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Hearing impairment and contributing factors among fertilizer factory workers

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Abstract: Introduction: Hearing impairment remains the main occupational health problem in the manufacturing industry, and its contributing factors have not been well controlled. **Methods:** Unmatched case control and comparative studies were carried out among fertilizer factory workers in Sarawak with the aim of determining contributing factors for hearing impairment. Respondents consisted of 49 cases that were diagnosed from 2005 to 2008 with 98 controls from the same work places. Chi-square test and Mann-Whitney test were used in a univariate analysis to determine the association between hearing impairment and the contributing risks being studied. **Results:** The results of the univariate analysis showed that hearing impairment was significantly ($p < 0.05$) associated with older age, lower education level, high smoking dose, high occupational daily noise dose, longer duration of service, infrequent used of hearing protection device (HPD), and low perception of sound on HPD usage. Multivariate logistic regression of hearing impairment after controlling for age found the following five variables: occupational daily noise dose ≥50% (OR 3.48, 95% CI 1.36-8.89), ≥15 years of services (OR 2.92, 95% CI 1.16-7.33), infrequent use of HPD (OR 2.79, 95% CI 1.15-6.77), low perception of sound on HPD (POR 2.77, 95% CI 1.09-6.97), and smoking more than 20 packs per year (OR 4.71, 95% CI 1.13-19.68). **Discussion:** In conclusion, high occupational noise exposure level, longer duration of service, low perception of sound on HPD, infrequent used of HPD, and smoking more than 20 packs per year were the contributing factors to hearing impairment, and appropriate intervention measures should be proposed and taken into considerations.

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1. Introduction

Hearing impairment due to noise remains one of the major occupational health problems since 1700 among manufacturing operators, which was exclusively noted by Ramazzini[1]. In the USA and European countries, it is estimated that around 30 million of their employees are exposed to potential noise hazards, and approximately 400-500 million employees are at a risk of developing hearing loss[2]. In Malaysia, a national survey was conducted in 1990 by the Department of Occupational and Safety Health (DOSH) among 45,974 employees from 302 factories, in which approximately 21.9% employees had hearing impairment and only 51.9% employees had a normal hearing threshold[3]. Annual report from the Social Security Organisation (SOCSO) and DOSH also revealed that the magnitude of hearing impairment due to noise remained constantly high until 2007[4,5]. The criterion used for hearing impairment assessment was the average of the permanent hearing threshold level of an employee at 500, 1000, 2000, and 3000 Hz, which is shifted by 25 dB or more compared to the standard audiometric reference level as stated by the Malaysian Factory Machinery (Noise Exposure) Regulations 1989[6]. The contributing factors of hearing impairment were categorized into occupational noise exposure, non-occupational noise exposure (such as free time noise exposure and firearm activities), individual susceptibility such as sociodemography (age, gender, ethnicity, and education levels), smoking habit, medical problems (hypertension, diabetes mellitus, hyper-

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cholesterolemia, and infections), ototoxic drugs, compliance to hearing protection device (HPD) usage, and knowledge and perception regarding noise and HPD. The NIOSH-1997 model estimates that the risk of suffering hearing impairment was 4.3 (95% CI 1.3-9.4) when person exposed to daily noise at 85 dB(A), having worked for more than 10 years and aged 40 years old[7]. Few studies have found that smoking habits, education levels, noisy entertainments, firearm activities, ototoxic drugs, medical problems, and HPD usage have contributed to hearing impairment[10,14,26]. These factors were generally studied using the exsisting study methods, with less focus on the awareness and opinion of the existing control measures. The fertilizer industry is one of the manufacturing sectors that produce high noise intensity during operation. We conducted a case control study to determine the contributing factors of hearing impairment with the aim to plan the required intervention and practical health improvement measures and provide essential information for future research.

