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## Noise induced hearing loss and its determinants in workers of an Automobile manufacturing unit in Karachi, Pakistan

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### Abstract

**Introduction:** Excessive noise is an important health hazard at the present time. It can lead to auditory and extra-auditory effects which affect the welfare of individuals and groups exposed. We carried out this study to understand the prevalence of Noise Induced Hearing-Loss (NIHL) in workers of an automobile manufacturing unit in Karachi, Pakistan.

**Method:** The study consisted of the following:

1. Determination of noise levels during different stages of work.
2. A questionnaire regarding subjective hearing loss of the workers; as well as their knowledge, attitude and behavior regarding excessive noise.
3. Tympanometry and Audiometry.
4. Health and safety survey.

Two hundred and seventy two workers participated in the study and out of them 206 underwent audiometric evaluation.

**Results:** The basic demographic, professional data and smoking habits of 272 workers participating in the study is as follows: 34.92% of workers belong to 41-50 years of age, 58.8% belong to Mohajir ethnic group, 19.1% were smoker/ex-smokers, 62% earned less than Rs 10,000/month, 87.5% received education for 0-10 years and 40% had work experience of 0-10 years. The majority of the workers were exposed to noise level higher than the safe limit of 85 dBA.

According to the WHO criteria [1] 61% of the workers were suffering from hearing loss. Those who were suffering from hearing loss were further evaluated according to Cole's criteria for NIHL [2]. Of the total number of workers who underwent audiometry 25% fulfilled the Coles' criteria [2] for NIHL. The age, duration of exposure and severity of exposure were important determinants of NIHL. The workers had insufficient knowledge regarding prevention of NIHL. The personal protective equipments were used inadequately. There was no clinical follow up or monitoring of hearing among the workers.

**Conclusion:** There is an urgent need for the government to take practical steps for making a policy and implement it so that occupational hearing loss can be prevented.

**Keywords:** NIHL; Age; Duration of exposure; Severity of noise; Personal protective equipment; Audiometry

**Abbreviations:** NIHL: Noise Induced Hearing-Loss; SPSS: Statistical Package for Social Sciences; PPE: Personal Protective Equipment

## Introduction

Hearing is important for a successful life. Loss of hearing affects life as well as employment, education and well being, and is therefore a challenge for an individual during their regular as well as his/her social life. At the work-place hearing loss decreases not only efficiency but also puts a questionmark on the individual's safety as well.

Hearing loss is an important cause of disease's burden [3]. Globally, 360 million persons are suffering from disabling hearing loss; in South Asia 27%, East Asia 22%, Asia Pacific 10%, Central Asia 9%, high income group 11%, Latin America and Caribbean 9%, Central/East Europe 3%, Middle East 3%, Sub Saharan Africa 9% and North Africa 3% [4].

Adult-onset hearing loss is the fifteenth most serious health problem which leads to social isolation and to serious economic burden [5]. 16% of the disabling hearing loss in adults worldwide is due to occupational noise, while in different sub-regions ranges from 7% to 21% [5]. Noise induced hearing loss (NIHL) is more common in less developed countries [5]. It is getting worse over the years with continued occupational noise exposure [6] and is irreversible [7], but could be prevented [8]. It is the second most common form of acquired hearing loss [9].

In the USA, 9 million workers are exposed to sound levels of 85 dBA and above 10 million have NIHL. In European Union, 28% of workers reported that at least 25% of the time at work they are exposed to loud noise [5].

Excessive noise causes community annoyance, elevated blood pressure, stress, sleeping difficulties, reduced performance and tinnitus [5]. It also leads to changes in serum lipid, triglycerides, platelet count, plasma viscosity and glucose [10-15].

The majority of adults suffering from NIHL belong to Asia, where NIHL is a serious health problem. Asian countries are developing/less developed and lack preventive and curative health services. There is lack of awareness of NIHL among workers, employers and health providers. This is the main barrier in prevention of NIHL in these countries [16].

In Pakistan, there are large numbers of people who are not aware of the adverse effects of noise. Noise is the major cause of preventable hearing loss globally [9]. The economic burden due to NIHL is tremendous and has been estimated to be billions of dollars. The condition further aggravates the dependence of these socially handicapped people.

The aim of the present study was to assess the prevalence and characteristics of the hearing loss in people working in noisy environment in an automobile manufacturing company. Our intention was to get evidence that will serve to inform the policy makers in the Government and the industry to institute control and safety measures, in order to raise the level of awareness of the workers regarding the health risks of their work.

## Methods

A cross sectional descriptive study was carried out in December 2011 in an automobile manufacturing unit in Karachi, Pakistan. Written consent was obtained from Chief Executive Officer of the company. Verbal consent was taken from subjects who were workers in different departments. The study consisted of noise monitoring, questionnaire, otoscopic examination, audiometry of the workers and health/safety survey. We used random method of sampling. 272 workers participated in questionnaire study. 206 workers i.e.76% of the sample underwent audiometry.

The noise survey was carried out by a trained health and safety coordinator with a sound level meter TES 1351 made in Taiwan. Calibration was done by the instrument department of the company. Noise level meter was placed at shoulder level of the worker. Nine readings were measured at three different times on the same day. The minimum and maximum were noted and average of 9 readings was calculated.

**In the questionnaire study:** A face to face interview was conducted by the trained interviewer. The workers were asked questions regarding hearing loss, tinnitus, knowledge, attitude and behavior regarding NIHL. Demographic data and smoking habits were recorded.

Otoscopy was carried out by a trained auditory technician. Both ears were examined. Workers were examined for wax and perforation of the ear drum. Those workers who were having cerumen or perforation of the tympanic membrane were excluded from the study.

