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Evaluating Tinnitus in Industrial Hearing Loss Prevention Programs

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Abstract: This study evaluated the interference of tinnitus on the quality of life for noise-exposed workers enrolled in a hearing conservation program. Noise measurements, a questionnaire, a Brazilian version of the Tinnitus Handicap Inventory (THI), and pure-tone audiometry were conducted with 52 participants (mean age, 29 years) who suffered from tinnitus. THI results indicated that tinnitus had the greatest influence in the functional scale (54%). Significant correlations ($p < .05$) were observed between the periodicity of tinnitus and noise exposure level; degree of tinnitus and exposure to chemicals; total THI score and the scores of the catastrophic, emotional, and functional scales; score of the emotional scale and the functional scale; and results of the THI and the general state of health. An evaluation of tinnitus and its impact could benefit tinnitus sufferers in the workplace.

Key Words: carbon monoxide; health indicators; hearing loss; risk factors

Most tinnitus research has focused on effective treatments and the mechanisms of the cause, detection, and perception of tinnitus. Among the risk factors for tinnitus, the most prominent are age, gender, various diseases (otological, metabolic, neurological, and vascular alterations and dental factors), hearing loss, and exposure to noise, ototoxic drugs, caffeine, nicotine, and alcohol [1–4].

In addition to its medical and audiological aspects, the psychosocial consequences of tinnitus can be of significance and have also been investigated. Tinnitus can alter an individual's ability to function in professional, social, and leisure activities and in family relationships, hence affecting the quality of life [5,6].

Several questionnaires purport to evaluate the impact that tinnitus exerts on daily life. In addition to being beneficial for clinical applications, the tinnitus questionnaires are valuable for understanding the relationship between personality and the psychopathology of tinnitus, its impact on the daily life of persons who suffer from tinnitus, the difficulties and the perception of social support in relation to the problem, and the incapacities and the difficulties produced by tinnitus that can seriously affect quality of life [7–9].

Tinnitus is a common complaint among noise-exposed workers, and in some countries it is even recognized as a work-related condition for compensation purposes. Occupational hearing loss prevention initiatives rarely focus on the prevention and management of tinnitus. No specific guidelines were located with such purpose.

The objective of our study is to evaluate the impact of tinnitus on the quality of life of workers who are exposed to noise and enrolled in a corporate hearing conservation program.

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The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

SUBJECTS AND METHODS

Subjects

We enrolled participants from a meat-packing facility in the state of Rio Grande do Sul, Brazil. The company

employs 372 workers (120 female, 252 male) working in two fixed 8-hour and 48-minute shifts.

We administered a questionnaire to all the employees of the company (N = 372) at the beginning of the training sessions of their hearing conservation program. The questionnaire gathered information on demographics and occupational and medical histories for each worker. Among the questions, two asked about the presence of tinnitus and its laterality. Eighty-two individuals (22% of the total population) had experienced tinnitus and were invited to participate in the study. Twenty (24%) of the 82 were not able to participate because they lost their jobs before collection of data, 5 (6%) declined to participate saying that they no longer had symptoms of tinnitus, and 5 (6%) were on vacation at the time of data collection. Therefore, the final sample of the study consisted of 52 participants: 11 females (9% of the total of 120 noise-exposed female workers in the studied plant) and 41 males (16% of the total of 252 noise-exposed male workers in the studied plant).

Our study was approved by the Committee for Ethics of the Tuiuti University of Paraná (UTP) under the protocol number 063/2006.

Pure-Tone Audiometry

To assess the workers' hearing status, we performed otoscopy and pure-tone audiometry, according to the requirements of the Brazilian legislation [10]. We tested the participants in a soundproof booth that met the requirements of ANSI S 3.1.-1991 for audiometric testing environments. Certified audiologists conducted the audiological tests. The equipment used was an Interacoustics audiometer, model AD 229, with TDH-39 earphones, calibrated according to ISO 8253. We performed pure-tone audiometry for all subjects at frequencies of 0.5, 1, 2, 3, 4, 6, and 8 kHz. Thresholds were considered as normal if they were equal to or less than 25 dB HL. We also performed daily biological calibration checks on the audiometer immediately before testing subjects.