2. Methodology

2.1 Subjects

A study in fertilizer factory in Sarawak was conducted. The factory was selected on the basis of high incidence of hearing loss and to assist the factory in optimizing their hearing conservation program. Case-control and comparative studies were performed in the identified cases, with healthy male employees from similar workplaces. From January 2005 to June 2008, 256 employees were required to attend an annual audiometric test as part of their hearing conservation program. About 63 employees were found to have hearing impairment and only 49 cases that had fulfilled the inclusion and exclusion criteria and willingness to participate were included as subjects.

2.2 Survey Methodology

Case control and comparative studies were conducted with unmatched 1:2 by 49 and 98 male subjects from June 2008 until November 2008. The minimum total samples required for this study were 78 samples as based on the Rachiotis *et al.* study by using the Fleiss formula[8,9]. Throughout the survey, the methods used included a Pure Tone Audiometric (PTA) test, a questionnaire, a personal dosimeter report, and recent fasting blood sugar and cholesterol results. The PTA machine was approved and calibrated conforming to the standard requirement by DOSH. The audiometric tests were conducted in the factory clinic located 0.2 km from the workplace. The attenuation of sound in the booth complied with the requirements of regulations[6]. The audiometric tests were conducted by trained qualified technician after otoscopy examination by doctor. The annual audiogram was screened to determine hearing impairment by looking into the latest two audiogram results, and repeated PTA tests were done for confirmation. The PTA tests were performed after 14 hours free from end of work shifts. The self-administered questionnaire session were conducted in the factory's clinic with the presence of the investigator. The questionnaire is mainly for getting information about the contributing factors. A validated questionnaire about knowledge and perception was developed by Arezes *et al.* and had been applied in a few previous studies[10]. The internal reliability of the questionnaire was *Cronbach's alpha*=0.80 after a pretest carried out among non-sample study populations. The statements of noise exposure knowledge and HPD knowledge and perception were scaled using Likert's five point scales ranging from "agree strongly" to "disagree strongly." Whereas the risk source perception statements were scaled by five ranks from "very high risk" to "no risk." The report of personal dosimeter at same work places was conducted in 2006 by registered industrial hygienist. This report was similar to previous noise exposure assessments since no major changes occurred in work process, machine used, and factory designs. *Quest NoisePro DLX-CBL* dosimeter was used with standard *ANSI* S1.25 and was calibrated frequently with Quest calibrator *Model QC-10*. The list of daily personal noise dose in different job titles and work locations was tabulated. These findings were used to determine daily noise dose exposure subjects by questioning their job title and work location since joining this factory. If they choose more than one work location, the longest place their work was chosen. Based on the noise exposure regulations, the 100% daily noise dose means subjects who work in 8 hours per day equivalent to 90 dB(A), whereas subjects who work in 12 hour shifts per day was adjusted equivalent to 87 dB(A)[6]. Fasting blood sugar and cholesterol tests results were based on existing medical records and were reanalyzed by an accredited laboratory in early 2008 as part of their healthy life style program. The normal value for fasting blood sugar and cholesterol was less than 6.1 mmol/*l* and 5.2 mmol/*l*, respectively. Every subject was involved in this program. Blood pressure status also based on existing medical records.

2.3 Diagnostic Criteria for Case of Hearing Impairment and Control

Hearing impairment was defined according to Factory Machinery (Noise exposure) Regulations 1989 criteria: in terms of average audibility threshold of 0.5, 1, 2, 3 kHz about 25 dB or more bilaterally[6]. The case inclusion and exclusion criteria consist of the fulfillment of hearing impairment definitions, free of ear infections or trauma or surgery, have been working for more than 6 months, no previous occupational history of noisy jobs and agree to participate. The control criteria comprise of current threshold frequencies of 0.5, 1, 2, 3, and 4 kHz less than 25 dB and absence of standard threshold shift. The con-

trol was selected by random sampling of worker name lists, have been working in the same factory, never had history of hearing loss, have been working for more than 6 months, and agree to participate.

2.4 Items Surveyed

The items surveyed included the following: (1) sociodemographic data (age, ethnicity, and educations level), (2) occupational noise exposure (daily noise dose and service duration), (3) HPD (frequency of usage, attendance of training, and knowledge and perception), (4) non-occupational noise exposure (free-time noise and firearms), (5) smoking in packs per year, (6) medical condition (hypertension, hyperglycemia, and hypercholesterolemia), and (7) knowledge about noise and perception of risk source.

