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ORIGINAL PAPER

PREVENTION OF HEARING LOSS AT WORK

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Abstract

Aim: The purpose of the current contribution was to present the results of a study on the occurrence of hearing loss in people exposed to loud noise in working environments. *Design*: A cross-sectional, observation study. *Methods*: The research method used was audiometric examination, expressed as percentage of hearing loss (HL) according to Fowler. *Results:* The study results were analysed using absolute and relative frequencies. The association between variables was evaluated using a Chi-Quadrat Test at the significance level of $p = 0.05$. Cramer´s V was used to measure strength of association. The set included 300 respondents up to 55 years of age, working in hazardous working environments and exposed to noise for at least five years, in six companies situated in the Banska Bystrica self-governing region. The results indicate that the association between the degree of hearing loss and workplace risk category was not proven ($p = 0.932$). Similarly, the association between hearing loss occurrence and the sex of respondents was not proven ($p = 0.128$). The association between the period of noise exposure (in hours) and HL value ≥ 5%, taking into account the workplace risk category, was proven ($p < 0.001$). Cramer´s V of 0.576 indicates a medium strength association. In addition, the association between the degree of total hearing loss and the number of years spent in a noisy environment, regardless of the workplace risk category, was proven ($p < 0.001$). Cramer´s V of 0.386 indicates a medium strength association. *Conclusion:* The results of the current research confirmed the existence of the danger of hearing loss due to long-term exposure to noise in working environments. They also verified the effectiveness of measures to prevent its negative impact on employees´ health.

Keywords: noise, exposure to noise, hearing loss, health at work, audiometry.

Introduction

According to Kollár (2008) hearing is the second most important human sense. For common communication by speech and for speech development it is the most important. Bytešníková, Horáková, Klenková (2007) emphasize the importance of hearing not only for the reception of surrounding sounds, but also for sense of balance, rectilinear motion as well as rotational motion, and body position in space. According to the classification of the World Health Organization, hearing is considered ´normal´ if an audiometric examination shows that the threshold of hearing does not exceed 25 dB at any measured frequency. If the threshold of hearing is higher, it is termed ´hearing impairment´. 10% of adults are affected by hearing impairment, rising to 40% at ages over 75 (Plzák, 2013).

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According to Horáková (2012) hearing disorders affect more than 500 million people globally, and the figure is expected to increase. The estimate for 2015 is 700 million people with hearing impairment worldwide. Noise is considered to be one of the risk factors of hearing loss. Any sound invoking an unpleasant or undesirable auditory perception, or harmful effect, is regarded as ´noise´. Its definition is thus purely subjective and cannot be expressed objectively (Plzák, 2013).

According to experts (Šulcová, Čižmár, Fabiánová, 2012), noise of over 60 dB begins to irritate human ears. At this intensity it has a negative impact on the nervous system, and can cause the production of stress hormones, increased blood pressure etc. A value of 85 dB is referred to as a noise risk. In a study, Seidman and Standring (2010) found that approximately 10 million adults and 5 million children suffer from hearing disorders caused by chronic exposure to noise. Another 30 million people are at risk of this type of hearing loss. Hearing loss is more common in individuals of Europoid race who, in addition to exposure to noise, smoke and have

cardiovascular risk (Agrawal, Platz, Niparko, 2008). Moreover, it has been proven that those with diabetes are more frequently affected by hearing loss than those without (Chasens, Enock, DiNardo, 2010).

Noise is considered to be the most prevalent risk factor to health in work environments. Hearing loss caused by excessive long-term noise is the most common occupational disease in Europe. Records of hazardous work show that more than 87,000 Slovak employees work in noise at risk levels. When compared with the total number of 170,000 people performing hazardous work, it means that almost every second employee in hazardous professions works in excessive noise (Janoušek, 2005).

Based on Ordinance of the Government of the Slovak Republic No. 115/2006 Coll. on Minimum Health and Safety Requirements for Employees´ Protection against Hazards related to Noise Exposure, an employer is obliged to ensure the protection of employees from intrusive or harmful noise effects and create an environment in which noise exposure values for the relevant type of work are observed. The aforementioned law stipulates that the noise of the work environment should not exceed 40 dB wherever employees need to concentrate, or are involved in creative work. Their communications should be undisturbed.