Brazilian Version of the Tinnitus Handicap Inventory

We administered to the 52 participants the Brazilian version of the Tinnitus Handicap Inventory (THI) questionnaire, elaborated by Newman et al. [11] and adapted to Portuguese by Ferreira et al. [6]. The THI questionnaire is composed of 25 questions grouped into 3 subscales. The functional subscale, composed of 11 questions, evaluates the limitations that tinnitus induces in the mental, social, occupational, and physical areas. The emotional subscale, composed of 9 questions, includes affective answers for tinnitus (anger, frustration, irritability, and depression). Last, the catastrophic subscale is composed of 5 questions and examines the most severe reactions from tinnitus (desperation, loss of control, inability to face problems, inability to escape tinnitus, and fear of having a serious ailment) [12].

Three answer options are possible for each of the 25 questions. For the answer *yes*, four points are tabulated; for *sometimes*, two points are tabulated; and for *no*, zero points are tabulated. We used the overall result to identify the degree of severity of tinnitus for each individual and for completing an analysis of the total scores by scales.

McCombe et al. [13] suggested dividing overall scores into the following five levels: *degree 1* (0–16): slight tinnitus; *degree 2* (18–36): mild tinnitus; *degree 3* (38–56): moderate tinnitus; *degree 4* (58–76): severe tinnitus; and *degree 5* (78–100): catastrophic tinnitus.

Data Analysis

We calculated Pearson coefficients of linear correlation and tested their significances via the Student's *t*-test and Fisher's exact test, using a significance level of 5%. We also used Spearman's rank correlations to examine the results of exposure information versus the outcome.

RESULTS

Eighty-two workers (22%) of the total population of 372 workers in the studied company reported tinnitus in the first interview of this study. Because of attrition, we were able to study only 52 workers (14% of total population of the plant). Of all noise-exposed female workers in the plant, 11 (9%) reported having experienced tinnitus, and 41 (16%) of the noise-exposed male workers reported the condition. The average age of the sample was 29.2 years, and the average duration of noise exposure was 7 years. Company records indicated that 12% of the participants are exposed to noise levels lower than 80 dB, 15% are exposed to levels between 81 and 85 dB, 48% are exposed to levels ranging between 86 and 91 dB, and 25% are exposed to levels greater than 91 dB. All participants exposed to noise levels greater than 85 dB are required to use ear muffs, and information on their use and maintenance are given when workers are hired. Walk-through observations suggest that use of the hearing protection is high, but no information exists on the consistency of hearing protection use.

Company records also indicated that 15% of the participants who were exposed to noise were also exposed to other hazards. Of those, 62% were exposed to carbon monoxide (CO), 13% to CO and vibration, 12% to hydrochloric acid, and 13% to sodium hydroxide. Spearman's rank correlation coefficient results indicated a significant

Table 1. Number and Percentage of Subjects Reporting Problems with General Health, Auditory System Health, and Substance Use

	No.	Percentage
Health problem		
Vascular alterations	17	30
Metabolic alterations	4	8
Neurological alterations	3	6
Dental factors	18	35
Headaches	12	23
Sinusitis	19	37
Problems in auditory history		
Hearing loss because of explosion	3	6
Difficulty in listening	21	40
Feelings of pressure in the ears	17	30
Chronic ear problems	10	19
Mastoiditis	3	6
Vertigo	23	44
Hyperacusis	26	50
Earlobe surgery	0	0
Medical history		
Use of prescription drugs	38	73
Tobacco	10	19
Alcohol	3	6
Coffee, tea	37	71

correlation between noise levels and how often workers experience tinnitus ($p = .01$). Moreover, significant results were found for the degree of tinnitus and exposure to chemical pollutants ($p = .02$). Table 1 displays the findings pertaining to the health problems and auditory and medical histories described by the participants.

Pure-Tone Audiometry

We considered thresholds as normal if they were equal to or less then 25 dB HL. We observed that of the 52 participants, 71% had normal audiometric results, whereas 12% presented a bilateral high-frequency notch and 17% presented audiometric configurations of hearing loss due to causes other than noise, such as unilateral losses and flat audiometric configuration. Figure 1 displays the median audiometric thresholds of the study participants.

THI Results

The results of the relationship between tinnitus and the three THI scales are presented in Figure 2. The information pertaining to the severity of tinnitus is presented in Figure 3.