2.5 Ethics

The study received ethical clearance from the university medical research committee. Individuals were explained about the study purposes from each participant. The factory administrator had given permission to conduct the study.

2.6 Statistical Analysis

Univariate and multivariate logistic regression methods were employed. Data were analyzed by using SPSS 13.0 software package.

3. Results

3.1 General data

The response rate of this study was 96%. Six people were unable to participate because of long leave, refused to participate, or did not return the questionnaire after audiometer test. Of the 49 subjects with hearing impairment, severity of hearing impairment was mild in 43 subjects, moderate in 5 subjects, and severe in 1 subject.

3.2 Contributing factors

3.2.1 Socio-demography.

Table 1 shows that the median age in years for case group was 44 (IQR 10.5) and control group was 40 (IQR 6.5). Cases that aged more than 45 were 30.6% and five times greater as compared to the control group and this difference was statistically significant. The ethnicities were majority from Iban, Melanau, and Malay, and no association was found between groups after using Chinese as a reference race. Educational level showed majority of both groups had schooled until secondary level. But the case group was less educated as compared to control group. Univariate analyses showed 89.9% cases had school until secondary level as compared to 72.4% control, and this difference was statistically significant. Subjects who schooled until secondary level were three times at greater risk as compared to the control group.

3.2.2 Occupational noise exposure.

Table 2 shows that the job titles as an operator, technician, and lab technician among case and control group were not significantly different. Daily noise dose exposure showed cases were more exposed; about 61.2% as compared to control 23.5% and this difference was statistically significant between groups. In univariate analyses, cases were five times at greater risk to have been exposed to more than 50% daily noise dose as compared to controls. Service duration also showed an association between groups ($p<0.05$). A total of 77.6% of cases had worked more than 15 years as compared to 41.8% of controls. In univariate analyses, cases were five times at greater risk to have been worked more than 15 years compared to controls.

3.2.3 Hearing Protection Device.

All the subjects wore the HPD, but the frequency of HPD usage showed significant associated with hearing impairment. Table 2 showed that 57.1% of cases were not wearing HPD all the time as compared to 26.5% controls. Cases with infrequent practice were four times at greater risk as compared to controls. Most of the reasons of not wearing all the time were unable to hear others (35%), overlooked to wear when they reach workplace (33%), uncomfortable (11%), and others. HPD training program as required by regulations showed that 40.8% of cases had never attended HPD training program as compared to 27.6% of control. But there is no association between groups ($p=0.10$). Knowledge on HPD showed that the case group had slightly lower score as compare to control group, but this differences was not significant. However, in the answers on HPD perception, there were lower scores of the case group as compared to the control group, and this difference was statistically significant. On further analyses found that there was an association between HPD perception and frequency of HPD practice ($p<0.05$).

3.2.4 Non-occupational noise exposure.

Table 3 shows an entertainment noise exposure during free-time; there was no association between groups ($p>0.05$). Firearm habits such as animal hunting and volunteering in military-like group activities were negligible.

3.2.5 Smoking.

Table 1 shows that smoking habits exist in 67.3% of cases and 41.8% of controls. On smoking doses, cases who smoke 11-20 packs per year and 21 and more packs per year were 20.4% and 22.4%, respectively. The control groups only practice 8.1% and 5.1%, respectively. There are statistically significant associations between both groups. At univariate stage, subjects who smoke 11-20 packs per year were 4.5 times at greater risk compared to control groups, whereas if subjects who smoke more than 21 packs per year were 8 times at greater risk.

