Medical Physics and Biophysics, Faculty of Medicine, University of Sarajevo, 71000 Sarajevo, Bosnia and Herzegovina*

[c]*Anesthesiology, Reanimatology and Intensive Medicine Clinic, Clinical Center University of Sarajevo, 71000 Sarajevo, Bosnia and Herzegovina*

[d]*Department of Pathology, Faculty of Medicine, University of Sarajevo, 71000 Sarajevo, Bosnia and Herzegovina*

[a]*Email: zerinakb8@gmail.com*

Abstract

Objectives: The aim of this article is to determine the prevalence of hearing impairment caused by noise among workers in two companies in Bosnia and Herzegovina, to correlate hearing loss with age and years of specific work experience, and to indicate the occurrence mechanisms for these impairments.

Methods: The study included 60 respondents who were divided into two groups: one group consisted of respondents with hearing impairment, and the second group respondents whose hearing was not impaired. Data were collected over a period of 5 years, by testing with sounds in frequency range 250-8000 Hz, which were graphically represented by audiograms. Statistical processing and comparison of the results of the control group and the group with hearing impairment were performed.

Results: The age of the respondents ranged from 31 to 65 years, and the length of service ranged from 1 to 37 years. Hearing impairment was found in 46 workers, while the rest of the respondents had normal hearing. The average value of the hearing threshold in respondents with hearing impairment at 1 kHz was 21 dB, and the average value of hearing impairment was 34.45 dB (mild hearing impairment).

----

* Corresponding author.

Majority of workers have a mild degree of impairment. The largest differences in the audibility threshold between the two groups of workers with and without impairment were noticed at 4 kHz in the age group 46 to 55 years, and in the group with work experience from 21 to 30 years.

Conclusion: Workplace noise effects are most clear in the 4 kHz frequency range. The age of the respondents and the years of work experience are significantly correlated with the hearing impairment: older workers and workers with longer work experience have greater hearing impairments.

Keywords: hearing impairment; noise; presbycusis; work experience; scotum.

1. Introduction

Noise will become a danger to human health with which we will have to fight as with cholera or plague. Roberta Koch, late 19th century All sounds that carry unwanted information, which can have various negative effects on human health are considered as noise. From the medical point of view, noise can be defined as a high-intensity sound that is capable of producing impairment to the inner ear. [1] According to a report by the World Health Organization (WHO), noise is one of the three most dangerous pollutants in the human environment (along with air and hydro pollution). We will base our research on industrial noise, the noise generated by the work process in industry. According to WHO recommendations and estimates, the upper limit of industrial noise safety, for 8 working hours, is 85 dB, while the upper limit of domestic noise, outside working hours, is 45 dB (during sleep the upper limit is 35 dB).

Table 1: Recommended noise levels

Room type	**Noise level (dB)**
Conference room	35
Office	40
Laboratory, measuring rooms	50
Canteen	50
Dressing room	55
Workshop	60
Manufacturing plant	75
Rooms with compressors and other machines (without constantly present persons)	90

Noise represent a significant problem of modern man who is, due to technological development and modernization of industry and transport, increasingly exposed to many harmful effects that noise has on hearing, but also on other organic systems. A particularly risky group is the working population who are employed in various industrial facilities and construction companies, and are exposed to noise for many years during eight working hours. Therefore, it is important to identify and prove the harmful effects of noise on human health and hearing impairment, and in this manner draw attention to the need for preventive measures to protect hearing and adequate treatment of patients with hearing impairment. *The direct consequences of noise* on the health of workers are partial deafness, deafness, tinnitus, various speech disorders and the occurrence of communication problems, problems with balance, both when standing and walking. *Indirect consequences of noise* are neurovegetative reactions (hypertension, endocrinological and other metabolic disorders), fatigue, irritability, and decreased work capability. Noise affects the sleep cycle: it leads to sleep disorders (shortened REM phase after noise exposure). Noise disrupts everyday activities, especially when performing complex mental activities. It leads to a feeling of helplessness, similar to that in depressed patients, resulting in increased and frequent mistakes in performing daily tasks. The consequences of noise exposure are also conduct disorders that manifest as aggression and social isolation. Robert Koch's predictions from the end of the 19th century that noise would become a danger to human health that we would have to fight, such as cholera or plague, came true. Measurement and assessment of noise levels can be performed subjectively or objectively. Subjective assessment of excessive noise is considered to be that noise that is so loud that it is impossible to communicate in a normal tone in the workroom at a distance of 1 to 2 meters. Objective evaluation is performed with sound intensity measuring devices. It is a measurement technique based on recording sound with instruments that have filters for sound frequency evaluation. According to that, excessive noise is considered to be a sound intensity level higher than 85 dB during eight hours. The noise intensity level is expressed in dB, and is defined as the ratio of the logarithms of the two intensities