Student's *t*-test results indicated significant correlations between the variables of the total THI score and the scores of the catastrophic, emotional, and functional scales ($p < .05$). A significant correlation also occurred between the scores of the emotional and functional scales ($p < .05$).

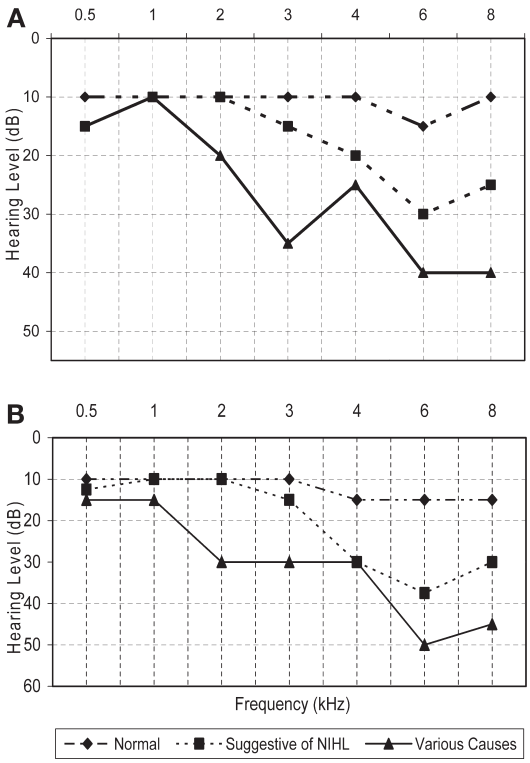

Figure 1. Median of hearing thresholds for the groups with normal hearing (all thresholds ≤25 dB hearing level [*HL*]), hearing loss configurations suggestive of noise-induced hearing loss (*NIHL*), and hearing loss from various causes. (A) Right ear. (B) Left ear.

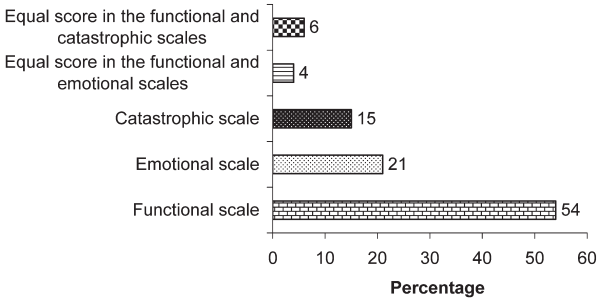

Figure 2. The distribution of poorest scores across scales of the Tinnitus Handicap Inventory, in percent ($n = 52$).

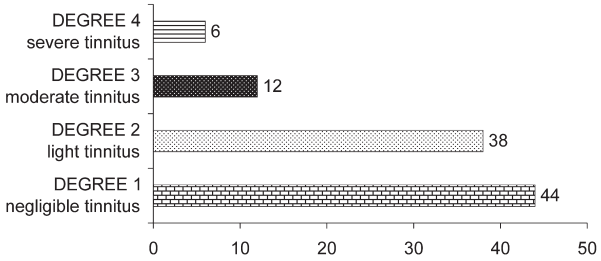

Figure 3. Percentage of participants by their degree of tinnitus severity ($n = 52$).

Table 2. Results of the Chi-square and Fisher's Exact Tests Involving the Functional, Emotional, and Catastrophic Scales Score and Each of Four Single Items from the Medical History ($n = 52$)

	Smoking		Alcohol		Coffee		Prescription Drugs	
THI Scale	***p* Value**	**Test**	***p* Value**	**Test**	***p* Value**	**Test**	***p* Value**	**Test**
Functional	.496	Chi-square	.588	Fisher's	.243	Chi-square	.045*	Fisher's
Emotional	.594	Chi-square	.243	Fisher's	.581	Fisher's	.515	Fisher's
Catastrophic	.524	Fisher's	.578	Fisher's	.019*	Fisher's	.586	Fisher's

THI = Tinnitus Handicap Inventory.
* $p < .05$.

Table 2 displays the correlations between the functional, emotional, and catastrophic scales and medical history. Two of the 12 pairings were significantly related: the functional scale and the use of prescription drugs ($p = .045$) and the catastrophic scale and coffee consumption ($p = .019$).

