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Field Study

Occupational noise-induced hearing loss in auto part factory workers in welding units in Thailand

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Abstract: Objectives: Most workers in auto part factories in Thailand are usually exposed to excessive noise in their workplace. This study aimed to assess the level of occupational noise-induced hearing loss and investigate risk factors causing hearing loss in auto part factory workers in the welding units in Thailand. **Methods:** This was a cross-sectional study. One hundred eighty subjects were recruited from 356 workers in the welding unit of three factories. Sixty eligible subjects in each factory were selected by systemic random sampling. The subjects were interviewed using a face-to-face questionnaire. Noise exposure levels and audiograms were measured by a noise dosimeter and an audiometer, respectively. **Results:** The findings confirmed that noise exposure levels of 86-90 dB (A) and exceeding 90 dB (A) significantly increased the risk of hearing loss in either ear. A noise exposure level exceeding 90 dB (A) significantly increased the prevalence of hearing loss in both ears. Regarding, a 10-pack-year smoking history increased the prevalence of hearing loss in either ear or both ears. In addition, subjects with employment duration exceeding 10 years significantly developed hearing loss in either ear. **Conclusions:** The engineering control or personal control by wearing hearing protection device should be used to decrease noise exposure levels lower than 85 dB (A) for 8 h. Moreover, if the exposure level reaches 85 dB (A) for 8 h, the employer needs to implement a hearing conservation program in the workplace.
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Introduction

Recently, many industries in Thailand are rapidly developing, and the machinery is widely used in production. Hazards caused by the machinery system have been recognized since a long time. Noise-induced hearing loss is one of the most common hazards in auto part factories, caused by the machinery system and working process[1)]. Die casting, pressing, and welding produce high noise levels, which result in a risk of developing a hearing problem among workers exposed to excessive noise for at least 8 h a day.

Workers in auto part factories in Thailand normally work for at least 8 h a day for 6 days per week. Die casting occasionally causes excessive continuous noise levels, while pressing usually causes excessive impulse noise levels. Therefore, most workers involved in these three processes usually wear an earplug. Welding also generates excessive noise from the working of the machinery and crushing of metal parts into metal pallets; however, most workers have not used a hearing protection device. The reason for the possibility of higher noise exposure among workers in the past could be insufficient noise control by engineering improvement, inadequate policy management, lack of knowledge related to noise-induced hearing loss among workers, and less company safety awareness.

Long-term exposure to a noisy environment may cause dizziness and tinnitus before clinically detectable hearing loss[2)]. Irreversible sensorineural hearing loss can occur with long-term exposure to continuous noise levels exceeding 85 dB (A) for 8 h a day or exposure to impact or impulse noise with a peak level of over 140 dB. Hearing

loss may gradually develop over a period of years; this occurs most rapidly during the first 6-10 years and usually starts at high frequencies, mostly at 4,000 Hz[3]. Some studies found that individuals who were 30-60 years old and who were exposed to noise for 5-10 years had an increased risk of hearing loss (0.2-0.8%) when exposed to average daily noise levels of 80 dB (A). This risk increased to 1.4-4.9% with daily noise exposure levels of 85 dB (A) and to 5.4-15.9% with daily noise exposure levels of 90 dB (A)[4]. Meanwhile, individuals who were 30-60 years old and who were exposed to noise exceeded 10 years had an increased risk of hearing loss 0.3-1.3%, 2.3-7.9%, and 10.3-24.7% with exposure to noise levels of 80, 85, and 90 dB (A), respectively[4]. In addition, individuals exposed to average daily noise levels of 85 dB (A) for 40 years had an increased risk of hearing loss (8%), and noise exposure level of at least 85 dB (A) for 8 h a day for 5 years can cause a permanent threshold shift[4,5].

Due to the standard noise level, the National Institute for Occupational Safety and Health (NIOSH) therefore recommends that a Recommended Exposure Limit (REL) for noise be 85 dB (A) for 8 h a day[6]. The Occupational Safety and Health Administration enacted a noise exposure limit that did not exceed 90 dB (A) for 8 h a day[5]. If noise exposure levels reach 85 dB (A) for 8 h, an employer needs to implement a hearing conservation program to the workers[4,5]. European countries and the United Kingdom recommend noise exposure limit values for lower and upper exposure action values of 80 and 85 dB (A), respectively, for daily or weekly personal noise exposure. The maximum noise exposure limit value for daily or weekly personal noise exposure is 87 dB (A)[7,8].