Pure tone audiometry examination was offered to all the workers who participated in questionnaire study and 206 workers responded positively. A pure tone clinical audiometer GSI 38, Westain Hearing Aid Company, USA was used. Each worker was explained the procedure and its importance. Air and bone conductions were tested at frequency of 0.25, 0.5, 1, 2, 4, 6 and 8kHz. All the records were entered manually. Hearing impairment was defined as an average air conduction threshold in the better hearing ear at 0.5, 1, 2 and 4kHz more than 25 dBA. The hearing loss was classified into mild (26-40 dBA), moderate (41-60 dBA), severe (61-80 dBA) or profound (more than 80 dBA). The better hearing ear was taken for calculation of the prevalence of hearing loss. In those workers who fulfilled the Coles' criteria of NIHL i.e. bilateral sensorineural hearing loss at high frequency with characteristic notch at 4 kHz was considered as NIHL and the rest as non-NIHL hearing loss.

**Occupational health and safety survey:** We carried out walk through survey of the factory and all findings were noted.

**Monaural and binaural hearing impairment:** Monaural and binaural hearing impairment is expressed in terms of % by using threshold average of frequencies 1, 2, 3 and 4kHz. Hearing impairment was defined as a threshold average greater than 25 dBA hearing level [17].

**Monaural hearing impairment:** % of monaural hearing impairment was calculated as follows:

1. From the audiometric results, the average of thresholds of hearing for frequencies of 1, 2, 3 and 4kHz was calculated.
2. Deduct from it 25 dBA (as there is no impairment up to 25 dBA).
3. Multiply it by 1.5.
4. Formula for monaural hearing impairment is given below:  

$$([1\text{kHz} + 2\text{kHz} + 3\text{kHz} + 4\text{kHz}] \times 4) \times 1.5 = \% \text{ of loss [17].}$$

**Binaural hearing impairment:**

1. From the % monaural impairment, multiply the percent of better ear by 5.
2. To this, add the percent of worse ear.
3. Divide it by 6. Formula for binaural hearing impairment is as follows:  $([\% \text{ better ear} \times 5] + [\% \text{ worse ear}]) \div 6 = \% \text{ binaural hearing loss [17].}$

**Data Analysis:** The data was entered into IBM Statistical Package For Social Sciences (SPSS) version 19 and analysis was carried out (Tables 1 and 2).

**Audiometry results**

dBA	Average of bone conduction at 0.5,1,2,4 kHz		Average of air conduction at 0.5,1,2,4 kHz		Average of air conduction of better hearing ear at 0.5,1,2,4 kHz
	Right ear	Left ear	Right ear	Left ear	
<25	48.1%	47.6%	25.7%	31.1%	38.8%
26-40	46.1%	43.7%	56.3%	51.9%	50.5%
41-60	5.8%	8.3%	16.5%	15.5%	9.7%
61-80	0%	0%	1%	0.5%	0.5%
>80	0%	0%	0.5%	1%	0.5%

**Audiometry findings**

Variable	Mean	Standard Deviation	Minimum	Lower Quartile	Median	Upper Quartile	Maximum
REBONEC500	27.0	6.2	10.0	25.0	25.0	30.0	50.0
REBONEC1000	23.9	7.0	5.0	20.0	25.0	30.0	55.0
REBONEC2000	26.0	9.6	10.0	20.0	25.0	30.0	65.0
REBONE4000	33.5	16.3	10.0	20.0	30.0	45.0	100.0
averageofREBC	27.7	7.8	13.0	23.0	26.0	33.0	55.0
LEBONEC500	26.8	6.7	10.0	25.0	25.0	30.0	50.0
LEBONEC1000	23.6	6.3	10.0	20.0	25.0	25.0	50.0
LEBONEC2000	26.7	10.3	10.0	20.0	25.0	30.0	70.0
LEBONEC4000	35.6	16.5	10.0	25.0	30.0	45.0	80.0
averageofLEBC	28.3	8.1	14.0	23.0	26.0	34.0	58.0
REAIR250	30.5	9.2	15.0	25.0	30.0	30.0	75.0
REAIR500	30.6	8.7	15.0	25.0	30.0	30.0	80.0
REAIRC1000	28.9	8.3	20.0	25.0	25.0	30.0	80.0
REAIRC2000	29.6	12.4	15.0	20.0	25.0	30.0	80.0
REAIRC4000	39.3	18.1	10.0	25.0	30.0	55.0	100.0
averageofREAC	32.2	10.1	16.0	25.0	29.0	38.0	83.0
LEAIRC250	30.7	9.7	15.0	25.0	30.0	30.0	75.0
LEAIRC500	30.0	8.8	15.0	25.0	30.0	30.0	80.0
LEAIRC1000	28.3	9.3	15.0	25.0	25.0	30.0	85.0
LEAIRC2000	30.0	13.2	15.0	20.0	25.0	30.0	95.0
LEAIRC4000	40.7	19.0	15.0	25.0	30.0	60.0	95.0
averageofLEAC	32.4	10.6	19.0	25.0	28.9	38.0	84.0

**Mean, median and standard deviation of audiometric result**

Age distribution of the workers			
20-30 years	31-40 years	41-50 years	50 years
50(18.38%)	70(25.73%)	95(34.92%)	57(21%)
Duration of work in years			
0-10	11-20	21-30	>30
109(40%)	98(35.6%)	58(21%)	2.9%
Ethnicity of workers			
Mohajir	Pathan	Punjabi	Baluch &Sindhi
160(58.8%)	33(12.1%)	26(9.3%)	17(6%)
Smoking			
Smokers	Ex-smoker	Non-smokers	Not answered
41(15.1%)	11(4%)	214(78.7%)	6(2.2%)
Monthly salary in Pak rupees			
<Rs 10,000	Rs10-20,000,	Rs 21-30000	Rs >30,000
174(62.4%)	77(27.6%)	15(5.4%)	3(1.1%)
Level of education			
0-10years	11-12yrs	13-15yrs	>15yrs
237(87.5%)	14(5%)	10(3.7%)	10(3.7%)

Table 1: Basic demographic data.

