TECHNIUM
SOCIAL SCIENCES JOURNAL

Vol. 82/2026

A New Decade for Social Changes

Technium Social Sciences Journal
Vol. 82, 312-321, April, 2026
ISSN: 2668-7798
www.techniumscience.com

Noise in the Workplace: Assessment of Occupational Hearing Loss Risk Based on Audiometric Changes

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Abstract. Noise-induced hearing loss (NIHL) occurs as a result of long term exposure to workplace noise. The aim of the study was to identify job positions with an increased risk of hearing impairment due to occupational noise exposure, by analyzing changes in audiometric findings over a six-month period of work under conditions with elevated noise levels. The study included participants exposed to workplace noise and participants working in a quiet environment, employed in the same companies but in different job positions. Audiometric examinations were conducted at baseline and after six months of follow-up. Paired and independent-samples t-tests were applied. A statistically significant difference in hearing loss was found among participants exposed to occupational noise during the six-month period ($t = 4.84$, $df = 35$, $p < 0.001$), while no significant difference was observed among participants working in a quiet environment ($t = 1.64$, $df = 35$, $p = 0.109$). A significant difference was also identified between the noise-exposed group and the control group in mean hearing threshold values at baseline and at the final assessment after six months ($t = 4.13$, $df = 71$, $p < 0.001$). Occupations with an increased risk of the development and progression of hearing impairment were identified. The results confirmed the need for continuous monitoring and implementation of preventive hearing protection measures in high-risk workplaces, including oil refineries, textile and metal industries, the wood-processing sector, and selected service industries.

Keywords. Noise-induced hearing loss, Audiometry, High-risk workplaces

1. Introduction

Noise represents the most common cause of preventable hearing loss through the application of preventive measures [1]. Technological and industrial development has resulted in increased sound intensity and the emergence of noise, which today represents an increasingly significant risk factor in the workplace. Working in a noisy environment has a direct impact on workers' health, leading to reduced work efficiency and productivity, an increased number of errors and occupational injuries, fatigue and stress, sleep disturbances, and progressive NIHL. Previous research [2] indicates that workers with hearing impairment experience pronounced difficulties in performing work tasks, particularly in terms of personal safety, and exhibit higher rates of absenteeism and a significantly increased risk of occupational injuries. Studies by Parent-Thirion et al. [3] have shown that a substantial proportion of workers are exposed to excessive noise levels for at least one quarter of their working time, and that the period between NIHL and the onset of the first clinical symptoms may extend to several years, depending on the duration and intensity of noise exposure. Research further shows that occupational noise exposure globally accounts for approximately 16% of hearing loss cases among adults. Although it does not increase the risk of premature mortality, this form of hearing impairment causes significant limitations in daily and professional functioning, creating a serious health and economic burden for individuals and society [4].

To date, no effective treatment has been found for NIHL [5]. Hearing damage may occur because of sudden exposure to noise (a single loud sound exceeding 130 or 140 dB) or through its progressive effect (high noise levels resulting from continuous exposure to moderate or high-intensity noise). Research related to working in noisy environments [6] shows that workers who have previously been diagnosed with hearing impairment experience further deterioration of their hearing status, which, due to prolonged noise exposure, is irreversible in nature. Workers with hearing impairment who are employed in high-noise workplaces are at additional risk because of potential damage to their remaining hearing capacity. Work in facilities where noise is present should be permitted only for workers with fully healthy and less noise-sensitive hearing organs. In this way, occupational hearing loss could be prevented, as workers who are sensitive to noise would be protected and assigned to jobs in less noisy environments.

Metal processing with CNC machines (lathes, mills, grinders) involves certain risks even with protective equipment. Most of these factors develop over time and are impossible to avoid. This can be attributed, among other things, to changes in the working environment, machine wear, malfunctions, and non-compliance with occupational health and safety regulations [7]. Sources of workplace noise may include the entire production process, machinery, motor vehicles, air-conditioning systems, ventilation and maintenance of equipment in production facilities.

The aim of this study was to identify workplaces with an increased risk of hearing impairment due to occupational noise exposure, through the analysis of changes in audiometric findings over a six-month period of continuous exposure to a working environment with elevated noise levels.