$$L = 10\log\frac{I}{I_0} \ \text{(dB)}.$$

In the measurements we often have a variable noise level, and, therefore, an *equivalent noise level* is defined: a constant noise level that would at the same time have the same effect on a person as the observed variable noise. The equivalent noise level is calculated by the formula

$$L_{Aeq,T} = 10\cdot\lg\left[\frac{1}{T}\int_0^T \frac{p_A{}^2(t)}{p_0{}^2}dt\right] = $$
$$= 10\cdot\lg\left[\frac{1}{T}\int_0^T 10^{0,1\cdot L_A(t)}dt\right] \ \text{(dB)}$$

T- measurement time, - $p_A(t)$ current sound pressure value, - $L_A(t)$ variable noise intensity level.

$$p_0 = 20 \ \mu\text{Pa}.$$

In practice, the time interval of noise exposure *T* is divided into a series of intervals in which it is possible to consider the noise level constant, so the equivalent noise level is calculated by the formula

$$L_{Aeq} = 10 \cdot \lg\left[\frac{1}{T}\int_0^T \frac{p_A{}^2(t)}{p_0{}^2}dt\right] =$$
$$= 10 \cdot \lg\left[\frac{1}{T}\sum_{i=1}^{n}\left(t_i \cdot 10^{0,1 \cdot L_{A_i}}\right)\right] \text{ (dB)}$$

n - number of time intervals in which the noise level is constant,

$T = \sum t_i$ - total time of noise exposure, L_{A_i} - average noise level in a given time interval t_i.

The pathogenesis of acoustic trauma of the inner ear involves several mechanisms:

a. *Hypoxia due to spasm of the auditory artery* - noise affects the autonomic nervous system and leads to an increase in sympathetic tone, which causes spasm of the artery that feeds the receptor cells of the Corti's organ. Measurements showed that hearing impairment first occurs in the 4 kHz frequency range [2].

b. *Excessive stimulation of receptor cells* leads to the production of reactive oxygen containing molecules which causes oxidative cell death. In some experiments performed on animals, the positive effect of antioxidants on hearing preservation has been proven, even when the animals have been exposed to excessive noise. Cell impairment can only result in fatigue and exhaustion of cells with hairs or their death [3,4].

c. *Nerve impairment in the case of acute acoustic trauma* is caused by rupture of postsynaptic dendrites due to overstimulation, known as excitotoxicity. This impairment usually heals within five days and the synapse functionality is restored. Repeated ruptures can cause irreversible hearing impairment. In addition, acoustic trauma can cause demyelination at specific places of the auditory nerve, thereby slowing the transmission of electrical signals from receptor cells to the auditory cortex [5].

Table 2: Allowed noise level at different jobs

	Job description	Maximum allowed noise level *L* (dB)
1	Demanding mental work	45
2	Office work, school classes, doctors' offices	55
3	Mechanized office work, department stores	65
4	Physical work that requires attention, work that requires use of hearing and sound signals	70
5	Less complex physical jobs that require attention and caution	75
6	Routine physical work that requires accuracy and use of hearing in the work process	80

Noise-induced hearing impairment leads to hearing loss at high frequencies of 3-4 kHz, especially at about 4 kHz, while some improvement is observed in the area of the highest frequencies. There are several reasons why this 4 kHz band is the most sensitive. Although the noise encompasses a wide frequency band, the resonance of the outer ear and ear canal has already amplified the noise in the 2-4 kHz range as the sound reaches the cohlee. Therefore, this area shows the greatest impairment due to noise exposure. Another reason is the position of high frequency sensitive receptor cells in the basal part of the cochlea

Table 3: Daily allowed noise leve

Noise exposure time	$L_{A,eq}(dB)$ Noise level $L_{A,eq}(dB)$
25 h	80
8 h	85
2 h 30 min	90
47 min	95
15 min	100
4 min	105
1 min 30 s	110
28 s	115
9 s	120