At present, the Thai government has enacted a regulation in 2006 to control noise exposure levels in workers. The regulation ensures that the noise exposure level must not exceed 90 dB (A) for 8 h a day[9]. Moreover, if the exposure level reaches 85 dB (A) for 8 h, an employer needs to implement a hearing conservation program in the workplace. A hearing conservation program contains at least hearing conservation program policy made by the employer and is announced to employees and prevents occupational noised-induced hearing loss in the workplace, noise monitoring in the workplace, hearing monitoring of employees, and provides responsibility to the personnel in the program[10].

Noise is a major factor responsible for hearing loss. Other factors such as employment duration, age, and cigarette smoking also affect hearing loss[11,12]. Therefore, our aims were to assess occupational noise exposure levels that induced hearing loss and investigate risk factors resulted in hearing loss in auto part factory workers in welding units in Thailand.

Materials and Methods

This was a cross-sectional study. Three auto part factories are located in Phra Nakhon Sri Ayutthaya, Rayong, and Saraburi provinces. These factories were randomly selected with the criteria of similar metal auto part production. The number of total workers in each factory was approximately 600 people, and there were 120 workers in the welding unit in each factory. Die casting, pressing, welding, and painting processes were similar to each other. The background noise level in the welding unit was similar to that in the other units. They were 20-50 years old and were working in the welding unit for at least 8 h a day, 6 days a week for more than 1 year. The subjects exposed to continuous noise levels exceeding 80 dB (A) for at least 8 h each working day. They voluntarily participated. Exclusion criteria included unilateral or bilateral deaf workers and chronic middle ear infection confirmed by a physician's records.

Sixty workers were systemic random sampled from each factory; totally 180 subjects from 3 factories.

Personal information regarding age, education level, pack-year smoking history, music earbuds use, job position, employment duration, perception of the noise level in the current and previous job, and previous earplug use were interviewed by a researcher. Pack-year smoking was calculated by multiplying the number of years of smoking by the number of cigarettes smoked per day divided by 20[13].

A Spark® model 706 noise dosimeter was used, with its performance based on the standards of ANSI S1.4-1983, ANSI S1.25-1991, IEC 60651-1993, IEC 60804-1993, and IEC 61252-1993. It was annually calibrated by the National Institute of Metrology (Thailand). Field calibration was done by researcher before and after sampling. The noise dosimeter was set up to 90 dB (A) of the standard level, 5 dB of the exchange rate, and 80 dB (A) of the threshold level[14]. Individual noise level was measured by the researchers during working time for 8 h for one time because the production process was consistency. The microphone of the noise dosimeter was tapped in the hearing zone to measure the noise exposure level of each subject. Time-weighted average of 8 h (TWA-8 h) in dB (A) was recorded by the dosimeter.

Audiometry was performed using Audiometer GSI 18. This calibrated audiometer met the specifications according to ISO 389-3 1994 / American National Standard Specification for Audiometers, S3.6-1969. Audiometric testing of the subjects was conducted in an audiometric booth. The hearing threshold was examined by an audiologist from a qualified company. Pure-tone air conduction audiometry was performed to determine the hearing thresholds in the frequencies of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz for both ears of all sub-

jects using an audiometer with earmuffs. The measurement of hearing thresholds was done in 5 dB increments. The subjects were considered to have noise-induced hearing loss in either ear if an average threshold shift at high frequency (3000, 4000, 6000, and 8000 Hz) had been recorded for more than 25 dB in each ear. If an average threshold shift exceed 25 dB at high frequency in both ears, the subjects had both ears hearing loss. Audiometry was performed at least 14 h after the last exposure to noise in the workplace. The subjects underwent audiometry before working to avoid the temporary threshold shift. If subjects could not be tested before working, earplugs were used to prevent the fault audiogram from a temporary threshold shift.