2. Methods

2.1.1. Sample of respondents

The sample consisted of working-age participants employed in various occupations within the private and public sectors. The first control subsample included 36 workers who were not exposed to noise in the workplace, while the second included 36 workers who were exposed to noise as part of the work process. The sample was balanced according to the criterion of occupational noise exposure, with 50% of participants forming the test group (noise-exposed) and 50% forming the control group (not exposed to noise). This balance in exposure contributes to the representativeness of the sample and the potential reliability of the study results. Participants with previously diagnosed hereditary hearing loss, as well as those whose hearing impairment resulted from previously identified illnesses or injuries, were excluded from the sample.

2.1.2. Method of conducting the study

The study was conducted in an audiology clinic as part of routine occupational health examinations of workers employed in various sectors. By reviewing anamnesis data, existing medical documentation, and the results of diagnostic procedures performed, insight was obtained into the possible causes of hearing impairment in the participants. Hearing assessments were carried out in the morning hours, after a recovery period, to reduce the risk of auditory fatigue resulting from prior noise exposure and to ensure measurement accuracy without the influence of temporary threshold shifts. In accordance with ethical principles, all participants provided written informed consent to take part in the study, with prior approval obtained from the healthcare institution in which the research was conducted.

2.1.3. Measuring instrument

Pure-tone audiometry was used as the assessment method, conducted to evaluate hearing using pure tones at the threshold of audibility. A Madsen Xeta pure-tone audiometer was used. NIHL identified on the audiogram manifests as bilateral hearing impairment at high frequencies, between 3 and 6 kHz, with hearing recovery at 8 kHz in the early stages of exposure. At the onset of exposure in this frequency range, the hearing threshold at 8 kHz is better than at 4 kHz. In cases of acute noise exposure, the hearing threshold decreases across a relatively broad frequency spectrum immediately after exposure, although the impairment remains most pronounced between 3 and 6 kHz. Such a temporary decrease in hearing usually recovers within several hours. In this case, the condition does not involve damage to the cochlear sensory cells but rather auditory fatigue. With chronic exposure and chronic hearing impairment, hearing loss becomes permanent, with no possibility of recovery. Over time, patients develop irreversible progressive high-frequency hearing loss, which may also extend to the mid-frequency range.

Audiometric assessments were performed using Otosuite software, which allows access to anamnesis data and monitoring of changes in hearing status. Testing was conducted at baseline and at the final measurement, with the final assessment performed after six months of continuous occupational noise exposure.

2.1.4. Data processing methods

Descriptive analysis included the calculation of basic statistical indicators, including frequencies and percentage distributions, to present the fundamental characteristics of the sample and the distribution of variables. An independent t-test was applied to assess the association between noise exposure and the progression of hearing impairment over the six-month follow-up period. A paired t-test was used to assess within-group changes, as hearing impairment was measured at two time points (baseline and final). All collected data were checked for completeness and accuracy of entry, and the analysis was conducted in accordance with ethical principles and standards for data collection and processing.

2.1.5. Ethical Issues/Statement

The study was conducted at the “Sv apostol Luka” Hospital in Doboj, Bosnia and Herzegovina, within the Department of Otorhinolaryngology. Approval for the implementation of the study was obtained from the Hospital Ethics Committee. All participants provided written informed consent to participate in the study. Participation in the research was strictly anonymous and voluntary.

Results

The study included 72 participants. In the noise-exposed group, 61.1% were male and 39.9% female, while in the non-exposed group, 44.4% were male and 55.6% female, reflecting that males are more often exposed to noisy work environments due to heavy machinery operation. Age distribution varied by year of birth: among noise-exposed participants, 33.3% were aged 46–55 and 56–65, 22.2% were 36–45, and 11.1% were 26–35. In the non-exposed group, 47.2% were 46–55, 27.7% were 36–45, and younger and older age groups were less represented. Mean ages were 50.14 ± 11.45 years (noise-exposed) and 46.00 ± 9.59 years (non-exposed), with no significant difference ($t = 1.61$, $p = 0.111$), indicating age is unlikely to influence observed differences.