An integral part of measures to protect the health of employees at increased risk of noise exposure is medical supervision. Employers are obliged to provide preventative medical examinations (pre-employment, periodic and exit examinations) if exposure to noise exceeds the upper exposure action value (Kabátová, Profant, 2012). An elaborate system of preventative examinations in relation to noise exposure has been established to ensure the detection of hearing loss (Act No.124/2006 Coll.). The provision of preventative care for employees´ health is provided by an occupational health services team (defined by the Act No. 355 Coll.). A community nurse is also part of the team. The occupational health service is responsible for consultancy on healthy and safe working conditions provided to employers and employees (Šulcová, Čižmár, Fabiánová, 2012). According to Bašková et al. (2009), the main pillars of the community nurse model in the occupational health service are primary, secondary and tertiary prevention, health support in relation to the factors of work environment and the evaluation of the degree of risk in selected populations. The task of the community nurse, according to Šupínová et al. (2013), is also the identification and analysis of hazards presented by work and the work environment; proposals to eliminate harmful impacts on health at work; and the preparation of optimum solutions for employees´ deployment in terms of potential health hazards and the required work performance.

The community nurse, as a member of the occupational health service, also participates in the workplace assessment and its risk categorization, divided into four categories according to the level and type of factors of work and the work environment which may influence employees´ health. The first category includes workplaces where there is no risk of damage to health from work and the work environment. The second category includes work in which damage to health is not anticipated. The third category includes work activities and work environments which may cause damage to health. The fourth category includes work (limited to a maximum period of one year) in which it is not possible to reduce, by technical or organizational measures, employees´ exposure to factors of work and the work environment to the prescribed limit (Act No. 355 Coll.). The risk categorization of a workplace is decided by the Regional Office of Public Health. An employer is obliged to keep and maintain records on each employee performing hazardous work. Only persons fit to work in hazardous workplaces may be employed there (Kabátová, Profant, 2012). Therefore, the task of prevention is to avoid or diagnose at an early stage any temporary adaptation or permanent hearing loss. Preventative examinations include tone audiometry: a subjective examination method in which hearing is examined using an audiometer. In cases of hearing impairment, if causality with job performance is proven, it is considered an occupational injury (Buchancová et al., 2013). Where a work environment without factors harmful to health is not achievable, personal protective equipment is necessary and must be provided by the employer. Employees are obliged to use it correctly (Šoltés et al., 2008).

Aim

The purpose of the 2014 research was to examine hearing in respondents according to their length of stay in noisy work environments, and workplace risk category. We also measured the effectiveness of hearing protection measures in hazardous work environments.

Methods

Design

A quantitative, cross-sectional, observation study.

Sample

Hearing sensitivity decreases with age, becoming particularly evident at 50 to 55 years of age (Kabátová, Profant, 2012, p. 246). Thus respondents up to 55 years of age were included in the set. Diagnosis requires proving the successive development of hearing disorders causally linked to working in a noisy environment. In order to be able to judge the efficiency of hearing-protection measures respondents working in hazardous environments for at least five years were included in the set.

The selection of respondents was deliberate and targeted. The set consisted of 300 respondents (265 men and 35 women), from six companies located in the Banska Bystrica self-governing region (four aluminium companies, one forestry company, one printing works). The age span of the respondents ranged from 23 to 55 years of age. The average age was 41.38. The respondents included in the research set had to meet the following predetermined criteria: up to 55 years of age, working for at least five years in a hazardous work environment and exposed to noise.

Procedure

Occupational hearing loss means damage to the ear caused by excessive noise. An examination of hearing threshold would most commonly find a symmetrical perception disorder which exceeds the permitted levels of hearing loss according to Fowler. Therefore, the research method used was an audiometry examination. The total percentage of hearing loss according to Fowler (HL) was measured, using an MA31-type clinical audiometer. The measurements were made by a nurse with a master´s degree and audiometry certificate, who was a member of the occupational health service team. When evaluating the audiometry results, the subject´s age and the noise exposure time were considered.

Data collection

The measurements were made from September 2014 to December 2014 and were carried out in connection with periodic preventative examinations, required by law (Act No. 355/2007 Coll.). The dynamics of hearing impairment development, meaning an average change of HL value in one year expressed as a percentage, is monitored in each subject. A 5% loss of total hearing is considered significant. The total development of impairment is evaluated. Any unfavourable HL value measured results in increased health checks on the affected employee, or his/her redeployment to a workplace with a lower degree of risk. The measured HL of each respondent was complemented with demographic and occupational data; (age at the time of measurement; sex; length of employment in the hazardous workplace in years; length of noise exposure during a single work shift in hours; workplace risk category).

Data analysis

Significant interactions of qualitative variables were evaluated using a Chi-Quadrat Test at the significance level of $p = 0.05$. The strength of association was measured using Cramer´s V. The statistical software t Stat was used for statistical analysis.