Statistical analyses were conducted using SPSS Version 16.0. Bivariate analysis was performed using the chi-square test to identify variables. Only variables with *p*-values less than 0.20 in the chi-square tests were included in the multivariable logistic model[15]. Logistic regression analysis was used in the multivariate analysis to assess the interaction between sensorineural hearing loss and various factors. The odds ratio (OR) and 95% confidence intervals (95% CIs) were also calculated. Differences were considered significant if the two-sided *p*-value was 0.05 or less. Multicollinearity analysis assessed moderate or high inter-correlations or inter-associations among the independent variables in the regression model. If the variance inflation factors exceeded 4, it indicated a reason to be concerned about multicollinearity[16].

This study was reviewed and approved by the Institutional Review Boards of Ethical Committee of College of Public Health Science, Chulalongkorn University. The subjects were informed about the study details as well as any potential harm or risk that may be caused and that they could withdraw from the study at any time without giving any reason. They were assured of confidentiality. Informed consent about the study protocols and the consent form was signed by the subjects and the study investigator.

Results

1. General characteristics of subjects

The collective data showed that the range of noise exposure level in subjects aged 21.05-49.09 years was between 80.8 and 97.0 dB (A). The audiogram indicated that the hearing threshold shift in all subjects exceeded 25 dB at 4000 Hz and that for some of them, the threshold shift exceeded 25 dB at 3000 and/or 6000 Hz. However, most subjects had a normal hearing threshold shift at 8000 Hz. The range of pack-year smoking was 0-37.5, and the range of employment duration was 1.03-17.11 years.

Table 1 demonstrates the difference in general characteristics among the subjects of the three factories. There were no significant differences in the noise exposure level, audiogram, age, education level, pack-year smoking, employment duration, and noise level perception in the previous and current job among the subjects of the three factories. However, there were significant differences in music earbuds use, job position, and previous earplug use among the subjects in these three factories.

2. Noise exposure level associated with hearing loss and risk factors affecting hearing loss

Table 2 shows that the independent variables among the subjects in three factories associated with an abnormal audiogram in either ear or both ears. The factors that were significantly associated with an abnormal audiogram in either ear were noise exposure level, pack-year smoking, employment duration, age, factory group, job position, and education level. The result showed that previous earplug use, music earbuds use, and noise level perception in the previous and current job were not significantly associated with an abnormal audiogram in either ear.

The independent variables significantly associated with an abnormal audiogram in both ears were noise exposure level, pack-year smoking, and education level. The results showed that employment duration, age, previous earplug use, music earbuds use, group, job position, and noise level perception in the current and previous job were not significantly associated with an abnormal audiogram in both ears.

Logistic regression analysis (Table 3) confirmed a significant association of noise exposure level with the prevalence of hearing loss in either ear. It indicated that subjects with a noise exposure level of 86-90 dB (A) and exceeding 90 dB (A) had a significantly higher prevalence of hearing loss in either ear than those with noise exposure levels less than 86 dB (A). In addition, an at least 10-pack-year smoking history and employment duration were significantly associated with an increase in hearing loss in either ear.

Table 4 indicates that the subjects with noise exposure levels exceeding 90 dB (A) had a significantly higher prevalence of hearing loss in both ears than in those who had noise exposure levels of less than 86 dB (A). In contrast, subjects with noise exposure levels of 86-90 dB (A) had no significant difference in hearing loss in both ears compared with those who had noise exposure levels less than 86 dB (A). These findings showed pack-year smoking was significantly associated with an increase in hearing loss in both ears. In contrast, education level was not significantly associated with an increase in hearing loss in both ears.

Table 5 assesses the inter-associations among the independent variables in a regression model. Our results indicated that noise exposure level, pack-year smoking, and employment duration did not have inter-associations in either ear. In addition, there were no inter-associations be-