2. Metodology

Hearing impairment measurement data, collected over a period of 5 years, were used in this paper. The parameters used in the analysis and data processing are: age, duration of total work experience, duration of specific work experience, degree of hearing impairment in the right and left ear, frequency to which hearing is preserved, scotoma, frequency at which scot occurs, hearing threshold, working place and working ability of employees. Audiometry is a method of hearing testing that is based on generating sound into some acoustic, pure tones of precisely determined frequency and intensity, which is conducted through the headphones to the ear of the respondent who needs to hear it. Tones of frequencies from 250 Hz to 8 kHz are examined, and the result is graphically presented by a finding - audiogram. The expected value is taken from the expected value of -10 dB to 20 dB at all frequencies, where the graph does not have to be a straight line (*„minimum auditory curve“*). An audiometer is a device that is used to practically determine the degree of hearing loss. 8 to 10 tons of different frequencies are examined, on the base of which an audiogram is made, which graphically shows hearing impairments in the areas of individual frequencies. When normalizing noise, we use a relation

$$L_A = N + 5 \quad \text{(dB)}$$

where N = 85 dB for eight-hour working hours

Table 4: Action of noise on a human

N	L_A (dB)	Effect of noise on a human
55	60	Psychological action
55-85	60-90	Serious psychological and neurovegetative interferences
85	90	Area of hearing impairment
>115	>120	Area of acute hearing impairment

Statistical data processing was performed by standard statistical methods, and the obtained results are presented in tables and charts by number of cases, arithmetic means (X) with standard deviation (SD), standard error of arithmetic mean (SEM), mode, median, minimum and maximum value. Student 's *t* - test, χ^2 - test and correlation method were used to determine the difference between groups. The value of $p<0.05$ was considered statistically significant. We used Microsoft Excel from the Microsoft Office 2010 software package for data processing. Analyzing the difference in the specific work experience of respondents with hearing impairment and respondents without hearing impairment, using the *t*-test of arithmetic mean differences, it was found that the *t*-value is equal to 5, which is greater than the limit value t=2, for the number of degrees of freedom 58 and $p<0.005$, we reject the null hypothesis and accept the alternative with error $p<0.05$ and certainty $P>95\%$. The determined difference in the average values of the years of specific work experience in affected and non-affected respondents is statistically significant, which means that the frequency of hearing impairment increases with increasing years of work experience.

Table 7: Descriptive statistics of hearing impairment degree in affected group

Hearing impairment degree in affected group	
Mean	32.457
SEM	1.415
Median	28.7
Mode	22.5
SD	9.594
Min	21.2
Max	56.2
Total	46

The degree of correlation between hearing impairment and specific work experience of the respondents is 0.578 (moderate to strong association). The degree of correlation between hearing impairment and the age of the respondents is 0.43 (weak to moderate association).

Table 8: Descriptive statistics of hearing impairment threshold in group with and without impairment

Hearing threshold of affected group		Hearing threshold of control group	
Mean	21,087	Mean	16,786
SEM	1,262	SEM	1,125
Median	20	Median	17,5
Mode	20	Mode	20
SD	8,558	SD	4,209
Min	10	Min	5
Max	55	Max	20
Total	46	Total	14

Analyzing the difference in the hearing thresholds of respondents with hearing impairment and respondents without hearing impairment, using the *t*-test of the difference of arithmetic means, it was found that the *t*-value is equal to 1.8 which is less than the limit value t=2 for the number of degrees of freedom 58 and p=0.076, we accept the null hypothesis with error p<0.05 and certainty P>95%. The determined difference in the average values of the hearing threshold in affected and non-affected respondents is not statistically significant. The degree of correlation between age and hearing threshold is 0.45 (*weak to moderate correlation*). The degree of correlation between the years of specific work experience and the audibility threshold is 0.44 (*weak to moderate correlation*).