Table 3 presents the correlations of the THI results with the health problems described by the participants ($n = 52$). We observed a significant correlation between headaches ($p = .0458$) and the duration of tinnitus.

We separated the participants into two groups: The first was composed of 37 participants with normal hearing (71%), and the second included 6 participants (12%) with a bilateral high-frequency notch. We did not include the remaining 9 individuals (17%), who displayed other audiometric configurations of hearing loss in the statistical analysis.

For the participants with normal hearing ($n = 37$), we noted a significant correlation between the total THI and the functional ($p = .000$), emotional ($p = .000$), and catastrophic ($p = .033$) scales and between the emotional and functional scales ($p = .001$). For the participants with a high-frequency notch ($n = 6$), we verified a significant correlation between the total THI and the functional ($p = .000$), emotional ($p = .039$), and catastrophic ($p = .001$) scales (Table 4). We also observed a significant correlation between the duration of noise and the functional scale ($p = .039$).

DISCUSSION

Twenty-two percent of the noise-exposed participants complained of tinnitus, a finding comparable to rates of 25% reported by Sahley and Nodar [14] and 15.5% reported by Zimmermann [15]. The prevalence of tinnitus complaints in male subjects was 16% and in female subjects was 9%, similar to what has been reported [16–18]. It is important to notice that the average age of the population of our study (29.2 years) is younger than in other studies, which reported results from groups whose mean ages varied from 40 to 50 years and who had a short duration of noise exposure (average, 7 years) [18–21] .

Seventy-one percent of the participants with tinnitus complaints presented normal audiometric results, which suggests that tinnitus can be an early indicator of auditory risk from exposure to noise. In addition, we observed a significant correlation between the periodicity of tinnitus and noise exposure level ($p < .05$). This means that the individuals exposed to higher levels of noise experienced tinnitus more frequently as compared to individuals who were exposed to lower noise levels and experienced tinnitus rarely, monthly, or sporadically.

The application of the Brazilian version of the THI was both easy and expedient, as indicated by Newman et al. [11], Ferreira et al. [6], and Dias et al. [22]. In the THI, tinnitus was shown to have the greatest relationship to the functional scale (54%), indicating that its impact is more noticeable in social, daily, and reading

Table 3. Results of the Fisher's Exact Test for the Correlation Between Health Problems and Auditory Problems ($n = 52$)

Medical History	**Catastrophic Scale**	**Functional Scale**	**Emotional Scale**	**Duration of Noise**	**Duration Tinnitus**
Arthritis	.529	1.000	1.000	1.000	.469
Headaches	.146	.088	.659	.589	.045*
Vascular disease	.240	.698	.162	1.000	.456
Neurological disease	1.000	.485	1.000	1.000	1.000
Sinusitis	.698	.698	.162	1.000	1.000
Dental factors	.190	.482	1.000	.645	.089
Metabolic disease	.652	.456	.698	.659	.407
Auditory history	.172	1.000	.406	.610	.165

* $p < .05$.

Table 4. Comparison of the Spearman Correlation Coefficient and Results of the Significance Tests Between Participants with Normal Hearing and with a Bilateral High-Frequency Notch

	Normal Thresholds ($n = 37$)		High-Frequency Notch ($n = 6$)	
Tinnitus Descriptors and/or THI Scores	***r***	***p Value***	***r***	***p Value***
Duration of tinnitus × duration of noise	0.0369	.828	0.1936	.713
Duration of tinnitus × total THI	0.1230	.468	0.2834	.586
Duration of tinnitus × catastrophic scale	0.2027	.229	0.7906	.061
Duration of tinnitus × emotional scale	0.0843	.620	0.3741	.465
Duration of tinnitus × functional scale	0.1042	.539	0.1426	.788
Duration of noise × total THI	0.0792	.641	−0.0588	.480
Duration of noise × catastrophic scale	−0.1571	.353	−0.0765	.965
Duration of noise × emotional scale	−0.1852	.272	−0.3622	.200
Duration of noise × functional scale	0.1405	.407	0.0230	.039*
Total THI × catastrophic scale	0.3506	.033*	0.6082	.001*
Total THI × emotional scale	0.6367	.000*	0.8331	.039*
Total THI × functional scale	0.9188	.000*	0.9780	.000*
Catastrophic scale × emotional scale	0.2201	.191	0.6089	.200
Catastrophic scale × functional scale	0.1249	.461	0.4510	.369
Emotional scale × functional scale	0.5348	.001*	0.7375	.094*