Results

Characteristic of the sample

According to their degree of risk, the workplaces of respondents were classified as categories 1, 2, 3 and 4. The largest number of respondents were employed in operations classified as Category 2 and Category 3 (Table 1).

Table1 Respondents by workplace risk category

Risk category	n	%
Category 1	2	0.67
Category 2	158	52.67
Category 3	128	42.67
Category 4	12	4.00
Total	300	100.00

The duration of respondents´ employment in a hazardous environment was at least five years, up to a maximum of 36 years. The average was 13.04 years, median 10.00 years, modus 5.00 years. The length of respondents´ exposure to noise during one shift was between one and eight hours. Maximum 8.00 hours, minimum 1.00 hour. Average 4.43 hours, median 5.00 hours, modus 7.00 hours.

Results

The results analysing total hearing loss against the length of stay in a noisy work environment are interpreted as absolute frequency, relative frequency, median and modus (Table 2).

The highest number of respondents with total hearing loss higher than 5 % was found in risk categories 2 and 3 (Table 3).

A HL of 5% can be regarded as moderate risk. Employees´ age and duration of work in a hazardous environment are also taken into consideration. The association between degree of hearing loss and workplace risk category was tested using a Chi-Quadrat Test with two degrees of freedom and a significance level of $\alpha = 0.05$. The degree of

respondents´ hearing loss is not associated with the workplace risk category p = 0.932.

Table 4 shows the composition of respondents by sex and HL in % in individual risk categories. The association between hearing loss and respondents´ sex was proved statistically. The hypothesis was tested using a Chi-Quadrat Test at the significance level of $\alpha = 0.05$ with three degrees of freedom. $\chi^2 = 5.683 < 7.815$, $p = 0.128 > 0.05$. We can state that in our research set hearing loss is not associated with the sex of the respondent.

Table 2 HL (%) measured in risk categories

Category	Average	Maximum	Minimum	Modus	Median
1	1.00	1.00	1.00	1.00	1.00
2	3.08	30.77	1.00	1.00	1.65
3	3.62	25.50	1.00	1.00	1.81
4	3.47	10.92	1.00	1.00	2.44
Total	3.31	30.77	1.00	1.00	1.76

Table 3 Risk categories in relation to HL ≥5 (%)

Workplace risk category	HL < 5	HL ≥ 5	Total
Category 2	126	32	158
Category 3	101	29	130
Category 4	10	2	12
Total	237	63	300

Table 4 Respondents by sex, HL (%) and workplace category

Sex	HL	Category				Total
		1	2	3	4	
M	< 5	2	114	83	9	208
	≥ 5	0	30	25	2	57
F	< 5	0	12	18	1	31
	≥ 5	0	2	2	0	4
Total		2	158	128	12	300

Table 5 Respondents by workplace risk category and hours of noise exposure in one work shift

Category	Number of hours								Total
	1	2	3	4	5	6	7	8	
2	14	7	1	2	1	0	6	1	32
3	0	2	1	2	1	4	15	2	27
4	0	0	0	0	0	0	2	0	2
Total									61

Table 5 shows an overview of respondents by their workplace risk category and the number of hours of noise exposure in one work shift. We checked for an association between noise exposure (in hours) and HL ≥ 5 %, taking into account workplace risk categories. The hypothesis was tested using a Chi-Quadrat Test with one degree of freedom and a significance level of 0.05. The association between duration of noise exposure in one work shift with degree of hearing loss was proven ($p < 0.001$). Cramer´s V of 0.576 indicates a medium strength association.

We tested the association between measured HL values and number of years spent in a noisy environment, regardless of the workplace risk category, using a Chi-Quadrat Test with six degrees of freedom and a significance level of 0.05. The value of $p < 0.001$ proves the association between degree of hearing loss and number of years spent in a

noisy environment. The Cramer´s V of 0.386 indicates a medium strength association.

Discussion

The purpose of preventative examinations performed in the context of health protection at work is to identify factors in work and the work environment that either potentially might lead or actually have led, to a deterioration in employees´ state of health.