S#	Department	Average (dBA)	Minimum (dBA)	Maximum (dBA)
1	Wire harness	67.8	62	78
2	Quality inspection department(QID)	69.6	61	82
3	Product support division (PSD 2)	73	53	107
4	Material operation department (MOD)	74.8	70	80
5	Quality audit department (QAD)	75.9	70	82
6	Vehicle inspection department 1(VID)	76.6	67	102
7	Rectification	78.7	70	89
8	Vendorized parts store(VPS)	79	71	89
9	Vehicle inspection department 2 (VID)	79.6	76	81
10	Primer shop	79.6	76	82
11	Paint shop	79.9	76	84
12	Pre-delivery inspection (PDI)	80.5	76	84
13	Complete knock down(CKD)	80.6	74	87
14	Tool and dye	82.2	72	88
15	Main shop	82.6	65	112
16	Body white	84.5	75	98
17	Pipe shop	84.5	76	94
18	Pretreatment electrolysis decomposition (PTED)	86	76	96
19	Bus body line	87	81	93
20	Internal material handling (IMH)	88.7	83	98
21	Frame drilling	89.2	70	97
22	Proto shop	90.8	88	96
23	Axle shop	91	79	99
24	Fiber reinforced Product (FRP)	92	89	97
25	Engine shop	92.8	75	112
26	Indus motor vehicle (IMV)	93.2	82	118
27	Hino line	93.6	78	112
28	Trim line 2	94	83	102
29	Special vehicle	94.9	88	104
30	Trim line 1	94.95	85	101
31	Sheet metal	95	85	100
32	Defense production(GT line)	97	94	104
33	Component	98.8	90	105
34	Prod engineering	100	88	109
35	Press shop	100.96	93.3	108

Table 2: Noise survey : Noise levels (dBA) in different departments of the work place.

### Statistical Analysis

Age, job duration, minimum noise exposure, maximum noise exposure and average noise exposure level were compared between NIHL and non-NIHL subjects with Wilcoxon rank sum test. P-values less than 0.05 (two-tailed) were considered as statistically significant.

Average noise and minimum noise did not differ statistically significantly between NIHL and non-NIHL subjects (p=0.64, p=0.17). However, there was significant median difference between maximum noise level where median value for non-NIHL was 101 and for NIHL subjects 96 (p=0.017). Thus there was no statistically significant relationship between average and minimum noise exposure. But maximum noise exposure has statistically significant relationship with NIHL. NIHL subjects were significantly older than non-NIHL subjects (Median=45 vs Median=41, p=0.011). Therefore there was statistically significant relationship between age and NIHL.

No statistically significant difference was noted between job duration and NIHL/non-NIHL subjects (p=0.39). Therefore duration of job has no statistically significant relationship with NIHL.

### Questionnaire for Hearing Evaluation

We obtained following results: 22% of the 272 workers complained that they can't hear in noisy background, 11% found problem hearing over telephone, 7.7% hear better from one ear than other, 5.9% turned TV volume too high, 9.6% had their ears examined, 9.6% suffered from ringing of the ears (Table 3).

S#	Questions	No		Yes	
		#	%	#	%
1	Do you have trouble following conversation with 2 or more people talking at the same time	262	96%	6	2%
2	Do you have problem hearing over telephone	238	87.5%	30	11%
3	Do you hear better from one ear then other when you are on telephone	247	90%	21	7%
4	Do people complaint that you turn the tv volume up too high	252	92.6%	16	5.9%
5	Do you have to strain to understand conversation	262	96%	6	2%
6	Do you have trouble hearing in noisy background	208	76.5%	60	22%
7	Do you have trouble hearing in restaurants	256	94%	12	4%
8	Do you have dizziness, pain, or ringing in ears	234	86%	34	12.5%
9	Do you find yourself asking people to repeat	263	96.7%	5	1.8%
10	Do family member or coworkers remarks about your missing what has been said	256	94%	12	4%
11	Do many people you talk to seem to mumble	260	95.6%	8	2.9%
12	Do you understand what others are saying and respond inappropriately	264	97%	4	1.5%
13	Do you have trouble understanding the speech of woman and children	265	97%	3	1%
14	Do people get annoyed because you misunderstood what they say	260	95.6%	8	2.9%
15	Had ears examined	242	89%	26	9.6%
16	Ringing in the ears	242	89%	26	9.6%

Table 3: Hearing evaluation of workers.

Summary of the result is as follows. 26.9% of workers consider that noise level at work site is very high. 86% know that loud noise causes NIHL. 89.6% consider that NIHL can be prevented by using PPE. 72.8% were using PPE. 46% were always using PPE when exposed to excessive noise (Table 4).

What do you think about noise level at work site?	Negligible		Low		High		Very high		Not answered	
	60	21.5%	31	11%	103	36.9%	75	26.9%	3	1%
What are the causes of NIHL?	Loud noise		Don't know		Others		Not answered			
	240	86%	5	1.8%	3	1%	24	8.9%		
How to prevent of NIHL?	Use of PPE		Noise reduction		Don't know		Others		Not answered	
	250	89.6%	5	1.8%	5	1.8%	8	2.8%	4	1%
Do you use PPE?	Yes		No		Not answered					
	203	72.8%	59	21%	10			3.6%		
Type of PPE used	Ear plugs		Ear muffs		Don't use		Not answered			
	181	64.8%	42	1%	35	12.5%	14	5%		
Hours per day you are exposed to excessive noise	0-2 Hours/day		3-6 Hours/day		8 Hours/day					
	53		19%		4		1.5%		215	
How often you use PPE?	Not at all		0-5 Hours/shift		6-7 Hours/shift		All the time		Not answered	
	26	9%	159	57%	25	9%	15	5%	47	16.8%
Do you always use PPE when exposed to excessive noise?										
No		Yes		Not answered						
133	47.7%	129		46%		10		3.6%		

Table 4: Knowledge, attitude and behavior regarding NIHL.