All 36 non-exposed participants had normal hearing. Among noise-exposed participants, 41.7% had mild, 36.1% moderate, and 22.2% severe hearing impairment.

Table 1. Distribution of respondents according to gender, age groups and degree of NIHL

Variables	Categories	Exposed to occupational noise		Not exposed to occupational noise	
		f	**%**	**f**	**%**
Gender	Male	22	61.1	16	44.4
	Female	14	39.9	20	55.6
Year of birth/ Age group	1960-1969 / 56–65 years	12	33.33	4	11.11
	1970-1979 / 46–55 years	12	33.33	17	47.22
	1980-1989 / 36–45 years	8	22.22	10	27.78
	1990-1999 / 26–35 years	4	11.11	5	13.89
Degree of NIHL	Good hearing	-	-	36	100
	Mild NIHL	15	41.7	-	-
	Moderate NIHL	13	36.1	-	-
	Severe NIHL	8	22.2	-	-

Legend: NIHL = noise-induced hearing loss; f = frequency; % = percentage
∗Year of birth $t=-1.61$, $p=0.111$

Table 2 presents the distribution of participants according to their place of employment. The largest proportion of both groups of participants was employed in an oil refinery, in the production (19.4%) and administrative (19.4%) sectors, followed by the textile industry (16.7% in production and 16.7% in administration), the metal industry (8.3% locksmiths and 8.3% administrative workers), the service sector (11.1% cooks and 8.3% waiters), and the wood-processing industry (8.3% machine operators using band saws and chainsaws, and 8.3% administrative workers). An equal proportion (2.8%) of participants were employed in the following occupations: shoe factory tailor, maintenance worker in a thermal power plant, auto parts production worker, gas station attendant, truck driver, deminer, police officer, and freight transport dispatcher. To adequately assess the impact of noise on the development of hearing impairment in the workplace, the control group subsample included administrative workers employed in the same companies but in different positions and working conditions where noise was not present.

Table 2. Distribution of participants by workplace

Workplace Workers exposed to occupational noise	f	%	Workplace Workers not exposed to occupational noise	f	%
Oil refinery worker	7	19.4	Administrative worker and inspector in an oil refinery	7	19.4
Garment factory tailor	6	16.7	Administrative worker and production supervisor in a garment factory	6	16.7
Cook	4	11.1	Waiter	3	8.3
Metal industry – locksmith	3	8.3	Admin	3	8.3
Wood processing worker	3	8.3	Wood processing administrative worker	3	8.3
Auto mechanic	2	5.6	Auto parts salesperson	2	5.6
Water utility maintenance worker	2	5.6	Water utility administrative worker	2	5.6
Worker in shoe factory	1	2.8	Administrative worker in shoe factory	1	2.8
Thermal power plant worker	1	2.8	Administrative worker in thermal power plant	1	2.8
Car parts production worker	1	2.8	Admin	1	2.8
Gas station worker	1	2.8	Admin	1	2.8
Truck driver	1	2.8	Admin	1	2.8
Mechanic	1	2.8	Admin	1	2.8
Deminer	1	2.8	-	-	-
Police officer	1	2.8	Admin	2	5.6
Transportation dispatcher	1	2.8	Admin	1	2.8

Legend: *f* = frequency; % = percentage

Table 3 shows the distribution of participants according to the machines they operate. Non-noise-exposed participants perform tasks that do not involve operating noise-generating machines. Noise-exposed workers operate presses (16.7%), heavy vehicles such as excavators and trucks (13.9%), sewing machines (11.1%), grinders and drills (8.3%), and generators, band saws, three-phase motors, and CNC machines (5.6% each). Chainsaws, milling machines, electric motors, firearms, boilers, and industrial washing machines were used by 2.8%. Additionally, 5.6% of noise-exposed workers did not operate machines directly but worked in noisy surroundings.

Among noise-exposed participants, 52.8% worked with heavy machinery (trucks, excavators, presses, CNC machines, three-phase motors, generators), 25% with smaller equipment and tools (grinders, drills, milling machines, electric motors, chainsaws), and 22.2% with specialized or industrial machines (sewing machines, band saws, diesel generators, boilers, industrial washing machines, firearms).