Table 1. Basic characteristics of subjects under study by group

Characteristics	Factory A n=60 (%)	Factory B n=60 (%)	Factory C n=60 (%)	*p-value*
Noise exposure level (dB (A))				0.080
<86	29 (48.3)	19 (31.7)	19 (31.7)	
>86-90	23 (38.3)	37 (61.7)	36 (60)	
>90	8 (13.3)	4 (6.7)	5 (8.3)	
Audiogram (average 3000-8000 Hz)				0.170
≤25 dB	49 (81.7)	41 (68.3)	48 (80.0)	
>25 dB	11 (18.3)	19 (31.7)	12 (20.0)	
Age (years)				0.496
20-30	13 (21.7)	18 (30.0)	18 (30.0)	
>30-50	47 (78.3)	42 (70.0)	42 (70.0)	
Education level				0.336
Junior High School	18 (30.0)	16 (26.7)	25 (41.7)	
Senior High School	24 (40.0)	25 (41.7)	16 (26.7)	
>Vocational Certificate	18 (30.0)	19 (31.7)	19 (31.7)	
Pack-year smoking				0.477
<10	54 (90.0)	54 (90.0)	52 (86.7)	
≥10	6 (10.0)	6 (10.0)	8 (13.3)	
Music earbuds use				0.002
No	26 (43.3)	41 (68.3)	23 (38.3)	
Yes	34 (56.7)	19 (31.7)	37 (61.7)	
Job position				0.003
Leader	14 (23.3)	22 (36.7)	6 (10.0)	
Worker	46 (76.7)	38 (63.3)	54 (90.0)	
Duration of employment (years)				0.906
<10	47 (78.3)	46 (76.7)	48 (80.0)	
>10	13 (21.7)	14 (23.3)	12 (20.0)	
Noise level perception in current job				0.114
Low	34 (56.7)	26 (43.3)	23 (38.3)	
High	26 (43.3)	34 (56.7)	37 (61.7)	
Noise level perception in previous job				0.105
Low	41 (68.3)	30 (50)	38 (63.3)	
High	19 (31.7)	30 (50)	22 (36.7)	
Previous earplug use				0.001
No	49 (81.7)	56 (93.3)	60 (100)	
Yes	11 (18.3)	4 (6.7)	0	

tween noise exposure level and pack-year smoking in both ears. This confirmed that noise exposure level, pack-year smoking, and employment duration were significantly associated with an increase in hearing loss in either ear. Noise exposure level and pack-year smoking were associated with a significantly higher prevalence of hearing loss in both ears.

Discussion

Our study found that most subjects in welding units in auto part factories exposed to noise levels exceeding 86 dB (A) had a high prevalence of hearing loss. The other risk factor that could affect hearing loss was employment of duration exceeding 10 years and pack-year smoking at least 10.

The limitation of this study was data collection from only three auto part factories in Thailand. This could not generalize the results to other factory groups. This was a cross-sectional study with results that did not reveal any definite cause-and-effect relationship. Only male workers in this welding unit were studied. Technical limitations could not be avoided. There were some subjects who could not undergo audiometry before working because of

Table 2. Distributions of independent variables and results of bivariate analysis (prevalence of abnormal hearing test results, in either ear and both ears, at different levels of independent variables) in three factories in Thailand

Independent variable	Distribution, n (%), total=180	Bivariate analysis of hearing test results			
		Abnormal in either ear		Abnormal in both ears	
		Prevalence, n (%)	*p-value*	Prevalence, n (%)	*p-value*
Noise level (dB (A))*†			*<0.001*		*<0.001*
<86	67 (37.2)	4 (9.5)		2 (13.3)	
≥86-90	96 (53.3)	25 (59.5)		7 (46.7)	
>90	17 (9.4)	13 (31.0)		6 (40.0)	
Pack-year smoking*†			*0.001*		*<0.001*
<10	162 (90.0)	32 (76.2)		8 (53.3)	
≥10	18 (10.0)	10 (23.8)		7 (46.7)	
Duration of employment (years)*			*0.095*		*0.623*
<10	141 (78.3)	29 (69.0)		11 (73.3)	
>10	39 (21.7)	13 (31)		4 (26.7)	
Age (years) *			*0.031*		*0.207*
20-30	49 (27.2)	6 (14.3)		2 (13.3)	
>30-50	131 (72.8)	36 (85.7)		13 (86.7)	
Previous earplug use			*0.750*		*0.807*
No	165 (91.7)	38 (90.5)		14 (93.3)	
Yes	15 (8.3)	4 (9.5)		1 (6.7)	
Music ear buds use			*0.290*		*0.787*
No	90 (50.0)	24 (57.1)		8 (53.3)	
Yes	90 (50.0)	18 (42.9)		7 (46.7)	
Group*			*0.170*		*0.520*
Factory A	60 (33.3)	11 (26.2)		4 (26.7)	
Factory B	60 (33.3)	19 (45.2)		7 (46.7)	
Factory C	60 (33.3)	12 (28.6)		4 (26.7)	
Job position*			*0.030*		*0.339*
Leader	42 (23.3)	15 (35.7)		2 (13.3)	
operator	138 (76.7)	27 (64.3)		13 (86.7)	
Education level*†			*0.156*		*0.101*
Junior High School	59 (32.8)	13 (31.0)		2 (13.3)	
Senior High School	65 (36.1)	20 (47.6)		9 (60.0)	
≥Vocational Certificate up	56 (31.1)	9 (21.4)		4 (26.7)	
Noise level perception in current job			*0.823*		*0.558*
Low	83 (46.1)	20 (47.6)		8 (53.3)	
High	97 (53.9)	22 (52.4)		7 (46.7)	
Noise level perception in previous job			*0.876*		*0.290*
Low	109 (60.6)	25 (59.5)		11 (73.3)	
High	71 (39.4)	17 (40.5)		4 (26.7)	