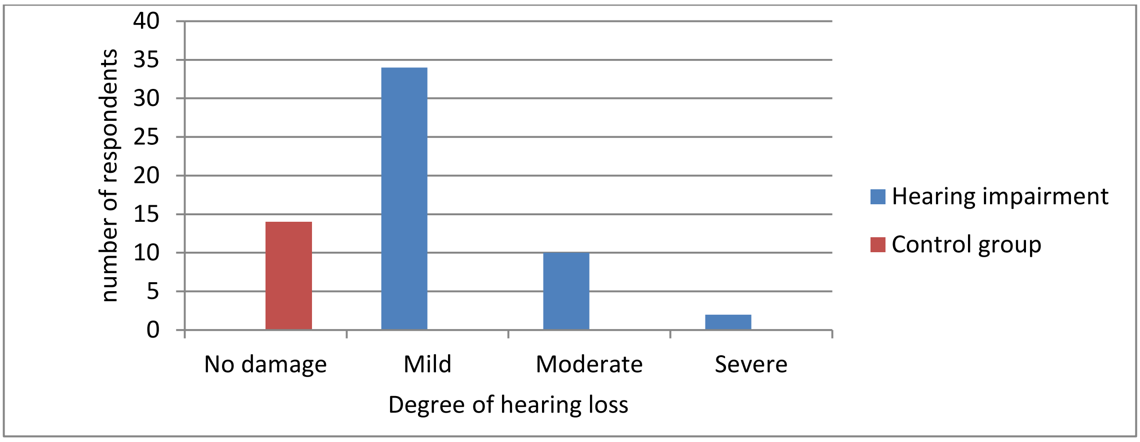

Figure 1: Distribution of hearing of respondents based on the criterion of hearing impairment

Analyzing the distribution of the state of hearing of the respondents, using the $\chi^2 -$ test, it was determined that the χ test value is equal to 37.07. Since the obtained test value is higher than the limit value of the test value = 7.815 for the number of degrees of freedom 3 and p<0,05, we reject the null hypothesis with error p<0,05 and certainty P>95%. The obtained distribution of the respondents according to the degree of impairment differs statistically significantly from the distribution that we would expect if the respondents were randomly distributed.

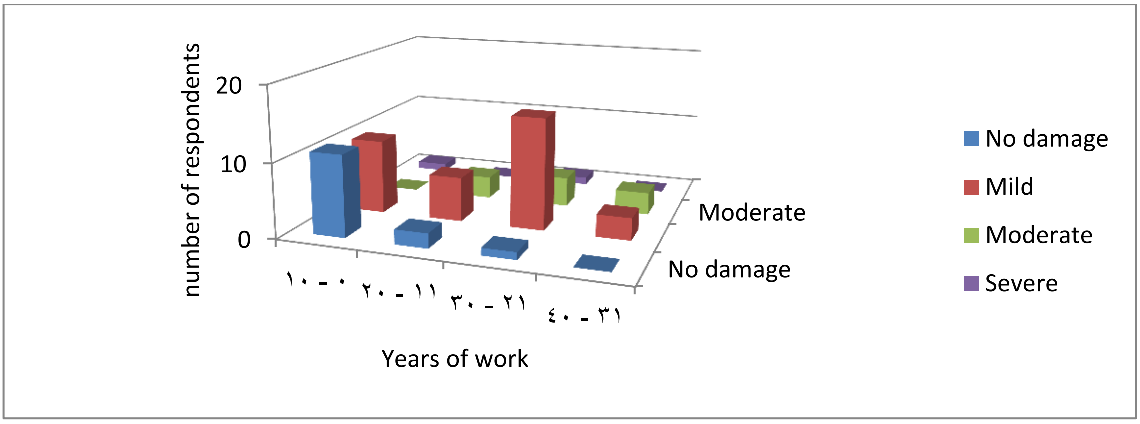

Figure 2: Distribution of hearing impairment in total sample in correlation to specific work experience

Analyzing the distribution of hearing impairment of the respondents in the total sample in relation to the specific work experience, using the χ^2 – test, it was found that the test value χ is equal to 21.96. Since the obtained test value is higher than the limit χ value test = 16.9 for the number of degrees of freedom 3 and *p*<0.05, we reject the null hypothesis with error *p*<0.05 and certainty *P*>95%. The obtained distribution of the respondents' hearing impairment differs statistically significantly from the distribution that we would expect if the respondents were randomly distributed. Analyzing the distribution of scotoma frequency among workers with hearing impairment according to age, using the χ^2 – test, it was determined that the χ test value is equal to 15.51. Since the obtained value is higher than the limit value χ test = 12.59 for the number of degrees of freedom 6 and *p*=0.017, we reject the null hypothesis with an error of *p*<0.05 and certainty *P*>95%.