Table 3. Grouped sources of noise and distribution of participants by type of machines and tools

Types of machines, tools and transportation vehicles that produces occupational noise	Weight category	Occupational noise present	
		f	**%**
Worker does not work with the machine that produces noise	-	-	-
Press	Heavy machinery	6	16.7
Truck and excavator	Heavy machinery	5	13.9
Sewing machine	Special equipment	4	11.1
Drill and grinder	Small equipment / tools	3	8.3
Diesel generator	Special equipment	2	5.6
Band waw	Special equipment	2	5.6
Three-phase motor	Heavy machinery	2	5.6
CNC machine	Heavy machinery	2	5.6
The worker does not operate a noise-generating machine but works in a noisy environment	No direct work with machine	2	5.6
Generator	Heavy equipment	2	5.6
Chainsaw	Small equipment / tools	1	2.8
Milling machine	Small equipment / tools	1	2.8
Electromotor	Small equipment / tools	1	2.8
Weapons	Special Equipment	1	2.8
Boiler for heating	Special Equipment	1	2.8
Industrial washing machine	Special Equipment	1	2.8

Legend: *f* = frequency; % = percentage

To identify workplaces at increased risk of hearing impairment, audiometric changes were analyzed over six months of continuous noise exposure. Pure-tone audiometry was used to determine hearing thresholds in both noise-exposed and non-exposed participants at baseline and after six months. Non-exposed participants showed no significant hearing changes (0.19 ± 0.55, $t = 1.64$, $p = 0.109$). Noise-exposed workers had an average hearing loss change of 1.83 ± 2.27 dB ($t = 4.84$, $p < 0.001$), indicating a significant increase in NIHL. Independent-samples

TECHNIUM SOCIAL SCIENCES JOURNAL

Technium Social Sciences Journal
Vol. 82, 312-321, April, 2026
ISSN: 2668-7798
www.techniumscience.com

t-test confirmed that hearing changes in noise-exposed participants were significantly greater than in non-exposed participants (t = 4.13, p < 0.001). These results indicate that six months of work in noisy environments significantly declines hearing, highlighting occupational noise as a high-risk factor.

Table 4. Association between occupational noise exposure and progression of NIHL over six months (t-test results)

Group	**N**	**Change in NIHL (M ± SD)**	**t-test within the group**	**P**	**t-test between the groups**	**p**
Workers exposed to occupational noise	36	1.83 ± 2.27	4.84	<0.001*	4.13	<0.001*
Workers in quiet environment	36	0.19 ± 0.55	1.64	0.109		

Legend: Change in NIHL: hearing loss over six months; M = mean, SD = standard deviation; paired t-test = within-group, independent t-test = between-group; p < 0.05 significant.

3. Discussion

In this study, participants exposed to workplace noise were predominantly male, whereas the non-exposed group included a higher proportion of female workers. This gender distribution reflects the fact that men are more likely to work in noisy environments involving heavy machinery and tools. Similar patterns have been reported in previous studies [8–10], indicating that men are generally at higher risk of occupational noise exposure. The age distribution also varied between the groups, with middle-aged and older workers more frequently found in noise-exposed positions. These observations align with prior research [11], which identified the 30–44 and 45–59 age groups as those at the highest risk of noise-induced hearing loss.

