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Noise-Induced Standard Threshold Shifts Of 85 And 90 Dba As Permissible Exposure Limits, Post-Shift Exposure Of One Month Duration

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Abstract

There has been an increased in the prevalence of occupational noise-induced hearing loss globally. Countries such as the US, India and Malaysia are adopting 90 dBA as the permissible exposure limit. Aims:The aim of this study is to explore occurrence of temporary standard threshold shifts on adopting different permissible exposure limits: 90 and 85 dBA. In this intervention study, there were 203 participants from two factories. They were exposed to noise levels above action level which is 85 dBA in one factory and 80 dBA in another factory; the permissible exposure limits were 90 and 85 dBA, respectively. The sample size required was 52 in each factory. Noise level was measured using personal exposure noise dosimeter and sound level meter. Data on hearing threshold levels were measured using manual audiometer. Hearing protection devices with appropriate noise reduction rate were used to reduce noise exposure among participants. There were no differences in terms of occurrence of temporary standard threshold shifts among participants between the two factories, based on intention-to-treat analysis and as per-protocol analysis according to Factories and Machinery (Noise Exposure) Regulations 1989,OSHA regulations and NIOSH recommended standard. This study concludes that there were no differences in terms of standard threshold shifts among employees who adopted 90 or 85 dBA as permissible exposure limits. Based on the current findings, countries adopting 90 dBA as the permissible exposure limit need not review their policies on lowering the limit, but rather implementation and enforcement of the legislations should be more appropriate.

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Keywords— Effects 85 or 90dBA; Noise; Threshold shift

Introduction

There has been an increased in the prevalence of occupational noise-induced hearing loss globally. The figure is alarming since the prevalence has doubled from 120 million in 1995 to 250 million in 2004 (Nelson, et al., 2005). In the US alone, millions of workers were exposed to noise levels above permissible exposure limit whereas in Germany, one sixth of the working population were exposed to these levels (Concha-Barrientos, et al., 2004). The countries in the East were not spared either. This occupational malady brought the total of Disability Adjusted Life Years due to noise to over 4 million (Nelson, et al., 2005), where the Western Pacific region contributed more than one quarter of them. Occupational noise-induced hearing loss is a development of hearing loss due to exposure to high levels of noise. There are different views with regards to levels of noise which may lead to this slow and irreversible occupational malady. According to the US Occupational Safety and Health Administration (OSHA), the permissible exposure limit is 90 dBA. The employees should not be exposed beyond this level for more than 8 hours (Franks, et al., 1996). As for the US National Institute of Occupational Safety and Health

(NIOSH), the exposure limit recommended is 85 dBA for the same duration of hours (Franks, et al., 1996).

The development of temporary threshold shifts among employees due to noise may lead to noise-induced hearing loss, if continuous exposure to hazardous noise ensues. Countries such as the US, India (Madison, 2007) and Malaysia (Laws of Malaysia, 2010) are adopting 90 dBA as the permissible exposure limit. In 2010, a total of 663 cases of occupational diseases were investigated in Malaysia. From this total, around 70% of them were diagnosed to have noise-induced hearing loss, making it as the most common occupational disease (Department of Occupational Safety and Health, 2013). The present study is conducted with the aim of exploring the occurrence of temporary standard threshold shifts upon adopting 85 and 90 dBA as the permissible exposure limits. It is of utmost importance to determine scientifically the adoption of permissible exposure limit as legal limit, since it will impose cost and enforcement issues besides introducing the necessity of hearing protection among workers.

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Research Methods

Study design and population

This is an intervention study comparing two factories which applied different permissible exposure limits in a hearing conservation program. Participants from Factory 1 were exposed to permissible exposure limits of 90 dBA while those from Factory 2 were exposed to 85 dBA. Upon enrolment in the present study, hearing threshold levels were measured at the outset and then followed-up at the first month. Hearing threshold levels were measured before the participants began to work at baseline, where they should not be exposed to noise levels beyond 80 dBA for a period of 14 hours (Laws of Malaysia, 2010). Hearing threshold levels were measured within one hour before end of a shift at the first month. A shift lasts for eight hours.

Recruitment of study area was initiated through online requests to safety and health officers. The details of study information were explained to the safety and health officers and human resource managers. Upon approval to conduct this study in the factories, information about this study was distributed to the participants and written consent was obtained. The participation of employees was voluntary, upon obtaining written informed consent.

All subjects in each factory recruited into the study were exposed to noise level above action level. The action level is defined as sound level of 85 dBA in Factory 1 and 80 dBA in Factory 2. The daily noise doses were equal to 0.5 in both factories (Laws of Malaysia, 2010), where the amount of exposure is half the dose of permissible exposure limits, 90 dBA in Factory 1 and 85 dBA in Factory 2. One of the exclusion criteria was subjects who refused to participate. Contract workers were not included since they were not permanently employed, and lorry drivers were excluded since they were not stationed in the factory. Those suffering diseases of the ear such as chronic suppurative otitis media or malignancy, employees who had experienced physical trauma to the ear due to penetrating injury or fall and also those who had undergone ear surgery were not included in this study. This information was obtained from a questionnaire.

Sample size:

Participants of this study were from the two factories in an automobile industry. The participants were exposed to different noise levels; which ranged from 80 to 98 dBA upon conducting initial noise area measurement. A total of 260 workers from the two factories were exposed to noise levels above the action level.Of the eligible participants, 203 of them participated in this study. The non-respondents were those who were involved in busy work procedures and who had the predilection not to participate in the study. Based on the results of Yates et al.(Yates, et al., 1976), sample size required was 43 respondents for each factory based on a two-sided significance level at 0.05 and power of 80%. The calculation of sample size was based on the Power and Sample Size Calculations software (Dupont & Plummer, 1990; Pearson & Hartley, 1970). Taking into account 20% who failed to follow up, the required sample size was 52 in each factory. Sample size limitation was addressed by communicating with the employees through phone calls and provided them with incentives (food) to participate.