### Analysis of Audiometry

Right ear: 56% had mild, 16.5% moderate, 1% severe and 0.5% had profound hearing loss. Left ear: 52% mild, 15.5% moderate, 0.5% severe and 1% had profound hearing loss. Better ear: 50.5% mild, 9.7% moderate, 0.5% severe and 0.5% had profound hearing loss (Tables 5 and 6). Thus prevalence of hearing loss among automobile manufacturing workers of Karachi was 61.2%. 50.5% were suffering from mild hearing loss, 9.7% moderate hearing loss, 0.5% severe and profound hearing loss respectively (Charts 1-4).

S#	Degree of hearing loss	Right ear	Left ear	Better hearing ear
1	No deficit	53(25.7%)	64(31%)	80(38.8%)
2	Mild	116(56%)	107(52%)	104(50.5%)
3	Moderate	34(16.5%)	32(15.5%)	20(9.7%)
4	Severe	2(1%)	1(0.5%)	1(0.5%)
5	Profound	1(0.5%)	2(1%)	1(0.5%)

Table 5: Hearing deficit in right and left ear and better hearing ear.

S#	Degree of Hearing loss in (%)	Right ear (% of workers who have hearing loss)	Left ear (% of workers who have hearing loss)	Binaural (% of workers who have hearing loss)
1	1-20%	54%	47.6%	58%
2	21-40%	18.92%	17%	13%
3	>41%	2.9%	4.5%	2%

Table 6: Percentage of Hearing loss in right, left ear and Percentage of binaural hearing loss.

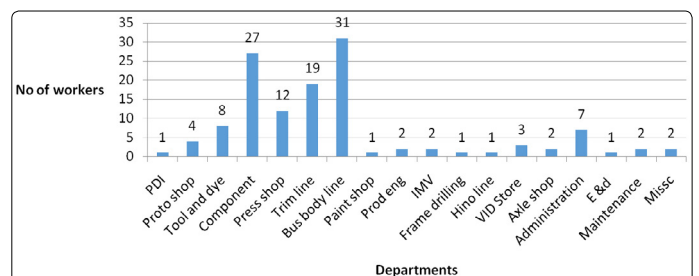


Chart 1: Number of workers with hearing loss(NIHL/Non NIHL) versus departments.

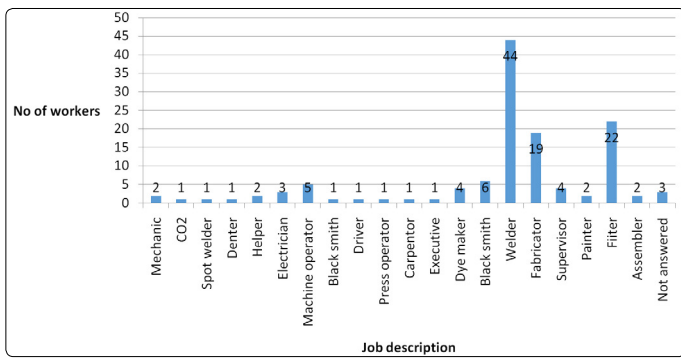


Chart 2: Number of workers with hearing loss(NIHL/Non NIHL) versus versus job description.

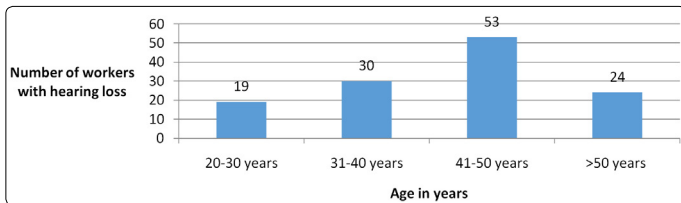


Chart 3: Number of workers with hearing loss(NIHL/Non NIHL) versus versus age.

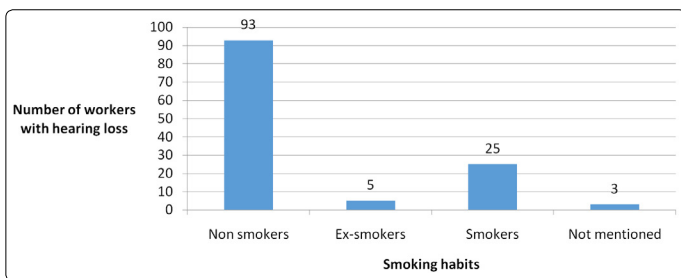


Chart 4: Number of workers with hearing loss (NIHL/Non NIHL) versus versus smoking.

### Noise Induced Hearing Loss

Those workers who were suffering from hearing loss, their audiometry reports were evaluated. Those who were suffering from bilateral sensorineural hearing loss at high frequency and having a characteristic notch at 4kHz were classified as suffering from noise related hearing loss. We found that 25% of the workers were suffering from noise related hearing loss (Charts 5-12).

53% of the workers suffering from NIHL belong to 41-50 years followed by more than 50 years, 20-30 years, and 31-40 years respectively.

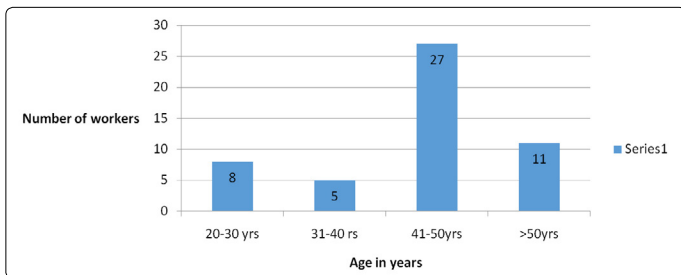


Chart 5: NIHL versus age.

The 45% workers suffering from NIHL were welders, followed by fitters, Dye makers, machine operators, electricians, painter, press operator, and coordinator respectively.