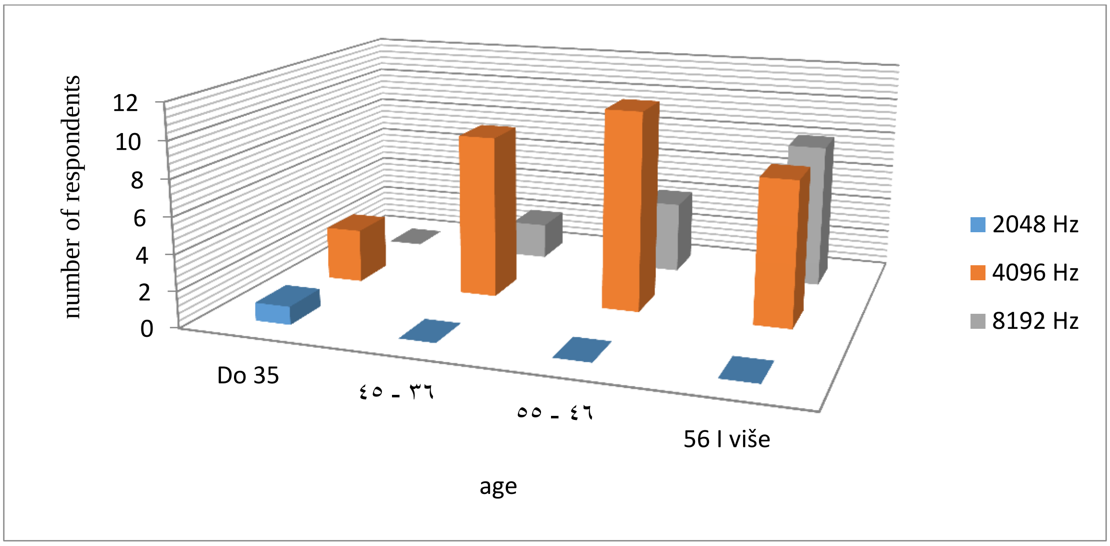

Figure 3: Distribution of scotoma frequency among workers with hearing impairment according to age

The resulting distribution of scotoma frequency among workers with hearing impairment differs statistically significantly from the distribution we would expect if respondents were randomly distributed. Analyzing the distribution of respondents with impairment in relation to the frequency at which hearing loss begins and the length of specific work experience, using the χ^2 – test, it was determined that the χ test value is equal to 4.28. Since the obtained chi test value is less than the limit value χ test = 7.82 for the number of degrees of freedom 3 and the p value is 0.233, we accept the null hypothesis with error $p<0.05$ and certainty $P>95\%$. The obtained distribution of respondents with hearing impairment in relation to the frequency at which hearing loss begins and the length of specific work experience does not differ statistically significantly from the distribution we would expect if the respondents were randomly distributed.

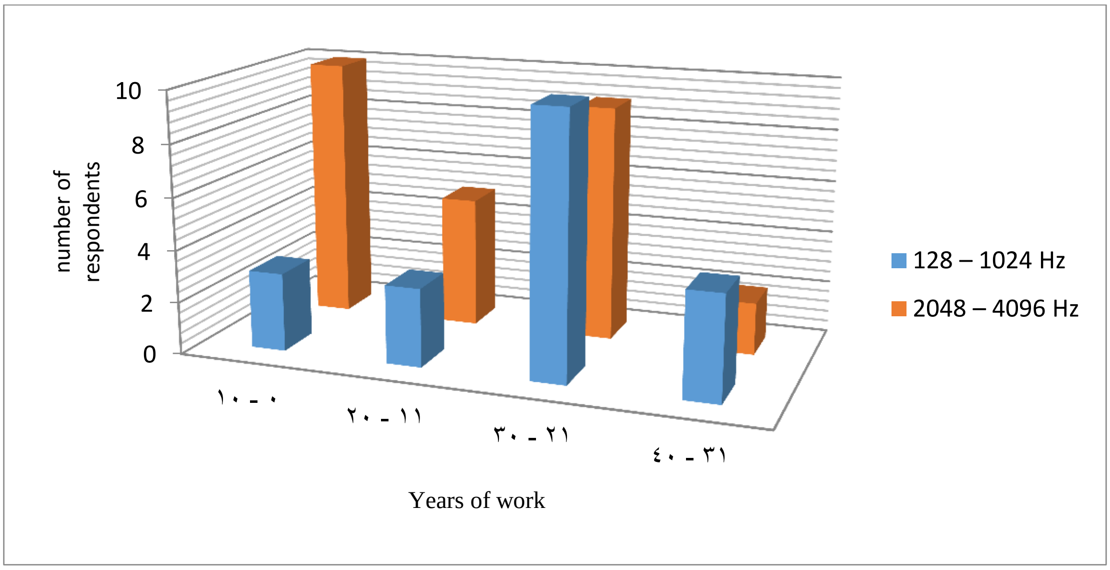

Figure 4: Distribution of workers with impairment in relation to frequency at which hearing loss begins and the length of specific work experience