THI = Tinnitus Handicap Inventory.
*$p < .05$.

activities involving concentration, auditory acuity, attention, and rest. The emotional scale was the second most affected and is related to manifestations of nervousness, frustration, irritation, depression, anxiety, insecurity, and difficulty in relationships with family and friends. The catastrophic scale demonstrated alterations related to desperation, intolerance to tinnitus, and loss of control in situations when experiencing tinnitus (see Fig. 2).

In Table 2, we found significant results involving the functional scale results with the use of prescription drugs and the catastrophic scale results with consumption of coffee. Schleuning [2] explained that caffeine and nicotine could aggravate tinnitus because they are stimulants and can induce the constriction of blood vessels. According to that author, doctors believe that 50% of patients with complaints of tinnitus improve significantly when they stop smoking or reduce caffeine intake.

Concerning the degree of severity of tinnitus, 44% presented degree 1 or "slight" tinnitus according to the classification by McCombe et al. [13]. It has been reported that degree 1 tinnitus is perceived only in quiet surroundings [23]. The THI indicated that even the degree 1 "slight" tinnitus experienced by most of the participants who reported tinnitus nevertheless had an impact on their quality of life.

We observed a significant correlation between tinnitus severity and exposure to noise and chemical pollutants, predominantly CO. The participants of the study who had such combined exposure had a higher degree of tinnitus severity. In recent decades, studies have demonstrated that simultaneous chronic exposure to CO and noise represents a potential risk to hearing, but reports of tinnitus exist only for cases of intense poisoning from CO [24].

In our study, the complaint of headaches was associated with the THI results. Sindhusake et al. [3] reported that a history of several health problems can be associated with tinnitus and its impact on quality of life. For instance, lesions in the neck and the middle ear and sinusitis and headaches increase the risk of tinnitus from 28% to 35%. The analysis of the THI results along with the audiometric results indicated that a considerably greater number of significant correlations were verified in the group with altered hearing, which was expected because the two conditions—compromised hearing and tinnitus—are often associated. Chung et al. [25] argued that hearing levels are the most important variable associated with tinnitus, which was prevalent in 33,168 noise-exposed workers in British Columbia, Canada. In our study, factors such as gender, age, tobacco, and exposure to firearms were not significantly associated with tinnitus. Coles [26], among several authors, reported that the worse the hearing is, the more probable is the occurrence of tinnitus. Knobel [20] mentioned a strong connection between tinnitus and hearing loss. Approximately 20% of the patients with hearing loss present complaints of tinnitus, whereas 90% of those with severe tinnitus had hearing loss. Sindhusake et al. [3] de-

tected an increase in risk for tinnitus of approximately 11% for each 10 dB HL increase in threshold in the better ear.

We observed a significant correlation between the duration of noise exposure and the emotional scale for the participants with high-frequency notches, suggesting an extra-auditory effect of noise.

The results of this study demonstrated that the prevalence of tinnitus was high (22%) in this population, despite the fact that study participants were young individuals who had a short duration of noise exposure. Moreover, a negative impact of tinnitus on the subjects' quality of life could de detected. This supports the inclusion of tinnitus prevention initiatives alongside workplace hearing loss prevention initiatives because of shared causal factors. The findings underscore the need for noise control and other effective strategies to mitigate causal factors. Information dissemination on the risks and prevention alternatives is of great importance, as is the management of tinnitus.

CONCLUSION

The Brazilian version of the THI proved to be an easy instrument to use for evaluating the impact of tinnitus on the quality of life of noise-exposed workers. The 22% tinnitus rate among workers, most of whom nonetheless had normal hearing, suggests a need to address tinnitus in occupational hearing loss prevention initiatives. Information on tinnitus prevention and treatment could have a measurable, positive impact on a person's quality of life. The use of an instrument designed to evaluate the impact of tinnitus on a person's life, such as the THI, can contribute to a greater understanding of the needs of a specific person or group (or both). Finally, it could be used in the design of appropriate strategies to manage tinnitus in the workplace.

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