3.2.6 Medical conditions.

Table 1 shows that hypertension was present in 14.3%

Table 1. Univariate analysis of individual susceptibility factors in hearing impairment

Factors	Case		Control		*p* value	OR (95% CI) Unadjusted
	n (%)	Median (IQR)	n (%)	Median (IQR)		
Age		44 (10.5)		40 (6.5)	0.001**	
<35	10 (20.4)		37 (37.8)		0.018*	1.00
35-39	10 (20.4)		26 (26.5)		0.494	1.42 (0.52-3.91)
40-45	14 (28.6)		24 (24.5)		0.116	2.16 (0.83-5.64)
>45	15 (30.6)		11 (11.2)		0.002*	5.05 (1.77-14.35)
Ethnic						
Chinese	6 (12.2)		15 (15.3)		0.770	1.00
Iban	15 (30.6)		28 (28.6)		0.614	1.34 (0.43-4.17)
Bidayuh	3 (6.1)		6 (6.1)		0.794	1.25 (0.23-6.69)
Malay	11 (22.4)		28 (28.6)		0.976	0.98 (0.30-3.18)
Melanau	9 (18.4)		17 (17.3)		0.659	1.32 (0.38-4.59)
Other Sarawak Ethnic	4 (8.2)		2 (2.0)		0.105	5.00 (0.72-34.92)
Others	1 (2.0)		2 (2.0)		0.865	1.25 (0.09-16.50)
Education Level:						
Primary School	6 (12.2)		0 (0.0)			
Secondary School	38 (77.6)		71 (72.4)			
Higher Institution	5 (10.2)		27 (27.6)			
Secondary School and below	44 (89.8)		71 (72.4)		0.020*	3.35 (1.20-9.33)
Higher institution	5 (10.2)		27 (27.6)			
Smoking in packs per year:						
0	16 (32.7)		57 (58.2)		0.001*	1.0
1-10	12 (24.5)		28 (28.6)		0.343	1.50 (0.64-3.66)
11-20	10 (20.4)		8 (8.1)		0.007*	4.50 (1.51-13.15)
>20	11 (22.4)		5 (5.1)		0.001*	7.84 (2.37-25.86)
Medical Conditions:						
High blood pressure						
Yes	7 (14.3)		8 (8.2)		0.250	1.88 (0.64-5.51)
No	42 (85.7)		98 (91.8)			
Blood Cholesterol						
High	24 (49.0)		37 (37.8)		0.130	1.72 (0.86-3.44)
Normal	25 (51.0)		61 (62.2)			
Blood Glucose						
High	11 (22.4)		11 (11.2)		0.070	2.29 (0.91-5.74)
Normal	38 (77.6)		87 (88.8)			

*significant at p<0.05, all Chi-square tests except ***Mann-Whitney* test
IQR=interquartile range

of cases and 8.2% of controls. Fasting hypercholesterolemia was found in 49% of cases and 37.8% of controls, whereas fasting hyperglycemia was higher in 22.4% of cases and 11.2% of controls. But all these medical condition had no statistical association between groups ($p>0.05$).

3.2.7 Knowledge of noise and perception of risk source.

Table 2 shows that the case group had lower knowledge scores as compared to control group, but there is no statistical difference. The risk source perception also found similar findings.

3.2.8 Multivariate Logistic Regression Analysis.

In Table 5, seven significant contributing factors identified by univariate logistic regression analysis were further analyzed by multivariate logistic regression analysis. Enter method was used and variable age was controlled in the analysis, since it showed high correlation (r=0.77) with duration of services. At the level of *alpha*=0.05, five factors qualified as the variables of multivariate logistic regression model: daily noise dose, duration of services, HPD used frequency, smoking habit, and perception about HPD. Nagelkerke R-squared of these contributing