Table 9: Relation between hearing impairment, scotoma frequency and frequency of hearing loss beginning

Hearing impairment (dB)	Scotoma frequency (Hz)	Frequency of hearing loss beginning (Hz)
40	8192	1024
56.2	4096	128
40	4096	128
40	4096	128
41.2	4096	1024
43.7	8192	128
56.2	4096	128
42.5	8192	128
42.5	8192	512
45	4096	128
51.2	8192	128
52.5	4096	128
41.2	4096	2048

The degree of correlation between the degree of hearing impairment in workers with moderate and severe impairment and the frequency of auditory scotoma is -0.209 (*negative weak association*). The degree of correlation between the degree of hearing impairment in workers with mild and severe impairment and the frequency of onset of hearing loss is -0.422 (*negative week to moderate association*).

3. Discusion

The study included a total of 60 respondents who were exposed to noise during working hours. Hearing impairments were found in 46 workers who make up the affected group, while the remaining 14 workers did not have hearing impairments. In our study, the average age of workers with hearing impairment was 50.56 years (31-65 years), and the average age in the control group, a group without hearing impairment, was 35.78 years (26-51 years). The average length of service in the impaired group is 21 years (1-37 years), and the average length of service in the control group is 6 years (1-23 years). These results confirm the results of other authors who prove that the number and degree of hearing impairment of workers exposed to noise increases in proportion to age and exposure duration [6]. The average hearing impairment in the group of patients is 32.46 dB, which is defined as mild hearing impairment. The degree of correlation between hearing impairment and specific work experience is 0.58 (*moderate to strong association*), while the degree of correlation between hearing impairment and age is 0.43 (*weak to moderate association*). The results obtained correspond with the results obtained by Kerketta S., Gartia R. and Bagh S. in their 2012 study, investigating the effects of noise levels to which workers of an Indian surface mine are exposed [7]. The average hearing threshold in workers with hearing impairment in our study is 21 dB (10-55 dB), while the average hearing threshold of the control group is 16.79 dB (5-20 dB). The audibility threshold was taken for a frequency of 1 kHz. Analysis of the average values of the height of the hearing threshold indicates that the hearing threshold is higher in workers with hearing impairment compared to the control group, but using the Student t-test no statistically significant difference was determined, which means that there is no significant increase in the threshold. audibility at a frequency of 1 kHz. It has been proven that in the case of hearing impairment caused by noise, the impairment most often occurs in the range of 4 kHz, which can justify this result. The degree of correlation between age and audibility threshold is 0.45 (*weak to moderate correlation*), while the degree of correlation between years of specific work experience and audibility threshold is 0.44 (*weak to moderate correlation*). We can conclude that with increasing age and increasing years of specific work experience, the audibility threshold is raised, which has been proven in other previous studies. Namely, hearing is most sensitive at the age of about 20, and after that hearing progressively weakens, mostly at high frequencies. The results are confirmed by research in Zimbabwe on workers exposed to 102 dB of noise during eight-hour working hours, and research on blacksmith workers exposed to constant, excessive noise [8]. One large study was conducted in Germany in 2011 and included 29,644 workers employed on construction sites. Workers exposed to noise had higher hearing losses compared to those not exposed to noise, as well as the reference population according to ISO 1999. A higher predictor of hearing impairment is the duration of noise exposure than the noise level to which workers are exposed [9]. The results of our study showed that the majority of workers (67.39%) exposed to noise have a hearing loss at a frequency of 4096 Hz. Of the workers from this group, the largest number of them are aged between 46 and 55, while the largest number of workers with scotoma at 8192 Hz are aged 56 and over. This matches with the previous knowledge that in the case of hearing impairment, the frequency range of 4096 Hz is most strongly affected by excessive noise, in contrast to impairment caused by aging and affecting higher frequencies. Namely, low frequency sounds (e.g. 300 Hz) when they reach the inner ear will lead to the appearance of an electric potential along the entire length of the cochlea and the greatest potential will occur at the top of the cochlea, i.e. on the helicotrem (28 mm from the oval window). Higher frequency sounds will cause the maximum electrical