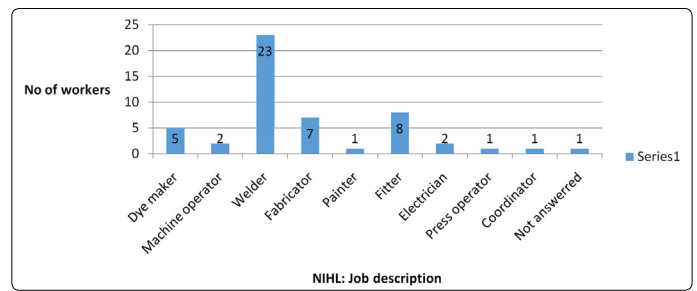


Chart 6: NIHL versus job description.

29.41% of workers belong to bus body line, followed by component, trim, tools and dye, press shop, protoshop, and axle shop, PDI respectively.

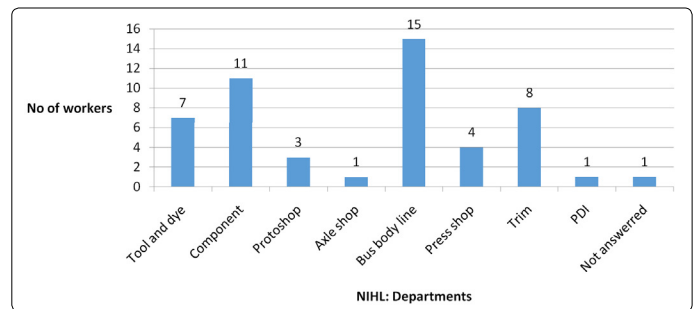


Chart 7: NIHL versus department.

41.17% workers had exposure of 11-20 years followed by 1-10 years and 21-30 years respectively.

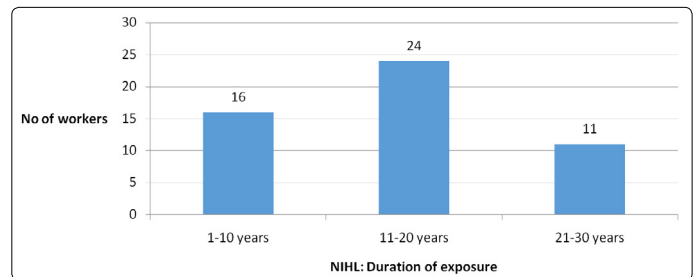


Chart 8: NIHL versus duration of exposure.

54.90% had an exposure of more than 90 dBA followed by 85 to 90 dBA and less than 85 dBA respectively.

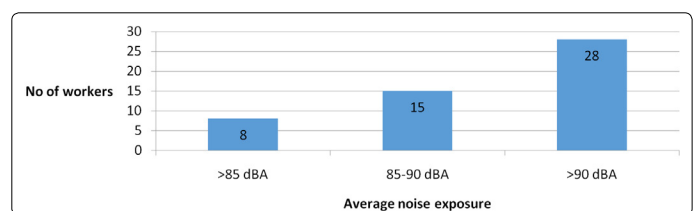


Chart 9: NIHL versus average noise exposure.

47.05% had exposure of less than 85 dBA followed by 85-90 dBA and more than 90 dBA respectively.

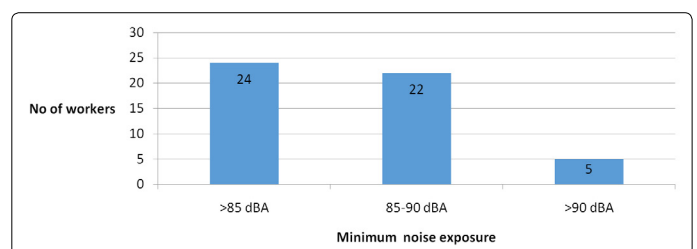


Chart 10: NIHL versus minimum noise exposure.

84.31% had exposure of more than 90 dBA followed by 85-90 dBA and less than 80 dBA respectively.

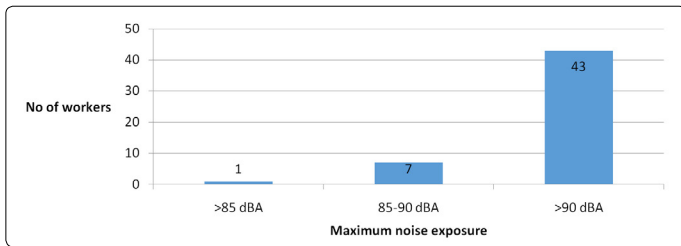


Chart 11: NIHL versus maximum noise exposure.

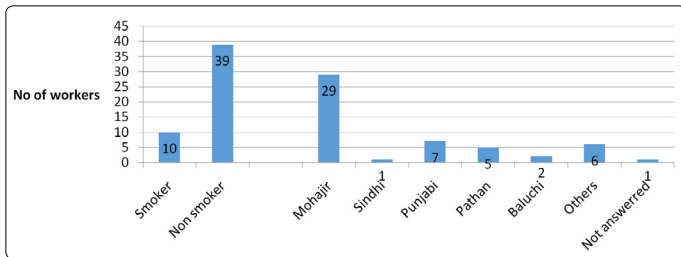


Chart 12: NIHL versus smoking, and ethnicity.

## Health and Safety Survey

We carried out a walk through survey of the company. A department of health and safety was present which was being run by qualified personnel. Health and safety coordinators, and safety engineers were present. Health and safety policy was signed by the chief executive. A clinic run by an occupational health nurse was present. 100% of the workers were provided with PPE by the company, but few of them were using it. Fire fighting system was adequate. First aid boxes were present in all shops. Labor canteen was neat and clean, food was served without cost.