Table 2. Univariate analysis of occupational factors in hearing impairment

Factors	Case		Control		*p* value	OR value (95% C.I) Unadjusted
	n (%)	Median (IQR)	n (%)	Median (IQR)		
Job Title:						
Operator	32 (65.3)		56 (57.1)		0.647	1.71 (0.17-17.17)
Technician	16 (32.7)		39 (57.1)		0.862	1.23 (0.12-12.74)
Lab Assisstant	1 (2.0)		3 (3.1)		0.629	1.00
Duration of Services:		19 (7.0)		14 (10.5)	0.001**	
≥15 years	38 (77.6)		41 (41.8)		0.001*	4.80 (2.20-10.50)
<15 years	11 (22.4)		57 (58.2)			
Noise Exposure Dose						
≥50% Dose	30 (61.2)		23 (23.5)		0.001*	5.15 (2.45-10.80)
<50% Dose	19 (38.8)		75 (76.5)			
HPD used frequency						
Not all the time	28 (57.1)		26 (26.5)		0.001*	3.69 (1.79-7.60)
All the time	21 (42.9)		72 (73.5)			
HPD Training Attended						
Never	20 (40.8)		27 (27.6)		0.100	1.81 (0.88-3.72)
Ever	29 (59.2)		71 (72.4)			
Noise knowledge:						
Low scores	13 (26.5)		15 (15.3)		0.100	#1.99 (0.86-4.63)
High Score	36 (73.5)		83 (84.7)			
Risk Source perception						
Low Scores	31 (63.3)		49 (50.0)		0.130	#1.72 (0.85-3.48)
High Scores	18 (36.7)		49 (50.0)			
HPD knowledge						
Low Scores	40 (81.6)		73 (74.5)		0.330	#1.52 (0.65-3.58)
High Scores	9 (18.4)		25 (25.5)			
HPD perception						
Low Scores	38 (77.6)		46 (46.9)		0.001*	#3.91 (1.79-8.51)
High scores	11 (22.4)		52 (53.1)			

*significant at p<0.05, all Chi-squares tests except **_Mann Whitney_ test, #Prevalence Odds Ratio

factors in the model was 0.43. The conclusion from multivariate analyses were as follows: 1) Cases were at greater risk 3.5 times when they had more than 50% noise exposure as compared to controls; 2) Cases who served more than 15 years were at three times greater risk as compared to controls; 3) Cases were at 2.8 times greater risk when they did not wear HPD at all the times as compared to controls, 4) Cases were at five times greater risk when smoking more than 20 packs per year as compared to controls; and 5) Low perception of sound on HPD were 2.8 times at greater risk. The model of these contributing factors with probability of hearing impairment is as below:

P (Hearing Impairment) =

1+Exp [− { − 3.577+1.247 (Daily Noise dose)+1.070 (Service Duration)+1.028 (HPD used Frequency) +1.018 (Perception about HPD)+1.549 (Smokes more than 20 packs per year)}]

4. Discussion

4.1 Consideration in Bias

Bias tends to occur in a case control study. In this research, the standardized questionnaire was used. Both univariate and multivariate logistic regression analyses were applied to control for confounders such as age. History of ear infections, ear trauma, ear surgery, and past noisy job were controlled at the early study design. Selection bias is also unlikely to occur among subjects, since hearing impairment case was selected based on the determined criteria, whereas the control group was randomly selected. Each audiogram was repeated for both groups and by reviewing previous results. The frequency tested among control group was extended until 4000 Hz, since NIHL tends to start at a higher frequency. Information bias as a result of exposure misclassification was lessened

Table 3. Univariate analysis of non-occupational factors in hearing impairment

Factors	Case n (%)	Control n (%)	*p* value	OR value (95% C.I) Unadjusted
Noisy Entertainment				
Exposed	11 (22.4)	19 (19.4)	0.66	1.20 (0.52-2.78)
Non-exposed	38 (77.6)	79 (80.6)		
Exposed to Firearm (1)				
Army	1 (2.0)	5 (5.1)	0.66***	
RELA-volunteer	1 (2.0)	0 (0.0)	0.72***	
Hunting	1 (2.0)	9 (9.2)	0.20***	
Social firing	1 (2.0)	3 (3.1)	1.00***	

All Chi-square tests, ***Yates correction done.

by performing exposure assessment without the assessor's knowledge on respondent's health status. Recall bias among the control cannot be avoided. Memory on duration of service probably creates difficulty among the respondents, but the answer was confirmed by factory human resource department.