*Variable entered in interim logistic regression model of either ear
†Variable entered in interim logistic regression model of both ears

job limitations. Therefore, earplugs had to be used to avoid the effect of a temporary threshold shift.

Only one personal noise exposure level measurement was done during the whole working hours because the process of auto part factory was consistency. The same assembly parts were continuously produced for at least 1 year so that the noise exposure level was constant.

The main strengths of this study are the noise exposure measurement and hearing assessment. Noise exposure level was measured by a personal sampling technique to individually assess the noise exposure levels. In addition, the noise exposure measurement was at the same time as audiometry. Audiometry was performed on Monday morning, which is the first day of the workweek, to avoid

Table 3. Multiple logistic regression analysis of hearing loss in either ear

variables	B	S.E	OR	(95% CI)		*p-value*
				Lower	Upper	
Noise exposure level <86 dB (A)			1			*<0.001*
Noise exposure level ≥86-90 dB (A)	2.52	0.63	12.48	3.66	42.54	*<0.001*
Noise exposure level >90 dB (A)	4.57	0.89	96.26	16.97	545.97	*<0.001*
Pack-year smoking ≥10	1.48	0.72	4.39	1.08	17.86	*0.039*
Duration of employment >10 years	1.54	0.48	4.68	1.82	12.05	*<0.001*
Constant	–3.67	0.64	0.03			*<0.001*

Table 4. Multiple logistic regression analysis of hearing loss in both ears

variables	B	S.E	OR	(95% CI)		*p-value*
				Lower	Upper	
Noise exposure level <86 dB (A)			1			*0.012*
Noise exposure level ≥86-90 dB (A)	1.49	0.86	4.42	0.82	23.74	*0.083*
Noise exposure level >90 dB (A)	2.85	0.96	17.31	2.63	114.08	*0.003*
Pack-year smoking ≥10	2.04	0.73	7.72	1.86	31.95	*0.005*
Junior High School						*0.288*
Senior High School	1.15	0.74	3.17	0.74	13.48	*0.119*
≥Vocational Certificate up	0.62	0.83	1.85	0.36	9.42	*0.459*
Constant	–4.71	1.03	0.01			*<0.001*

Table 5. Multicollinearity analysis for independent variables in either ear and both ears

Independent variables	Variance Inflation Factor (VIF)	
	Hearing loss in either ear	Hearing loss in both ears
Noise exposure level	1.030	1.023
Pack-year smoking ≥10	1.023	1.023
Duration of employment >10 years	1.009	-

the effect of a temporary threshold shift.

This study found that the risk factors for noise-induced hearing loss in either ear were noise exposure level, pack-year smoking, and employment duration. Noise exposure levels exceeding 86 dB (A) and cigarette smoking were the risk of hearing loss in both ears. The strongest risk factor for hearing loss was the noise exposure level. Subjects with noise exposure levels of at least 86 dB (A) had a higher significance of hearing loss. NIOSH limits the exposure of 85 dB (A) to protect hearing loss[6]. The American Conference of Governmental Industrial Hygienists recommended the same standards of noise exposure level of 85 dB (A) for 8 working hours as the threshold limit value to protect employees from hearing loss[17]. The Occupational Safety and Health Administration recommends that the noise exposure level should not exceed 90 dB (A) for 8 h working time but that the action level should be 85 dB (A) for 8 h, which is the same as the Thai regulation[5,9]. European countries and the United Kingdom recommend that the noise exposure limit values at the workplace should be in three levels. Lower exposure action values are a daily or weekly personal noise exposure of 80 dB (A), workers should use hearing protectors supported by their employers whereas those of upper values of 85 dB (A) workers is mandatory protected. A daily or weekly personal noise exposure level of 87 dB (A) is the maximum noise exposure limit value[7,8].