Training programs for the workers were carried out on regular basis. We found excessive noise in certain departments of the factory. The different shops were not segregated therefore noise produced by one shop was added to the noise produced by other shops thus there was an additive effect of noise. We observed that workers in the body line shop were bolting while lying in awkward position and creating excessive noise and vibration. In the paint shop, there was poor housekeeping, excessive paint dust and high temperature. Excessive noise was being produced via the hooter used by the loader. All grinded residues were sprinkled on the floor. The accidents were registered and investigated. MSDS were available. Yearly audit was carried out by ISO certifying organization. Air sampling and water sampling was carried out regularly. All industrial waste was collected safely and disposed off.

There was no record of occupational disease and injuries. All the workers were entitled to medical treatment at social security hospitals as well as at authorized private medical centers (Figure 1). The workers were entitled to paid sick leave. Biological monitoring was carried out for selected workers with pulmonary function and audiometry.

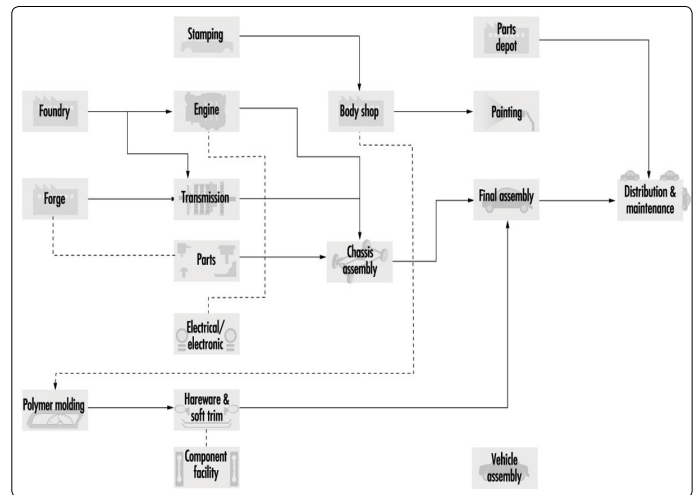


Figure 1: ILO Encyclopedia [18].

## Discussion

Automobile manufacturing particularly of heavy vehicle is a complicated and lengthy process. In Pakistan most of the parts, including the engine and chassis, are imported. The chassis is built up and engine is fitted over it and body of the vehicle is manufactured and all the components are installed. Most of the work is done manually. There are about 120,000 workers who are engaged by the automobile industry in Pakistan [19].

Automobile manufacturing industries have highest injury rates over all. There is high levels of chemical hazards and solvent exposure among production service workers during routine cleaning, spills management and confined spaces. There is excessive noise in all segments of industry leading to hearing loss. Most of the workers suffered from psychosocial stress. Increased rate of lung tumors and respiratory disorders found in foundry workers could be due to exposure to silica. There is increased incidence of tumors of GIT, Pancreas and larynx among machine operation workers. Those machine workers who are exposed to synthetic fluids suffer from skin disorders. Cumulative trauma disorders are common among assembly workers [18].

According to WHO classification, we found hearing impairment among 62% of the automobile manufacturing workers. Our result has been verified by a study in Indonesia where they found prevalence of hearing loss as 55.9% at a Power station, Sarawak Indonesia [20]. We classified hearing loss into mild, moderate, severe and profound. We found in our study that 50.5% were suffering from mild, 9.7% moderate, 0.5% severe, 0.5% profound hearing loss. Thus mild hearing loss was most common. We found hearing loss slightly more common in right ear as compared to left ear. Same result was found in a study on Nigerian traders in Nigeria [21]. The percentage of binaural hearing loss in 58.35% workers was ranging from 1-20%, in 13.1% was 21-40% and in 2.4% more than 40%. Thus most common binaural hearing loss is between 1-20%. We found that those who were suffering from hearing loss maximum 42.06% belonged to age group of 41-50 years, had exposure of 11-20 years. Bus body line

workers had maximum workers with hearing loss 24.60%. 34.92% were welders. 23.89% were ex-smoker/smokers. Most of them belong to Mohajir ethnic group and had 0-10 years of education.

In an automobile manufacturing unit rotors, gears, turbulent fluid flow, impact processes, electrical machines, internal combustion engines, pneumatic equipment, drilling, crushing, blasting, pumps, compressors are used [22]. These machines produce excessive noise which affect ears and causes hearing impairment, if exposure continues it leads to total hearing loss.

During our study we found that majority of the workers 78.7% were exposed to noise more than safe limit of 85dBA. The occupational risk of NIHL in industries that expose workers to continuous high levels of noise is well established [23]. Hearing may be affected by one time exposure to high noise or to continuous high noise level [24]. When an individual is exposed to excessive noise there is a change in hearing threshold which is temporary if he is removed from that environment his hearing threshold improves but if exposure is continuous then it leads to permanent change in hearing threshold and leads to permanent hearing loss. Noise induced hearing loss is one of the most common occupational health hazard [20] not curable [20,25] it causes worker's morbidity as well as loss to the industry.

According to Coles' criteria for making a diagnosis of NIHL there should be high frequency sensorineural hearing impairment, excessive noise exposure and a typical audiometric notch at 4000Hz. In our study we found that 24.75% of the workers fulfilled the criteria for noise induced hearing loss. Thus noise induced hearing loss among automobile manufacturing workers was 25%. This could be probably due to chronic exposure to noise level above 85dBA. In a study at an automobile manufacturing unit at Chennai, India [22] they found NIHL prevalence 18% which is less than our study. It could be due to low level of upper limit of noise exposure. We found upper limit as 118dBA whereas the other study in India found it to be at 110dBA. In addition there are multiple factors which are responsible for final outcome like race, genetics, individual susceptibility and use of personal protective equipment etc.

Studies carried out in other industrial sectors found NIHL in 100% of Nigerian traders [25], 96% ginning factory Maharashtra, India [17], 84% steel factory, Indonesia [26], 62.5% spice grinders Nigeria [27], 57% quarry workers Malaysia [28] 56.8% LPG cylinder infusion unit [29], 44% of electro production, Taiwan [30], 43.5% printing industry Nigeria [31], 38.5% oil company Shiraz, Iran [7], 38% two plants in Saudi Arabia [32], 34.90% heavy engineering Kolkata, India [33]. The prevalence of noise related hearing loss in the above mentioned studies is much higher than our findings. There was low prevalence of NIHL in 23% of gold mine workers Ghana [34], 23.6% stone crushing, Ghana [35], 15.9% metallurgical company Brazil [36], 6% ship builders Goa, India [37].