potential closer to the oval window. For example, for sound at 8 kHz, the corresponding maximum will occur at a distance of 5 mm, and the energy of that sound will be distributed over a smaller area and a smaller number of receptor cells. This means that if the same energy acts on a smaller area the corresponding affected cells will suffer more impairment than would be the case if that energy acted on a larger area. Practically, we can present this experimentally by producing sound with a frequency of 300 Hz and 8 kHz of the same level (e.g. 90 dB). In doing so, we will feel a significantly higher load at 8 kHz sound. This is why hearing cells are most sensitive to noise in the high frequency range of 3 kHz to 8 kHz, and most in the 4 kHz frequency. Strauss S. and associates conducted a study in South Africa in 2014 in which they aimed to describe the different effects of noise exposure and the effects of aging on hearing impairment. Respondents were divided into two groups depending on whether they were exposed to noise. A significant difference in hearing impairment in these two groups was observed mostly in the frequency range of 4 kHz in the age group of 36 to 45 years [10], which matches with our results. Singh L.P. included workers employed in industry in India in its research. Hearing was tested at low (250 Hz– 1 kHz), medium high (1.5-3 kHz) and high frequencies (4–8 kHz). The results showed that over 90% of blacksmith workers have hearing impairment that affects the mid-high and high frequency range. This research pointed to the need to use protection during working hours and the importance of regular systematic reviews [11]. Analyzing the distribution of workers with hearing impairment in relation to the frequency at which hearing loss begins and the duration of specific work experience, we came to the data that in the group with hearing loss at lower frequencies from 128 to 1024 Hz 50% of workers have work experience at specific job of 21-30 years and only 15% of workers have a specific work experience of up to 10 years, while in the group with hearing loss at higher frequencies from 2048 to 8193 Hz the largest number of workers (38.5%) have a specific job, work experience of up to 10 years, and 34.6% of workers have work experience of 21-30 years. The degree of correlation between hearing impairment in workers with moderate and severe impairment and the frequency of auditory scotoma is 0.209, which means that by increasing the degree of hearing impairment, scotoma occurs at lower frequencies, however, the degree of correlation indicates that this interdependence is weak. The degree of correlation between hearing impairment in workers with moderate and severe impairment and the frequency of onset of hearing loss is 0.422 (*weak to moderate association*), which means that greater hearing impairment begins at lower frequencies. A 1998 study conducted in Turkey included 130 workers employed in industry who were exposed to excessive noise during working hours. The control group consisted of 33 people with intact hearing. Sensorineural hearing loss was found in 71 workers and covered the frequency range of 4 to 6 kHz. It was shown that the impairment occurred within the first ten years of noise exposure, and in the following years there was a progression of impairment [12]. An important factor both in our study and in all the above-mentioned studies on hearing impairment with noise there is individual sensitivity. Some people can spend years in a risky workplace without developing a hearing impairment, while more sensitive individuals can get even a severe hearing impairment at the same time and in the same place. These facts were confirmed in a research paper published in 1984 in which workers employed in one weaving mill participated, and the results showed that hearing impairment in some workers occurs in the first months of exposure, in others somewhat later, and in others very late or never. This study also showed that the ability to adapt to extreme noise conditions decreases with age. This ability is greatest in workers who started working at a younger age and endured the longest exposure to noise. Workers who started working at a later age and achieved the lowest average duration of service had the lowest resilience. The results of these studies also indicate less resilience of those workers who were born and lived in the countryside compared to workers born in city. The first category of respondents had hearing impairment in 81% of cases and the second category had hearing impairment in 18% of cases [12]. Hearing loss caused by noise is difficult to distinguish from loss caused by aging. It is also known that men lose their hearing faster than women. Hereditary factors are also very important, as are socioeconomic status, ethnicity, disease, and general health (diabetes, high blood pressure), as well as some chemicals and medications.