In addition, our findings indicated that smoking combined with noise level was associated with hearing loss in either ear or both ears, which was consistent with previous findings[1,18-20].

Regarding employment duration exceeding 10 years, previous studies have suggested that exposure to 85 dB (A) for at least 5 years or more increases the risk of hear-

ing loss. Our results indicated that employment duration exceeding 10 years significantly increased the development of abnormal hearing, which was consistent with the findings of these previous studies[4,6,21].

It can be explained that smokers with noise exposure levels exceeding 90 dB (A) have a very high prevalence of abnormal hearing because toxic substances in cigarettes could be the cause of circulatory cochlear stenosis[18].

Our findings indicated that age, music earbuds use, job position, education level, and previous and current perception of noise level were not significant development of hearing loss. Exposure to excessive noise continuously was the main factor of hearing loss followed by aging[12]. Age, smoking, and noise exposure were synergistic, but it was possible that ototoxic substances in tobacco smoke chiefly synergistically affect hearing when combined with noise exposure, compared with age[11]. Therefore, age was the less effect to hearing loss. Our result was consistent with those in these previous studies[11,12].

Due to music earbud use in this study, we found that it did not significantly increase hearing loss which contrast with previous study. If the sound levels from two sources differ by at least 10 dB, the total sound level is the level of the highest sound between these two sources. Moreover, if sound levels from two sources are equal, the total sound level is one sound level plus 3 dB[22]. Our results showed that the noise level from earbuds was less than that in the workplace environment; therefore, earbuds use could reduce noise level into the ears. Thus, earbuds use was not significant in the development of hearing loss.

Subjects in this study were leaders and workers and had been working and were exposed to noise level in the same area of the welding unit. Therefore, job position was not significantly associated to hearing loss. Our findings showed that education level did not significantly increase hearing loss. Education level was not related to the use of a hearing protection device. Adequate policy making, safety culture, and worker's risk perception were factors that could routinely increase the use of a hearing protection device[23].

Regarding noise level perception of subjects in the working environment in the previous and current job were not significantly associated to hearing loss. The perception of noise level is subjective data depending on individual perception as well as understanding and interpretation, which varies by person or even day to day. Therefore, information obtained from subjective data is sometimes incorrect. This result of the study revealed that the noise level perception could not correctly express the noise exposure level in the workplace and could not relate to the audiogram.

This study showed that previous earplug use was not associated with hearing loss. The prevention of hearing loss could be successful by consistently using earplugs[24-26]. As the subjects in this study had not used an earplug since they started working in these factories, hearing loss could developed.

Our findings were consistent with previous studies that risk factors that significantly increased the prevalence of hearing loss were noise exposure levels of at least 86 dB (A) for 8 h, pack-year smoking at least 10, and employment duration exceeding 10 years. Aging, music earbuds use, job position, education level, noise level perception in the previous and current job, and previous earplug use did not significantly increase the prevalence of hearing loss.

The finding was confirmed that limit of the noise exposure level 85 dB (A) for 8 h prevented noise-induced hearing loss. This study could not confirm age or music earbuds use as being significant risk factors for hearing loss. This could be further studied in other subjects and different noise exposure levels.

Effective noise control or hearing loss prevention in risk workers in factories should be immediately assessed and implemented. It should focus on decreasing the noise exposure level by engineering controls includes designs or modifications of equipment, and processes reducing the source of excessive noise and/or using a hearing protection device and giving up smoking. If the noise exposure level reaches of 85 dB (A) for 8 h, the employers need to implement a hearing conservation program in the workplace. Moreover, performing follow-up audiometry to evaluate the hearing threshold shift is very important.

Further studies should investigate noise exposure levels in females and workers in other occupations or factories who have been exposed to noise levels similar to those in welding unit.

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