The difference in prevalence of hearing loss could be due to individual susceptibility or several other factors which

includes age, previous sensorineural hearing loss, smoking, ototoxic medication, type2 diabetes and hypertension etc [23].

Age is positively related to hearing loss [20,21,25,32-34,38]. The relationship between age related hearing loss and noise induced hearing loss is complex and controversial but it could be additive [39]. We found in our study that those workers who were suffering from NIHL 15% belongs to less than 40 years, 29.16% 40-50 years, 36.66% more than 50 years of age. We found that as age advances % of workers suffering from noise related hearing loss increases. Thus there is an upward trend in NIHL with age. The findings of our study have been verified by studies at a Lock factory, India [40] and a Power station at Sarawak, Indonesia [20]. We found a statistically significant relationship between age and NIHL  $p=0.011$ .

NIHL is a slow and gradual process [20]. Duration of exposure is an important determinant of noise induced hearing loss [20,23,24,33]. Sri H et al., [26] Nirmalya M et al. [33] found that as duration of exposure increases hearing loss increases. We found in our study that workers suffering from noise related hearing loss 47% had exposure of 11-20 years, 31.72% 0-10 years, 28.20% 21-30 years respectively. Thus we found that maximum number of workers had exposure of 11-20 years. Our findings have been verified by a study at Sarawak, Indonesia [20]. Though excessive noise affects hearing early but usually manifests after long period therefore only 13.72% who were having 0-10 years exposure had NIHL. The number of workers with NIHL after 20 years of exposure is less, it could be due to healthy workers effect i.e those workers who suffer from hearing difficulty changed their job to a less noisy factory or changed their profession [41]. We did not found statistically significant relationship duration of work and NIHL  $p=0.39$ .

NIHL is caused by repeated exposure to severe noise [21], it increases as severity of noise increases [25,33]. If a worker is exposed to a daily average noise level that is above 85dBA he might get permanent hearing loss over a period of time [7,42]. We found in our study as average noise exposure increases prevalence of noise related hearing loss increases. Those workers who had noise related hearing loss their average noise exposure in 15.68% of the cases was less than 85 dBA, 29.41% 85-90 dBA, 54.98% more than 90 dBA respectively. We did not found statistically significant relationship between average noise exposure and NIHL  $p=0.64$ .

We found that maximum number of workers suffering from NIHL had exposure of more than 90 dBA. This confirms that NIHL is related with severity of noise. Osibogun A et al. found that those who had noise exposure less than 90 dBA NIHL was found in only 11.3% as compared to 79.8% in those who are exposed to more than 90dBA [43]. The result of above mentioned study verifies our results. Thus in order to prevent noise induced hearing loss we should reduce level of noise at source. We found statistically significant relationship between maximum noise exposure and NIHL  $p=0.017$ .

Use of Personal Protective Equipment (PPE) is important for the prevention of NIHL. If PPE is used properly, exposure to noise can be reduced [26] which can lead to reduction in

NIHL. In our study we found that those who were suffering from NIHL 78.43% were using PPE for different durations at work. 50.98% were using PPE when exposed to excessive noise and only 3.92% were using PPE for 8 hours. We found that use of PPE was not satisfactory among workers. Similar results were found by Maisarah SZ et al. 5.1% [44] Emmanuel DK et al. 5.5% [35], Razman MR et al. 11.9% [45]. Hafiz Omer Ahmed 13.2% [46], Foluwasayo EO et al. 28% [47]. These studies verify our finding that PPE use was not satisfactory among industrial workers.

All workers who are exposed to excessive noise should be given training regarding NIHL. We found that majority of the workers knew about excessive noise and its relationship with NIHL but only 1.96% knew that noise reduction is the most important step in prevention of NIHL. It shows that workers' knowledge regarding prevention of NIHL was deficient. Hafiz OA [46], Razman MR et al. [45] found in their studies that workers' knowledge regarding NIHL was lacking. It verifies our results. There should be a structured training program for the workers regarding NIHL.

NIHL is a slowly progressive disease that is untreatable but preventable. The mainstay of management is early diagnosis. Early diagnosis needs pre-employment audiometry as well as annual audiometry of all workers who were exposed to excessive noise. We found in our study that 9.3% had undergone ear examination out of total subjects. Those who had NIHL only 5.88% had ear examination and none of them had audiometric evaluation. It shows severe deficiency in audiometry of the workers. Razman MR et al. found at saw mill, Malaysia that 3.6% had audiometry [46]. In saw mill, Malaysia clinical monitoring was slightly better than our results but still deficient. Atmaca I. Peker et al. found at a concrete factory, Turkey, 44.92% of the workers were undergoing audiometry every year and 19.7% at Iron and steel factory every 2 years [48]. They have better results than our study which could be due to better health and safety implementation.

An audiometric health surveillance program can be considered as a costly exercise and employers in developing countries might therefore be reluctant to undertake audiometry. A questionnaire study might be a cheaper alternative. We found in our study that 17.64% had trouble in hearing in noisy background, 11.76% mentioned that family members and co-workers observed missing words, 7.84% accepted that when they talked to different people it seems to them that they are mumbling. We found "trouble in hearing in noisy background" as most common symptoms among those suffering from noise related hearing loss (17.64%). This shows that a questionnaire study will give low prevalence rate of NIHL in our setting. The findings of our study have been verified by M. Rosso, R. Agius, N. Calleja, mentioned that a questionnaire for early detection of NIHL was having a 32% sensitivity and 79% specificity and this cannot be a valid substitute for audiometry [49]. Thus pure tone audiometry should be used more widely in developing countries and audiometry will remain main choice for early diagnosis of NIHL.