4.2 Sociodemography

Few studies have revealed that age is an important variable resulting in hearing impairment. This research showed that hearing impaired subjects have higher median age. The cases aged older than 45 years old were five times at greater risk as compared to controls. Model NIOSH-1997 estimated the risks were increasing at age 30, 40, 50, and 60 years[7]. At daily noise exposure of 80 dB and duration of service between 5-10 years, the risks at age 30, 40 and 50 were increased twice to 0.2, 0.4, and 0.6. For this research finding, as shown in Table 1, the risks increase as subjects getting older and are similar to the NIOSH model[7]. A study by Kjellberg concluded that older age workers were at risk of developing hearing impairment as compared to others[11]. In multivariate analyses, high correlation (r=0.9) was apparent with duration of services. As mentioned by Pyykko *et al.* that age factor always behaved as a confounder in risk analyses and sometimes interfering with noise exposure data[12]. In view of this scenario, age was controlled statistically. For ethnicity, this research was similar to a study by Mohd Nizam *et al.* in Sarawak in that there was no association between ethnic groups[13]. Population studies need to be done in order to relate between ethnicity and hearing impairment. For education levels in this research, it was not a contributing factor after adjusting other variables, even though univariate analyses showed significant associations. A study by Stanbury *et al.* in Michigan mentioned that graduates from non-higher institution have a higher risk of getting hearing loss[14]. But their study was a cross sectional design and self-reported hearing loss. In this research, lower education groups always have been hired as an operator rather than as a technician, which was found to have significant association. But in the univariate analyses between job titles and hearing impairment status, there were no significant association. This means education levels have a direct association with hearing impairment status. The reason why there is no association between job title and hearing impairment were probably because of promotion to higher post or change to other post.

4.3 Occupational Noise Exposure

In this research, hearing impairment subjects were at 3.5 times greater risk to more than 50% of daily noise dose compared to control. For the purpose of comparing other studies, 50% dose is equivalent to 85 dB. Studies by ISO, EPA, and NIOSH about the noise intensity exposure found at age 40 years, noise intensity at 85 dB will have increased risk to 10%, 12%, and 15%[7]. In NIOSH model also showed increasing risk 4-10 times in exposure from 80-90 dB[7]. A case control study in Nepal showed cases with hearing loss had noise exposure with OR 4.0 (95% CI 1.2-13)[15]. Rachiotis *et al.* study among the electronic manufacturing workers also concluded that an occupational noise exposure was the strongest predictor in hearing impairment with OR 7.5 and followed by age variable with OR 5.3[9]. In an aviation industry study by Kim J *et al.*, the relative risk of noise exposure, after controlling for age, was 4.3 (95% CI 1.7-10.5)[16]. All these findings were similar to this research. Some of the previous studies had made the comparison with non-noise exposure, as compared to this research, which used 50% daily noise dose, but the aim of this research was to look into the role of daily noise dose risk that caused hearing impairment. Noise exposure regulations also mention that the action level is 85 dB (A) or 50% noise dose exposure and PEL as 90 dB (A)[6]. Workers exposed above this level were at risk of having hearing impairment at about 3.5 times, which means that lower PEL can be proposed to regulators since other developed countries have implemented 85 dB(A) as a PEL and using 3 dB exchange rate for adjusting their allowable exposure duration.

Hearing impairment subjects in this factory had served

Table 4. Descriptions of knowledge and perception regarding noise and hearing protection among the hearing impairment