4. Conclusions

Based on the analysis of the obtained research results, we came to the following conclusions:

a. The average age of workers with hearing impairment (50.56 years) is statistically significantly higher than the average age of workers without hearing impairment (35.79 years).

b. The average number of years of specific work experience for workers with disabilities (21 years) is statistically significantly higher than the average number of years of specific work experience for workers without disabilities (6 years).

c. Age and years of service are positively correlated with the degree of hearing impairment, so that older workers and workers with longer service experience also have greater hearing impairments.

d. The largest number of respondents (56.67%) have mild hearing impairment and the smallest number of respondents (3.33%) have severe hearing impairment.

e. Most workers (67.39%) exposed to noise have hearing loss at a frequency of 4096 Hz. Of the workers from this group, the largest number of them are aged between 46 and 55, while the largest number of workers with scotoma at 8192 Hz are aged 56 and over.

f. The degree of correlation between hearing impairment in workers with moderate and severe impairment and the frequency of onset of hearing loss is 0.422 (weak to moderate correlation), which means that higher hearing impairments also affect lower frequencies.

g. People who have been exposed to noise for a long time may adapt and become less sensitive to the harmful effects of noise on hearing. People who are exposed to high levels of noise for the first time will get hearing impairment caused by noise faster.

References

[1]. Stucken EZ, Hong RS. Noise-induced hearing loss. Current Opinion in Otolaryngology & Head and Neck Surgery, 2014 Oct;22(5):388–93.

[2]. Guyton and Hall Textbook of Medical Physiology, Elsevier Health Sciences, 2016.

[3]. Lamm K, Arnold W. Noise-Induced Cochlear Hypoxia Is Intensity Dependent, Correlates with Hearing Loss and Precedes Reduction of Cochlear Blood Flow. Audiology and Neurotology, 1996;1(3):148–60.

[4]. Henderson D, Bielefeld EC, Harris KC, Hu BH. The Role of Oxidative Stress in Noise-Induced Hearing Loss. Ear and Hearing, 2006 Feb;27(1):1–19.

[5]. Kujawa SG, Liberman MC. Adding Insult to Injury: Cochlear Nerve Degeneration after "Temporary" Noise-Induced Hearing Loss. Journal of Neuroscience, 2009 Nov 11;29(45):14077–85.

[6]. Aljunid SM, Noraita BT. Noise Induced Hearing Loss in Manufacturing Industries: How Much Does It Cost to the Workers, Families and Society? Partridge Publishing Singapore, 2020

[7]. Kerketta S, Gartia R, Bagh S. Hearing threshold, Loss, Noise Levels and Worker's Profiles of an Open cast Chromite Mines in Odisha, India. 2012

[8]. Chadambuka A, Mususa F, Muteti S. Prevalence of noise induced hearing loss among employees at a mining industry in Zimbabwe. African Health Sciences, 2014 Jan 27;13(4):899.

[9]. Leensen MCJ, van Duivenbooden JC, Dreschler WA. A retrospective analysis of noise-induced hearing loss in the Dutch construction industry. International Archives of Occupational and Environmental Health, 2011 Jun 4;84(5):577–90.

[10]. Strauss S, Swanepoel DW, Becker P, Eloff Z, Hall JW. Noise and age-related hearing loss: A study of 40 123 gold miners in South Africa. International Journal of Audiology 2014 Mar 25;53 (sup2):S66–75.

[11]. Singh LP, Bhardwaj A, Kumar DK. Prevalence of permanent hearing threshold shift among workers of Indian iron and steel small and medium enterprises: a study. 2012, Noise & Health, 14(58), 119–128.

[12]. Çelik O, Yalçın Ş, Öztürk A. Hearing parameters in noise exposed industrial workers. Auris Nasus Larynx, 1998 Dec;25(4):369–75.

[13]. Davies HW, Vlaanderen JJ, Henderson SB, Brauer M. Correlation between co-exposures to noise and air pollution form traffic sources. Occup Environ Med 2009;66:347-350

[14]. Clark C, Martin R, Van Kempen E, et al. Exposure-effect relations between aircraft and road traffic noise exposure at school and reading comprehension: the RANCH project. Am J Epidemiol 2006;163:27-37

[15]. Tao L, Davis R, Hayer N, Yang O, Qiu W, Zhu L. Effect of cigarette smoking on noise-induced hearing loss in workers exposed to occupational noise in China. 2013

[16]. Epstein MJ. Sound and Noise: A Listener's Guide to Everyday Life. 2020, McGill-Queen's University Press.

[17]. Pleban D. Occupational Noise and Workplace Acoustics: Advances in Measurement and Assessment Techniques, Taylor & Francis Limited, 2020