The aim of the current research was to verify the association between the occurrence of hearing loss and exposure to noise in work environments using a set of 300 respondents and, based on the findings, to verify the effectiveness of measures aimed at health protection at work, namely the protection of hearing in situations where people are exposed to noise. The respondents worked in companies classified into all four risk categories (table 1). The measured values of total hearing loss were various for different risk categories (table 2). The dynamics of hearing loss, including the years of noise exposure and client´s age are evaluated by audiometric examination. Based on the aforementioned aspects, the development of impairment can be classified as ´favourable´, ´tolerable´ or ´unfavourable´ (Buchancová et al., 2003). In ´favourable´ developments of hearing loss, the long-run dynamics of hearing loss do not exceed 0.5% per year and the short-run dynamics do not exceed 2% per year. In ´tolerable´ development of hearing loss, the long-run dynamics of hearing loss range between 0.5 and 1% per year and the short-run dynamics do not exceed 2% per year. With ´unfavourable´ development of hearing loss, the long-run dynamics of hearing loss do not exceed 1% per year, and the short-run dynamics exceed 2% per year. In cases of unfavourable development it is necessary to eliminate exposure to noise and redeploy the worker to a workplace with a lower degree of hazard. For the reasons previously stated, there were various HL values in individual risk categories. The HL measured in respondents do not exceed the tolerable level indicating that the principle of hearing protection is observed. In the set of respondents we tested the association between the degree of hearing loss expressed as total hearing loss in %, and the workplace risk category (Table 3). The calculated value of $p = 0.932$ did not prove the association.

The risk of deterioration of hearing can also be reduced by preventing hazardous exposure to noise by using adequate hearing protection. According to Sprinzl and Riechelmann (2010), it is important to use noise protective equipment for ears providing attenuation of noise by 15–25 dB, which enables work in noisy environments.

According to experts, hearing loss in men is more common than in women (Agraval, Platz, Niparko, 2008). Identical conclusions were drawn by the authors of an Italian study (Roth, Hanebuth, Probst, 2011), according to which in Europe 30% of men and 20% of women have hearing loss of 30 dB by the age of 70, and 55% of men and 45% of women by the age of 80. The HL values measured in men and women of the monitored research set were comparable, in spite of the differences in absolute frequencies of both groups. The results did not prove the statistical association between sex of respondents and total hearing loss $p = 0.128$ (Table 4).

For the evaluation of noise exposure in terms of health protection and safety at work, which characterizes noise quantitatively, the quantity of noise is determining. According to Janoušek (2005), there is a standardized level of noise exposure, expressed as the exposure of an employee during an eight-hour work shift and 40-hour working week. We tested the association between the duration of noise exposure (in hours) and $HL \geq 5$ in relation to the workplace risk category (Table 5). The result reveals a medium strength association between the duration of noise exposure in one work shift and degree of hearing loss. A medium strength association between total hearing loss and the number of years spent in a noisy environment regardless of workplace risk category was established. The study is limited due to the fact that evaluation was the result of a one-off audiometric measurement. Although any measured unfavourable HL requires intervention by the employer, for precise tracking of developments in hearing loss dynamics, a nurse should evaluate the results of the audiometric measurements of each preventative examination once a year.

Conclusion

A work environment adequately adjusted to employees´ needs is not only an important factor in achieving good performances, but it also has a positive impact on the health and living standards of workers. The results of audiometry tests performed within periodic preventative examinations of 300 employees exposed to noise show that measures aimed at health protection at work in relation to noise exposure are observed and effective in the companies monitored. No association between degree of hearing loss and workplace risk category was discovered, which confirms the adequacy of hearing protection in all risk categories. The HL values measured were comparable for both sexes, meaning that the

differences in the occurrence of hearing loss in the monitored set are not associated with the sex of respondents. The results of this current research confirmed expert findings that degree of hearing loss is associated with length of stay in a noisy work environment in one work shift, in addition to total length of employment in a noisy environment. They also confirmed the existence of efficient legislative measures as a tool for health protection at work when implemented by an occupational health service.

Based on the above, we recommend the continuation of the prescribed preventative measures and that the occupational health service be responsible for the supervision of:

- The observance of legal regulations aimed at the protection of hearing at work, in accordance with workplace risk category.
- The safety and technical measures in the work environment.
- The equipping of workplaces with work clothes and other protective equipment.
- Employees´ use of personal protective equipment.

As an integral member of the team, the nurse´s activities, should focus on supporting the health of employees, and the enhancement, regeneration and renewal of health at work, and also the facilitation of work capability in accordance with prescribed legislative measures.

Ethical aspects and conflict of interest

The authors are not aware of any conflict of interests. The protection of respondents´ personal data and the protection of corporate data was strictly observed. Ethical aspects of the research were observed.

Author contribution

Concept and design (MŠ, MB), data analysis and interpretation (MŠ, MB), draft of the manuscript (MŠ, JV), critical revision of the manuscript (MŠ, MK, JV), final version of the manuscript (MŠ).

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