Factors	Low Score n (%)	High Score n (%)
Noise knowledge		
Exposure to high-noise levels can be dangerous for my hearing	5 (10.2)	44 (89.8)
Any high-noise level can be dangerous	4 (8.2)	45 (91.8)
It is not needed to use HPD in my workplace [(a)]	15 (30.6)	34 (69.4)
Noise can permanently affect my hearing	1 (2.0)	48 (98.0)
Noise in my workplace is not dangerous [(a)]	23 (46.9)	26 (53.1)
Total Scores	13 (26.5)	36 (73.5)
Risk Source perception		
Any high-level noise at a very close distance	14 (28.6)	35 (71.4)
Loud music	9 (18.4)	40 (81.6)
Very noisy machine	33 (67.3)	16 (32.7)
Noisy machines in maintenance	27 (55.1)	22 (44.9)
Traffic noise	42 (85.7)	7 (14.3)
Noise with misplaced HPD	29 (59.2)	20 (40.8)
Total Scores	31 (63.3)	18 (36.7)
HPD knowledge		
There are several types of HPD	18 (36.7)	31 (63.3)
All HPDs offer the same protection [(a)]	43 (87.8)	6 (12.2)
Protection depends on the duration of HPD use each day	14 (28.6)	35 (71.4)
I often avoid myself being exposed to noise	21 (42.9)	28 (57.1)
It is possible to reduce noise levels in my workplace	32 (65.3)	17 (34.7)
Total Scores	40 (81.6)	9 (18.4)
HPD perception		
When I use HPD, I cannot talk to my colleagues [(a)]	35 (71.4)	14 (28.6)
HPD do not allow me to hear useful sounds [(a)]	28 (57.1)	21 (42.9)
When I use HPD, I feel that I am not protected enough [(a)]	24 (49.0)	25 (51.0)
I exactly know how to correctly use my HPD	15 (30.6)	34 (69.4)
I cannot always use HPD as it should be used [(a)]	26 (53.1)	23 (46.9)
I know a better way to use HPD	24 (49.0)	25 (51.0)
I make all efforts to have my HPD always well fitted	12 (24.5)	37 (75.5)
I am sure that I use HPD in an efficient way	9 (18.4)	40 (81.6)
Total Scores	38 (77.6)	11 (22.4)

[(a)] inverse marks

for more than 15 year, three times longer as compared to controls. A study by Rachiotis *et al.* among electronic factory workers found that the frequency of hearing loss in workers with more than 14 years were 48% as compared to 12% for workers with less than 14 years[9]. NIOSH model also showed duration of exposure between 5-10 years and more than 10 years had increased risk to 1.5-2.0[7]. Gidikova *et al.* had found faster increment of hearing impairment frequency among the workers who served less than 10 years (about 5.45%). Whereas workers who served more than 10 years had gradual increment of hearing impairment frequency (about 26.5%) because of increasing noise exposures duration[17]. ACOEM also mentioned NIHL usually occurs slowly and has the highest frequency of occurrence during the first 10-15 years of noise exposure duration. But the frequency of occurrence becomes lower as the hearing threshold increases, which is different from age-related hearing impairment, which increases with duration[18]. A study in Taiwan among oil refinery workers also found increasing hearing threshold at higher frequencies (3, 4, and 6 kHz) to workers who had served for more than 15 years[19]. McFadden *et al.* also found chronic noise exposure can cause bad effects because of cumulative noise exposure[20]. This research used 15 years and the odds ratio of nearly 3 times was in line with previous studies.

Table 5. Multivariate logistic regression analysis of hearing impairment

Factor	Regresion Coefficient (β)	SE	*Wald*	*p*	Adjusted OR (95% C.I)
Noise Exposure Dose ≥50%	1.247	0.479	6.793	0.009*	3.48 (1.36-8.89)
Service Durations ≥15 year	1.070	0.470	5.185	0.023*	2.92 (1.16-7.33)
Not all the time uses HPD	1.028	0.451	5.190	0.023*	2.79 (1.15-6.77)
Low Perception Score About HPD	1.018	0.471	4.660	0.031*	#2.77 (1.09-6.97)
Smoking (packs per year)					
0 (0)			6.224	0.101	1.0
1-10 (1)	0.318	0.576	0.305	0.581	1.38 (0.44-4.25)
11-20 (2)	1.106	0.676	2.677	0.102	3.02 (0.80-11.37)
>20 (3)	1.549	0.730	4.507	0.034*	4.71 (1.13-19.68)
Low Education Level	0.277	0.608	0.208	0.648	1.32 (0.40-4.35)
Constant	–3.577	0.743	23.186	0.001	0.03

*significant at $p<0.05$, #Prevalence Odds Ratio

The noise knowledge and risk source perception were not contributing factors. This means that the case group is aware about noise hazards that they are facing. On details of the statements, the case group perceived that "traffic noise" was the least as the risk sources (Table 4). This means that they perceived noise risk based on the noise magnitude, which made them uncomfortable at workplace. The way workers perceived the risk of noise exposure could play an important role in their safety behavior[21].