Measures

Noise area and personal exposure noise measurement

Noise area measurement was measured using sound level meters (Laws of Malaysia, 2010), calibrated and approved by the Department of Occupational Safety and Health (DOSH) (Larson Davis, model Spark 706 RC and Spark 703+). In Factory 1, the zones were categorized into areas with levels of more than 90 dBA, between 85 and 90 dBA and below 85 dBA, whereas areas with levels of more than 85 dBA, between 80 and 85 dBA and below 80 dBA in Factory 2. Sound level meters were calibrated just before and after noise measurement.

Noise exposure among employees was measured using personal exposure noise dosimeter (Laws of Malaysia, 2010), calibrated and approved by the DOSH (Larson Davis, model Spark 706 RC and Spark 703+). The measurement was done in each job area, exceeding action level of the two factories. One employee represented a group of employees from the same job area (Laws of Malaysia, 2010). The noise dosimeters were worn by the participants for the entire shift while at work and were switched off during breaks. The average noise exposure was taken and recorded. The exchange rate of 5 dB was applied during measurement of noise in both study locations. The dosimeters were calibrated just before and after noise measurement.

We categorized groups of workers calculated for the area and not individual. This was practiced since within individuals, sound levels fluctuate from day to day(Rubak, et al., 2006).The instrument (sound level meter or dosimeter) which showed a higher measured level of noise, thus causing more damage to hearing, was used for calculating noise reduction rate (NRR).

Hearing threshold level

A manual audiometer was used to collect data on hearing threshold levels of the participants from Factory 1 and Factory 2, calibrated and approved by the DOSH (model asi 17 equipped with TDH-39 headphones). This audiometer was placed in a sound-proof booth, calibrated according to the Factories and Machinery (Noise Exposure) Regulations 1989(Laws of Malaysia, 2010). Initial audiometry assessments were taken as baseline audiograms and subsequent tests were taken at the first month for all participants from the two factories. The test frequencies measured were 500, 1000, 2000, 3000, 4000, 6000 and 8000 for both ears of the participants. To increase the reliability of measurements, two similar readings were taken before entering in the audiogram.

Intervention

Hearing protective device

Hearing protection devices (Laws of Malaysia, 2010) were used to reduce noise exposure levels among participants to levels ranged between permissible exposure limit and action level. These devices were distributed by safety and health officers to participants from the factories after initial audiometry assessments. Hearing protection devices were given to participants who were exposed to noise at and above permissible exposure limit. The noise levels were obtained after conducting noise area and personal noise exposure monitoring. Noise levels that showed higher results on these measurements among participants were taken into consideration for noise exposure reduction. The hearing protection devices are the reusable synthetic and corded types of earplugs. To ensure continuous usage of these devices, the participants were supervised at all times during work.

Noise levels in each job area were achieved by determining appropriate NRR. There was an addition of 7 dB to the calculated NRR in order to convert dBA to dBC. This calculation was done since the hearing protective devices were in dBC units. The figures obtained were then multiplied by 50% (50% derating) (Holthouser, 2000). The formula to calculate NRR is as follows:

$$\textit{Exposure of noise level in the specific job area} = \{\textit{Measured noise level} - [(NRR - 7) \times 50\%]\}$$ (Berger, et al., 2003)

(Factory 1 and Factory 2).

In Factory 1, the perceived noise level was reduced to levels between 85 and 90 dBA. In Factory 2, the perceived noise level was reduced to levels between 80 and 85 dBA.

Compliance

The continuous use of ear plugs among participants was ensured by providing checklists to supervisors of the two factories for monitoring purpose. We also monitored by regular spot checks in these factories on the use of these hearing protection devices.

Blinding

The participants and safety and health officers did not know the adoption of levels on permissible exposure limits. The outcome assessor (audiometric technicians) were blinded from the allocation arm, as they did not know which factory was adopting 85 or 90 dBA as the permissible exposure limit during the measurement of hearing thresholds. The same technicians (single observer for each worker) carried out the assessment at the outset and also at the first month. The statistician who analyzed the data was blinded to factories that had embraced 85 dBA or 90 dBA as the permissible exposure limits. We were not blinded as NRR needed to be considered in each job area for both factories.

Statistical analyses

The data analyses were performed using SPSS version 20 for Windows. Data of participants who were lost in follow-up were imputed as per-protocol analysis and by baseline values using intention-to-treat principle. An independent t-test was used to analyze the difference in means for continuous characteristics such as age and duration of employment variables. A Chi-square test was used to detect differences in the frequencies of categorical characteristics such as cigarette smoking, exposure to hand-arm vibration and also exposure to hobbies risk for hearing loss between participants of the two factories. A Fisher's exact test was used to detect differences in the frequencies of alcohol consumption among the participants in two groups. Finally, a Chi-square test for association was conducted between the participants from the two factories on development of standard threshold shifts at various frequencies. According to the Factories and Machinery (Noise Exposure) Regulations 1989(Laws of Malaysia, 2010), standard threshold shift is considered to occur if there is the presence of more than 10 dB shift over 2000 to 4000 Hz relative to the baseline audiogram. According to the OSHA regulations (Berger, et al., 2003; