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Original Article

Hearing Loss in Persons Exposed and not Exposed to Occupational Noise

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OBJECTIVE: This study aimed to compare hearing loss in individuals at risk and those not at risk for occupational noise and to compare working loss by gender.

MATERIALS and METHODS: The analysis used data from a current Czech Ministry of Health grant project called Epidemiological and Genetic Study of the Frequency of Hearing Loss (2011 to 2015; NT12246-5/2011). The analyzed sample comprised 4988 participants. Hearing was tested using pure-tone threshold audiometry, tympanometry, and measurement of the stapedius reflex.

RESULTS: Females at risk and those not at risk for occupational noise who were younger than 44 years and older than 75 years were found to have no statistically significant differences at any pure-tone threshold audiometry frequency. In females aged 45 to 74 years, statistically significant differences were found. In males, hearing loss was observed as early as 18 years of age. When comparing males and females at no risk for occupational noise, there were no statistically significant differences at any of the frequencies in those younger than 29 years. In females aged 30 years or older, statistically significant differences were observed at various frequencies in all age groups. When comparing males and females at risk for occupational noise, statistically significant differences were more frequent than in employees not exposed to noise.

CONCLUSION: Hearing loss in females does not significantly vary depending on occupational exposure. The opposite is true for males. However, the maximum differences in mean levels did not exceed 10 dB. It is therefore clear that noise is a preventable factor, and the use of personal protective equipment is warranted.

KEYWORDS: Hearing, auditory threshold, noise

INTRODUCTION

Hearing is considered to be the second most important of the five human senses. However, it is the only sense that is constantly alert and cannot be switched off, unlike, for example, vision, which can be switched off by closing the eyes during sleep. Sound perception with the human ear may be characterized using the hearing range (i.e., the range of frequencies that can be heard by the human ear), loudness, and auditory threshold. The auditory threshold is characterized as the minimum sound level that an individual can hear at a particular frequency. It is the sound that can just be heard by the ear [1, 2].

Hearing is considered normal if the hearing loss is less than 20 dB at all measured frequencies. An auditory threshold of more than 20 dB at two or more frequencies between 125 Hz and 8000 Hz is referred to as hearing impairment, irrespective of whether the patient is aware of it.

Significant risk factors for hearing impairment are age and gender, with the prevalence being higher in males, in particular, at higher frequencies. More than 92% of persons older than 85 years are diagnosed with hearing impairment. Hearing impairment also becomes more pronounced with increasing age. After 55 years of age, the prevalence of age-related hearing impairment, or presbycusis, increases. Hearing impairment may be classified as conductive (e.g., tympanic membrane perforation or fluid accumulation in the middle ear), perceptive (e.g., cochlear hearing impairment due to noise), and mixed, i.e., a combination of the two. There are many causes of hearing impairment, including a decrease in the blood supply to the inner ear at an older age, tumors, infarction, or occupational noise exposure [3, 4].

Noise is defined as any sound that is unpleasant, disturbing, or harmful to humans. Noise not only has a negative impact on the human ear but also influences the functioning of other systems. The effects are both specific (e.g., acute acoustic trauma, noise-in-

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duced hearing impairment, or impaired processing of new information) and systemic, with noise exposure being clearly shown to produce an acute increase in heart rate and blood pressure [5-7]. Every day, millions of workers worldwide are exposed to occupational noise. Although this issue is most pertinent to the industrial production and construction industries, attention should be paid to other settings, such as telephone exchanges, schools, orchestras, bars, and cafes [6, 8-10]. This study aimed at comparing hearing loss in individuals at risk for occupational noise and those not at risk, and comparing working loss by gender.

MATERIALS and METHODS

The analysis used data from a grant project. The data have been collected since the beginning of 2011; as of the end of 2014, the sample comprised a total of 9377 individuals. A questionnaire was compiled to obtain the personal, family, and occupational histories of the participants. Patients were asked open questions to report their occupational history, namely their position, length of employment (years), risk of occupational noise (presence or absence of noise at the workplace), length of exposure to noise (years), and the use of personal protective equipment, with respondents selecting from three options (earplugs, earmuffs, and helmets) if applicable. Also included were the results of subjective pure-tone threshold audiometry as well as objective tympanometry and measurement of the stapedius reflex. The participation of the patients was voluntary, and written informed consent was obtained. Ethics committee approval was received for this study from the ethics committee of University of Ostava School of Medicine.

The analyzed sample comprised 4988 participants. Although data from 9377 persons were obtained by the end of 2014, not all of the data were suitable for analysis. Some individuals were excluded based on the comparison of the mean auditory thresholds for both ears, the condition being that participants had normal auditory thresholds in both ears, or perceptive hearing loss, also in both ears. If all necessary conditions are met, perceptive cochlear hearing loss may be recognized as an occupational disease, and compensation may be awarded. Conductive hearing loss is associated with occupational injuries, and the auditory threshold does not decrease due to long-term exposure to noise. Thus, the highest proportion of individuals were excluded due to conductive or combined hearing loss or asymmetric hearing impairment (as many as 16.6% of the original sample). Conductive or mixed impairment is also associated with poor tympanometry results (type B and C tympanograms); therefore, another 14.5% of individuals were excluded due to negative pressure, high pressure, or otitis media diagnosed by tympanometry. Another typical sign of threshold impairment in persons exposed to occupational noise is symmetric hearing loss, i.e., identical hearing loss in both ears. Nearly 15% of individuals were excluded due to differences between the right and left ears of more than 10 dB at frequencies of 500 Hz, 1 000 Hz, 2000 Hz, and 4000 Hz (Table 1).

For clarity purposes, participants included in the analysis were labeled as Group 1 and Group 2. Group 1 comprised those with no risk for occupational noise, a total of 3011 individuals, of whom 73.7% were females and 26.3% were males. The mean ages were 53.85 and 44.43 years, respectively. Group 2 included participants exposed to occupational noise, a total of 1977 persons, of whom 24.2% were females and 75.8% were males. The mean ages were 55.10 and 47.58 years, respectively. In both groups, participants were divided into 5 age subgroups, using the World Health Organization classification, and by gender (Figures 1 and 2). The mean length of exposure to occupational noise was 14.86 years for females and 18.36 years for males (Table 2).

Table 1. Subjects excluded from the original sample

Reason for exclusion	Absolute number (percentage)
Original sample	9377 (100%)
Poor tympanometry results	1358 (14.5%)
Age under 18 years	76 (0.8%)
Impairment (conductive × combined × asymmetric)	1560 (16.6%)
Difference of more than 10 dB at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz	1395 (14.9%)
Analyzed sample	4988 (53.2%)
Group 1 - males and females at no risk for occupational noise	3011 (60.4%)
Group 2 - males and females at risk for occupational noise	1977 (39.6%)

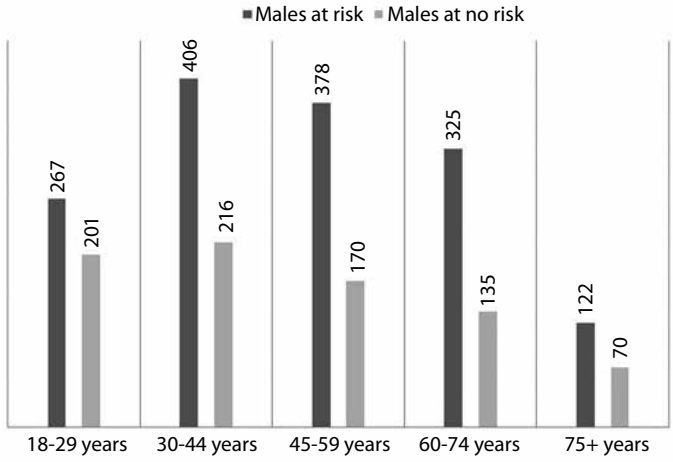

Figure 1. Distribution of males in the age groups

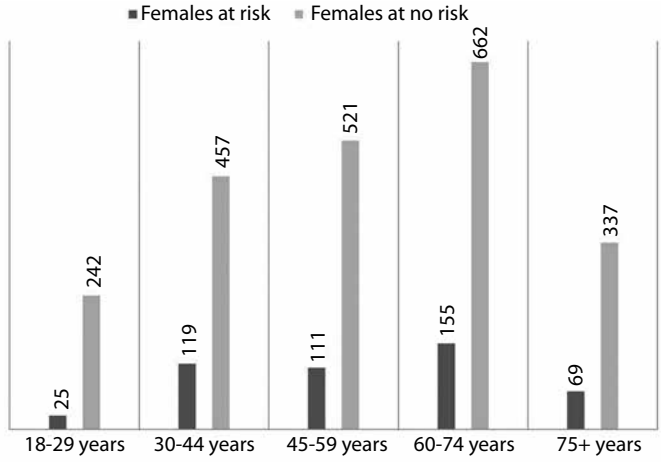

Figure 2. Distribution of females in the age groups

Table 2. Analyzed sample characteristics

Occupational noise		Males	Females
No (Group 1), a total of 3011 persons	Number (%)	792 (26.3%)	2219 (73.7%)
	Mean age (SD; min; max)	44.43 years (18.76; 18; 92)	53.85 years (17.98; 18; 108)
Yes (Group 2), a total of 1977 persons	Number (%)	1498 (75.8%)	479 (24.2%)
	Mean age (SD; min; max)	47.58 years (17.55; 18; 108)	55.10 years (16.45; 19; 88)
	Mean length of exposure (SD; min; max)	18.36 years (12.23; 1; 48)	14.86 years (11.32; 1; 46)

Table 3. P values for hearing loss comparisons

		Frequency [Hz]								
Groups compared	**Age groups**	**125 Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**3000 Hz**	**4000 Hz**	**6000 Hz**	**8000 Hz**
Females at risk and those at no risk for occupational noise	18–29 years	NS	NS	NS	NS	NS	NS	NS	NS	NS
	30–44 years	NS	NS	NS	NS	NS	NS	NS	NS	NS
	45–59 years	p=0.023	NS	NS	NS	NS	NS	NS	NS	NS
	60–74 years	NS	NS	NS	NS	NS	p=0.026	p=0.029	NS	NS
	75+ years	NS	NS	NS	NS	NS	NS	NS	NS	NS
Males at risk and those at no risk for occupational noise	18–29 years	NS	NS	NS	NS	p=0.004	p=0.003	p<0.001	p=0.047	NS
	30–44 years	NS	NS	NS	NS	p=0.023	p=0.009	p=0.015	NS	NS
	45–59 years	p=0.037	p=0.008	NS	NS	NS	p=0.006	p<0.001	p<0.001	NS
	60–74 years	NS	NS	NS	p=0.007	p<0.001	p<0.001	p<0.001	p<0.001	p=0.001
	75+ years	NS	NS	NS	NS	NS	NS	NS	p=0.029	NS
Females × males at no risk for occupational noise	18–29 years	NS	NS	NS	NS	NS	NS	NS	NS	NS
	30–44 years	p=0.008	p=0.004	p=0.002	p=0.009	p=0.002	NS	p=0.039	NS	NS
	45–59 years	NS	NS	NS	p=0.012	NS	p=0.007	p<0.001	p=0.010	NS
	60–74 years	NS	NS	NS	NS	NS	p<0.001	p<0.001	p<0.001	p<0.001
	75+ years	NS	p=0.043	p=0.038	NS	NS	p<0.001	p<0.001	p<0.001	p<0.001
Females × males at risk for occupational noise	18–29 years	NS	NS	NS	NS	NS	NS	NS	NS	NS
	30–44 years	NS	p=0.015	p=0.049	NS	NS	NS	p<0.001	NS	NS
	45–59 years	NS	p=0.012	NS	NS	NS	p<0.001	p<0.001	p<0.001	p<0.001
	60–74 years	NS	NS	NS	NS	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
	75+ years	NS	NS	NS	NS	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001

NS: not significant

The most frequent professions among employees at risk for occupational noise were miners (493 persons) and manual workers (432 persons), followed by operators (106 persons), locksmiths (89 persons), machine operators (43 persons), and others. By contrast, those at no risk for occupational noise mostly performed administrative jobs (as clerks, accountants or retired administrative workers; a total of 428 persons), followed by shop assistants (271 persons), building maintenance workers (painters, decorators, tillers, or insulation workers; 208 persons), teachers (190 persons), students (144 persons), and others.

Statistical Analysis

The sample was analyzed using descriptive statistics. Hearing losses were compared with the Wilcoxon nonparametric test (Mann-Whitney U test) at a significance level of 5%. The results were processed with Stata (Data Analysis and Statistical Software, version 13.0; StataCorp LP, Texas, USA) for Windows. Tables and graphs were created using Microsoft Excel (MS Excel, version 2007, Microsoft Corporation; Washington, USA).

RESULTS

Auditory thresholds were compared in persons at risk and those not at risk for occupational noise. The table shows P values for hearing loss at various frequencies in males and females (Table 3). Females younger than 44 years and those older than 75 years were found to have no statistically significant differences at any pure-tone threshold audiometry frequency. In the third age group, ie., those aged 45 to 59 years, the only statistically significant difference was noted at 125 Hz. In the 60 to 74 age group, there were statistically significant differences at 3000 Hz and 4000 Hz. In males, however, hearing loss was already observed in the youngest participants. In the first age group, statistically significant differences were found at 2000 Hz to 6000 Hz. The same was true for the second age group, the only exception being 6000 Hz, which had no statistically significant differ-

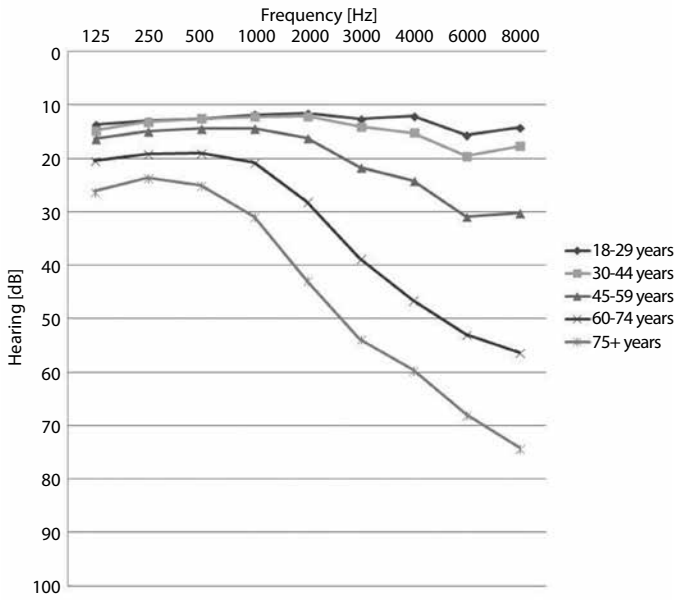

Figure 3. Mean hearing loss in subjects at no risk for occupational noise: MALES

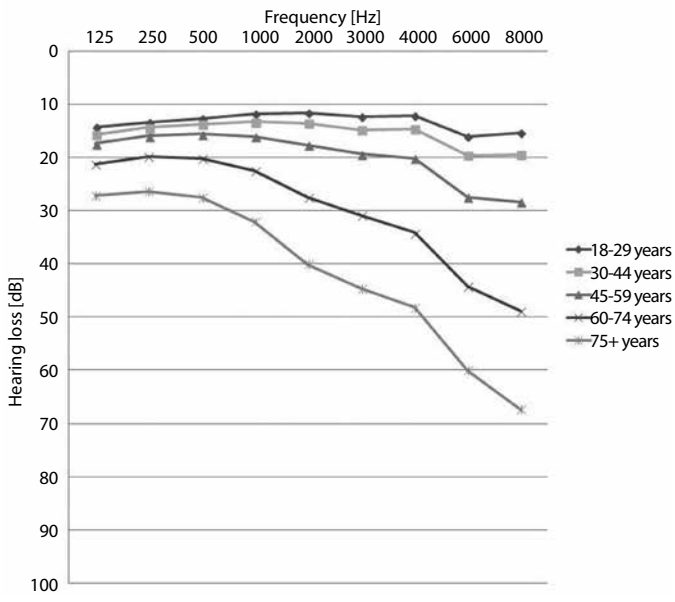

Figure 4. Mean hearing loss in subjects at no risk for occupational noise: FEMALES

ence. In the third age group, statistically significant differences were observed at 125 Hz, 250 Hz, 3000 Hz, 4000 Hz, and 6000 Hz. In the fourth age group, statistically significant differences were noted for all frequencies from 1000 Hz to 8000 Hz. In the 75+ age group, the only statistically significant difference was found at 6000 Hz.

When comparing males and females at no risk for occupational noise, there were no statistically significant differences at any of the frequencies in those younger than 29 years. In the second age group, statistically significant differences were noted at all frequencies from 125 Hz to 2000 Hz and at 4000 Hz. In the third age group, there were statistically significant differences at 1000 Hz, 3000 Hz, 4000 Hz, and 6000 Hz. In those aged 60 to 74 years, statistically significant differences were seen at 500 Hz and at all frequencies from 3000 Hz to 8000 Hz. In the 75+ age group, statistically significant differences were found at 250 Hz, 500 Hz, and all frequencies from 3000 Hz. The mean hearing loss in males and females at no risk for occupational noise is shown in the graphs (Figure 3, 4). When comparing males and females at risk for occupational noise, statistically significant differences were more frequent. In the youngest participants, similar to the no-risk group, no statistically significant differences were seen at any of the frequencies. In the second age group, statistically significant differences were observed at 250 Hz, 500 Hz, and 4000 Hz. In the third age group, there were statistically significant differences at 250 Hz and at all frequencies starting from 3000 Hz. In both the fourth and fifth age groups, statistically significant differences were noted for frequencies 2000 Hz and higher.

The maximum differences in mean levels did not exceed 10 dB. The mean hearing losses in males and females at risk for occupational noise are shown in the graphs (Figure 5, 6).

DISCUSSION

Noise is the most important occupational risk factor in the Moravian-Silesian Region. In 2014, the number of employees in at-risk workplaces reached 95,376, and the number continues to rise, largely because of an increasing number of assembly plants in industrial parks around the towns of Ostrava, Karviná, and Frýdek-Místek. In males, the dominant risk factor is noise (almost 40% of all males at occupational risk); in females, the proportion has decreased in comparison to that in previous years. In the Moravian-Silesian Region, nearly 20,000 females are at occupational risk, with less than 23% being at risk for noise exposure, a percentage similar to that in the present study (24.2% of females at risk for noise) [11].

Working individuals may be exposed to some occupational factors that, under certain circumstances, may have a negative impact on human health. This may manifest as an occupational disease. One such occupational risk factor is noise, particularly in males. In 2013, a total of 983 cases of occupational diseases were reported in the Czech Republic, of which 281 (28.6%) were in the Moravian-Silesian Region, the largest proportion throughout the country. The Moravian-Silesian Region has the highest proportion of reported occupational diseases caused by physical factors, including noise-induced perceptive cochlear hearing loss; in 2013, a total of 13 cases (12 males, 1 female) were reported, of which 5 males were in the Moravian-Silesian Region. Employees at risk for occupational noise in the present study included workers (metal workers, machinists, foundry workers, etc.; 22.5%) and production operators (5.5%). The largest subgroup in the sample were miners (23.5%). Only three miners, however, were recognized as having an occupational disease [12]. In the long-term perspective, the incidence of noise-induced perceptive cochlear hearing loss tends to decrease. According to a study analyzing data on occupational diseases in various European countries, apart from the Czech Republic (13 cases reported in 2013, 31 cases in 2004, and 55 cases in 1996), the same trend has been observed in Finland, the United Kingdom, Italy, Norway, and France. By contrast, a tendency to increase has been noted in the Netherlands, Spain, and Switzerland [13].

The present study showed statistically significant differences in hearing loss at various frequencies in various male age groups. The results

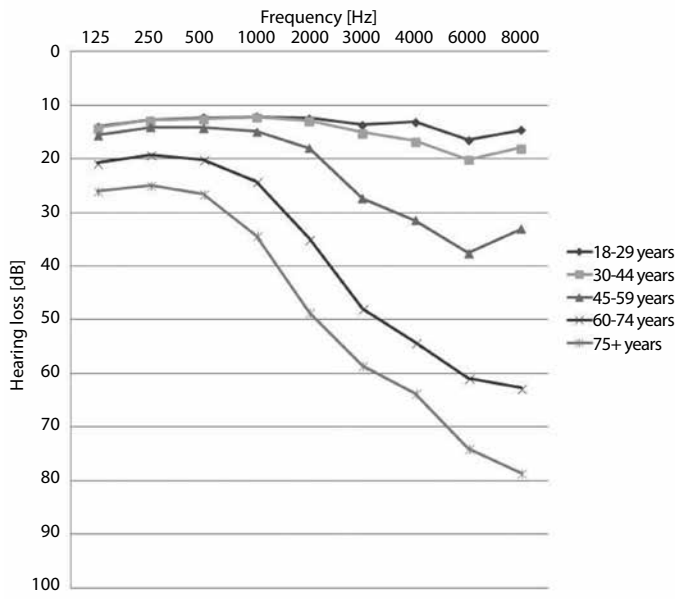

Figure 5. Mean hearing loss in subjects at risk for occupational noise: MALES

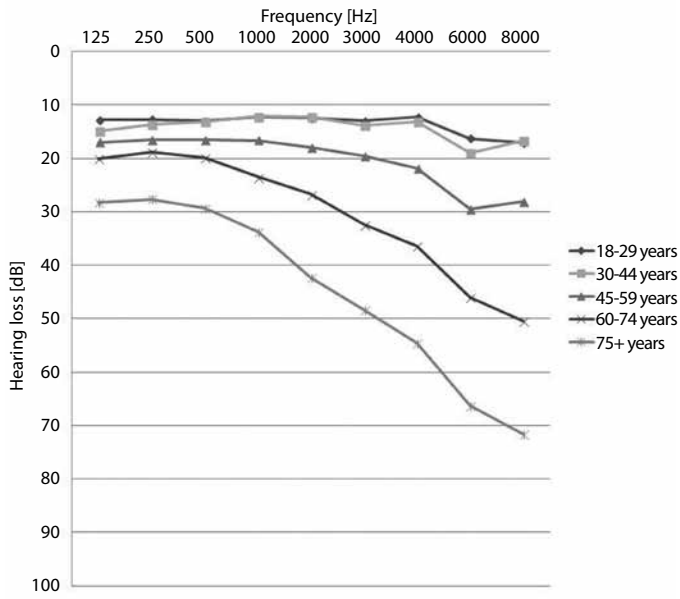

Figure 6. Mean hearing loss in subjects at risk for occupational noise: FEMALES

suggest that males at risk for occupational risk have a higher auditory threshold than those at no risk. The highest rates of statistically significant differences at frequencies measured by audiometry were seen in males aged 60 to 74 years, followed by the 45 to 59 age group. This is consistent with data from a Norwegian study reporting hearing impairment in employees aged 55 to 74 years working in the construction and manufacturing industries, the latter being associated with the burden of occupational noise in the Czech Republic as well [14]. The Norwegian study focused on railway workers, including train and track maintenance workers, at risk for occupational noise, with railway traffic controllers not exposed to noise as controls; the study concluded that at-risk workers younger than 45 years had hearing thresholds comparable to the controls, while those aged 45 years or older had slightly greater hearing losses. These findings are comparable to those in the present study [15].

A 1965 Scottish study of hearing loss in female weavers reported mean hearing loss levels with respect to length of exposure and age. In the Scottish study, the length of exposure was 15 to 19 years in workers aged 35 to 39 years. In the present study, the mean length of exposure in the 30 to 44 age category was 7.23 years. When comparing the two samples irrespective of the participants' age, the results of the present study were more favorable only at 4000 Hz, with 13.1 dB hearing loss, as compared to nearly 30 dB in the Scottish study. In the present study, the hearing losses at all frequencies are less than 20 dB, which is within normal ranges. The results were very similar at other frequencies [16].