4.4 Hearing Protection Device

Even though all the subjects had worn the HPD, the practice frequency at designated areas showed that the case group was not wearing HPD all the time (Table 2). They were at 2.8 times greater risk when not wearing HPD all the time as compared to controls (Table 5). A study by Starck *et al.* found that paper and pulp factory workers who wore HPD for 50% of the required duration showed more hearing loss[22]. Further questions on the reasons of not wearing frequent HPD all the time were the inability to hear others while using it, overlooked to wear, and feeling uncomfortable. Sataloff *et al.* also found that the reasons for not wearing include the HPD is uncomfortable, may disturb their hearing, limit conversation, and the incorrect perception that they will lose their hearing[23]. Reasons assumed show that the understanding of HPD function and its suitability need to be emphasized during training. Presence in training sessions on HPD was higher among the control group, but there was no significant association. This means that HPD usage was not related to the HPD session they had attended.

The knowledge on HPD was lower among case and control groups but was not much different. The lower scores corresponded to the statements on "all HPDs offer the same protection" and "it is possible to reduce noise levels in my workplace." This means that they have insufficient knowledge about HPD types and functions. But the perception on HPD was lower among case group as compared to control group, and there was significant difference. This means that poor perception on HPD practice was a risk factor to have hearing impairment. The lower scores corresponded to the statements on "when I use HPD, I can't talk to my colleagues" and "HPD don't allow me to hear useful sounds" (Table 4). This means that they were less aware of the HPD function. Similar questionnaires by Arezes also found lower score[10]. The way workers perceive the risks they are exposed to can be an important input for a better understanding of risk management and ultimately to their own safety[24]. It seems reasonable to assume that risk perception in workplaces can, at least to a certain extent, influence workers' behavior and thus their exposure to risks[25].

4.5 Smoking Habits

Smoking habit was categorized as doses by packs per year. Cases that smoked more than 20 packs per year were 4.7 times more at risk compared to control groups. A previous study by Noorhassim and Rampal showed multiplicative effect of age and smoking on hearing impairment and a high prevalence of hearing impairment in those smoke more than 20 packs per year[26]. A similar study by Nakanishi *et al.* found that as the number of packs per year of exposure increased, the risk for high frequency (4 kHz) hearing impairment increased in a dose-dependent manner, but the risk for low frequency (1

kHz) hearing impairment did not[27]. Gruckshanks and Klein also found smoking increased hearing impairment[28]. Barone found active smoker had increased the hearing loss rate with ratio 1.39:1 and that the rate increases with number of packs per year [29]. A study in Tehran, Iran also found smoking habit increased risk of hearing impairment[30]. Some of the researchers found additive effects of smoking and noise exposure[31]. Physiologically, smoking can influence blood flow in the cochlear through peripheral vessels, increase blood viscosity, and decrease oxygen supply[32]. These effects have been found in animal and human studies[33].

The limitation of this research is the study population, which only depends on respondents who were still working. Cases of resignations and those who are promoted to the other jobs cannot be excluded. The knowledge and perception of noise and HPD probably are not reflected before they have hearing impairment.

5. Conclusion

All the five contributing factors were in line with other studies. Hearing impairment was related with daily noise dose and duration of services. Engineering and administrative controls should be advised in lowering the exposures. The employer should be emphasized from time to time. Safety and health committee could play major role on compliance to existing legislations. Continuous education may focus on training needs assessment. HPD used and perception must be intensified and corrected. Appropriate HDP design could be proposed to answer simplicity practice. Smoking habit should be reduced by integrating into their healthy lifestyle program with emphasis on behavioral changes.

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