The study found that workers employed in oil refinery facilities, the textile and metal industries, the wood-processing sector, and various service activities—including maintenance, auto parts production, work at gas stations, operation of heavy vehicles, demining, and police work—operate machinery and tools or work in environments with high occupational noise exposure. It was determined that performing duties in the sectors is significantly associated with an increased risk of developing NIHL. The level of occupational noise exposure is often not uniform within the same occupations but varies considerably depending on specific work tasks and job organization. The obtained results are consistent with existing knowledge on occupational noise exposure. Previous studies confirm that work in industrial, technical, and construction sectors increases the likelihood of occupational hearing loss. Research has shown that the mining, construction, and manufacturing sectors most frequently exhibit the highest prevalence of noise exposure [12]. Other studies [13] have shown that the prevalence of noise exposure can vary significantly within a single occupation; for example, in construction, it ranged from 50% in the service industry sector to 76% in the combined transportation, warehousing, and utilities sector. Studies have reported that average binaural hearing loss among men is highest in wood-processing, mining, construction, military, and agricultural occupations [14]. Other research indicates that workers with a history of occupational noise exposure are most commonly employed in manufacturing, mining, assembly, maintenance and repair, and transportation sectors [15].Within the utilities sector, a significant proportion (43%) of workers exposed to noise has been reported. Researchers [16] emphasize that the highest percentage of noise measurements exceeding permissible exposure limits occurs in agriculture, forestry, fishing and hunting, construction, mining, quarrying, oil and gas extraction, manufacturing, and trade. Studies have found that the rate of excessive noise exposure is highest in automobile manufacturing, shipbuilding, and the production of aerospace and other transportation equipment [17]. Analysis of work tasks showed that NIHL is most frequently present among workers who operate noise-generating machines and equipment (presses, trucks and excavators, sewing machines, grinders, drills, generators, band saws, three-phase motors, CNC machines, chainsaws, milling machines, electric motors, firearms, heating boilers, and industrial washing machines), confirming that work with heavy machinery combined with intensive work processes increases the risk of hearing impairment. Metal-cutting machine tools are a common source of occupational noise, with lathes, milling machines, and drills producing noise levels up to 104 dB, metal-cutting saws up to 115 dB, and grinders up to 134 dB [7]. An electric drill produces sound levels of around 95 dB, a chainsaw about 100 dB, noise levels in wood processing and woodworking range from 90 to 100 dB, and in the metal-processing industry from 85 to 130 dB [18]. Internal combustion engines operate at approximately 125 dB, compressors at 113 dB, and pneumatic tools and motors at up to 134 dB [19]. Work involving powered tools, machines, and equipment in mines, refineries, and industrial plants, as well as the operation of heavy vehicles, is carried out at high noise intensities and levels. Although technical solutions for noise reduction exist, high-noise tools remain widely available, while information about the risks of noise exposure is very limited and insufficient [20]. The obtained results show that there is a statistically significant difference in the mean values of hearing impairment between participants exposed to workplace noise and those working in a quiet environment over the six-month exposure period. Although the follow-up period was relatively short, measurable and statistically significant changes in the degree of NIHL were recorded. These findings indicate that workers employed in noisy workplaces are exposed to an increased risk of developing hearing loss. Similar results have been reported in studies in which audiometric testing was used to assess hearing thresholds in workers exposed to occupational noise [21]. Based on audiogram analysis, an association was observed between the duration of noise exposure and a reduction in audiometric values in both ears. Approximately 33% of working-age adults exposed to workplace noise have audiometric findings indicative of NIHL, and 16% of noise-exposed workers have clinically confirmed hearing impairment [12]. Previous studies [22] have shown progression of hearing loss among noise-exposed workers, with significant deterioration of audiometric thresholds compared to non-exposed workers. Results of a longitudinal study [23] indicate that workers exposed to continuous workplace noise above 65 dBA over a six-month follow-up period experienced significantly greater hearing deterioration compared to workers with lower exposure levels. Similar findings were confirmed in studies that identified statistically significant differences in audiometric hearing thresholds when comparing three-year follow-up results between noise-exposed workers and those in quiet, non-exposed work environments [24].

4. Conclusions

The study shows that workers in oil refineries, textile and metal industries, wood-processing, and various service activities—including maintenance, auto parts production, gas stations, heavy vehicle operation, demining, and police work—are at increased risk of NIHL. Hearing impairment was most frequent among those operating noise-generating machines, such as presses, trucks, excavators, sewing machines, grinders, drills, generators, band saws, three-phase motors, CNC machines, chainsaws, milling machines, electric motors, firearms, boilers, and industrial washing machines. Significant differences were found between noise-exposed and non-exposed participants after six months. These results emphasize the need for preventive measures, regular audiological exams, and occupational safety strategies.

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