In a Chinese study, men exposed to occupational noise were shown to have greater hearing loss than women. This finding is in agreement with results of other studies as well as with ours. In the Chinese study, a total of 49.2% of participants had a difference of more than 15 dB between the right and left ears at frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. In this study, these participants were not excluded for further analysis. In contrast, in our study, participants who had differences of more than 10 dB between the right and left ears were excluded from the analysis (14.9%), due to potential confoundings. In the Chinese study, there were no differences in hearing loss between the ears. In our study, the differences in hearing loss between the ears were not investigated due to the abovementioned exclusion procedure. However, we observed similar hearing losses in both ears. Therefore, the average hearing loss is the mean of the average hearing losses in the right and left ears. As one of the conditions for noise induced hearing loss is symmetry of the hearing loss between the ears [17], almost 47% of participants were excluded from the original sample.

Another study investigating differences in auditory thresholds between men and women, as well as differences in hearing loss between the ears, is a recent study from Brazil that was conducted on dance teachers. As the occupation of dance teacher is more common among women, there were more women in this study compared with our study, where the majority of the sample was male. Another difference between the Brazilian study and our study is the age of the participants. In the Brazilian study, the average age was 32 in both the dance teacher group and the controls, while in our study, the average age was about 47 years in those exposed and those not exposed to occupational noise. This may be explained by the type of occupation, as dance teachers are on average younger than members of most other occupations. In addition, in the Brazilian study, the range of the measured frequencies was greater (from 125 Hz to 16,000 Hz). However, in the Brazilian study, no statistically significant differences in hearing loss between the participants exposed and those not exposed to occupational noise were found at any frequency (except for 9000 Hz, which was not measured in our study). This finding may have been affected by the small sample size (32 cases and 32 controls) [18].

Another study examining hearing loss in people at a risk for occupational noise is a recent study by Lie et al. [19] conducted in Norway. Using an audiometric examination from the years 1994 to 2011, the aim of this study was to describe the prevalence of hearing loss in a

sample of 12,055 rail workers. In this study, 82% of participants were men and 18% were women, which is similar to our study, where the majority of the sample was male. However, in the Norway study, age was not considered in the audiograms. Despite this fact, hearing losses were confirmed with increasing frequencies, as in this study. The findings showed that the audiometric curves in women exposed and those not exposed to occupational noise were virtually unchanged. In the Norway study, typical notches of noise induced hearing loss at a frequency of 4000 Hz were observed among men, while in our study, no notches were obvious at any frequencies. In addition, in our study, the audiometric curves seemed to be explained by age-related hearing loss. Notches at the frequency of 6000 Hz were described in an Italian study by Maccà et al. [20] that was conducted on participants exposed to occupational noise (n=113) compared with controls (n=148). The audiometric curves followed a typical shape for age-related hearing loss only in the control group in the Italian study, while in our study, this shape was observed for all participants (exposed and not exposed to occupational noise). In the Italian study, the highest hearing losses were in participants aged 50 to 59 years. However, the hearing losses were not as high as in our study. These results may have been influenced by the small sample size in the Italian study and the lower age of the participants in the Norwegian study (their ages were between 15 and 59 years) [19, 20].

Noise is one of the main occupational risk factors. Males are considerably more at risk of noise exposure than females. Hearing loss in females does not significantly vary depending on occupational exposure. In males, statistically significant differences between those exposed and those not exposed to occupational noise were observed as early as at the age of 18 years. There were no significant differences in individuals at no risk for occupational noise younger than 29 years. In older age groups, significant differences were only observed at some frequencies. In workers at risk for occupational noise, significant differences between males and females were more frequent. However, the maximum differences in mean levels did not exceed 10 dB. It is therefore clear that noise is a preventable factor, and the use of personal protective equipment is warranted. As a result, the number of reported cases of occupational noise-induced perceptive cochlear hearing loss tends to decrease despite the fact that the number of jobs in which workers are exposed to noise continues to increase. If all precautions are taken to protect hearing in at-risk employees, occupational noise contributes only slightly to hearing loss.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of University of Ostava School of Medicine.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.K., E.M.; Design - V.J.; Supervision - J.J., V.J.; Resources - M.K.; Materials - M.K., P.S., K.V.; Data Collection and/or Processing - M.K., P.S., K.V.; Analysis and/or Interpretation - H.T.; Literature Search - M.K.; Writing Manuscript - M.K.; Critical Review - M.K., H.T., V.J.

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Conflict of Interest: No conflict of interest was declared by the authors.

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