Smoking has been characterized as a risk factor for hearing loss [38,50]. According to Mizoue T et al. the combined effect of exposure to noise and smoking may be additive [38]. We found in our study that 19.60% of those suffering from NIHL were smokers. This shows a weak relationship between smoking and NIHL. Joo HS et al., [51] Mohammadi S et al. [52] found in their study that there was increased frequency of hearing loss in smokers as compared to non-smokers who were exposed to excessive noise. Their findings are different from our finding it could be due to selection bias or deliberately hiding of smoking by the workers due to fear of losing their jobs.

Tinnitus is described as the hearing of sound in the absence of any external noise and it can be very distressing for a person. Neghab M, et al. mentioned that tinnitus is found among those who are suffering from hearing loss and is more common when there is exposure to excessive noise [7]. According to MH Azizi Tinnitus is a NIHL symptom and it should be considered in those suffering from NIHL [25]. We found tinnitus in 9.55% of the total subjects. The result of our study has been verified by various studies, which have reported that the prevalence of tinnitus in populations exposed to noise at work are 5.9% to 87.5% [53]. The variability could be due to factors such as the type of participant, the characteristics of the noise exposure and the definition of tinnitus used [53]. Out of 26(9.55%) who had tinnitus, 17(65.38%) participated in audiometry. Out of 17(65.38%) who had tinnitus and participated in audiometry, 12(70.58%) had hearing loss, 75% of them had non noise related hearing loss and 25% had noise related hearing loss. Thus we found a strong relationship between tinnitus and hearing loss.

Those workers who had tinnitus, 70% of them had hearing loss. We did not find strong relationship between noise induced hearing loss and tinnitus because only 3(5.88%) of those who had noise induced hearing loss had tinnitus also. Our observation is different from various studies carried out which shows that noise induced hearing loss is associated with tinnitus [53]. This could be due to the reason that 35% of those who had tinnitus did not participate in audiometry, it could be a deliberate attempt to hide hearing deficit due to fear of losing their job. Tinnitus is related to severity of noise and duration of exposure [53]. We have found same result as mentioned above i.e. 93.30% had exposure of more than 85 dBA and 38.46% had exposure of more than 20 years. We found tinnitus a good screening test for hearing loss and is cost effective.

## **Conclusion**

Occupational noise is a significant cause of adult-onset hearing loss. The burden of hearing loss caused by excessive noise at work has many consequences for individual and society. Multiple factors contribute to occupational NIHL but major contributor is lack of prevention.

Occupational exposure to noise can be reduced by reducing the noise at the source. Hearing loss prevention programs should include: noise control, noise assessments,



audiometric monitoring, appropriate use of PPE, worker's education, record keeping and program evaluation. Hearing loss prevention programs needs commitment and resources. If there is a will there is a way.

In light of our research we recommend to all stake holders that they should make policies regarding prevention of noise induced hearing loss and implement it so that human sufferings and economic loss can be prevented.

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## Supplementary Data

### Noise Induced Hearing Loss Among Automobile Manufacturing Workers In Karachi, Pakistan.

#### Demographics

1	Name:
2	Company identity number:
3	Department:
4	Age:
5	Sex:
6	Ethnicity:
7	Marital status:
8	Smoking habit:
9	Salary:
10	Job designation:
11	Job description:
12	Duration of job:
13	Education:

#### Evaluation of Hearing

S#	Question	Yes	No
1	Do you have problem in hearing over telephone?		
2	Do you hear better through one ear than the other when you are on the telephone?		
3	Do you have trouble following conversation with two or more people talking at the same time?		
4	Do people complain that you turn the TV volume too high?		
5	Do you have to strain to understand conversation?		
6	Do you have trouble hearing in noisy background?		
7	Do you have trouble hearing in restaurants?		
8	Do you have dizziness, pain or ringing in ears?		
9	Do you find yourself asking people to repeat themselves?		
10	Do family members or coworkers remark about your missing what has been said?		
11	Do many people you talk to seem to mumble?		
12	Do you misunderstand what others are saying and respond inappropriately?		
13	Do you have trouble understanding the speech of woman and children?		
14	Do people get annoyed because you misunderstood what they say?		

#### Medical History

S#	Questions	Yes	No
1	Have you ever had ears examined to assess hearing?		
	If yes when		
2	Do you experience any ear problem?		
	If yes how would you describe it?		
	Pain		
	Ringing in the ears		
	Poor hearing of normal speech		
	Others		

#### Work Environment

1	How would you describe the noise level at your work site?		
	Negligible		
	Low		
	High		
	Very high		
2	Do you feel ringing of the ears at the end of day	Yes	No

#### Knowledge Regarding Hazards of Excessive Noise

S#	Questions	Yes	No
1	You heard of noise induced hearing loss?		
2	If yes, what do you think causes this in workers?		
	Loud noise		
	Don't know		
	Other		
3	How do you think this problem could be prevented?		
	Personal protective equipment		
	Noise reduction		
	Dont know		
	Others		

#### Use of Hearing Protective Equipment

S#	Questions	Yes	No
1	Do you use any protective equipment for ears?		
2	If use which equipment?		
	Premolded ear plugs		
	Formable ear plugs		
	Ear muffs		
3	How many hours a day you are exposed to noise		
4	How often do you put on hearing protection?		
	Not at all		
	1 hour/shift		
	1-5 hours/shift		
	6-7 hours/shift		
	All the time		
5	Do you always wear the hearing protection when you are exposed to excessive noise?	Yes	No

#### Clinical Examination

S#	Otосcopy	Yes	No
1	Ceruman		
2	Ear drum perforation		

#### Audiometry

S#	Hearing	0.5 kHz	1 kHz	2 kHz	4 kHz	7 kHz	8kHz
1	Bone conduction						
2	Air conduction						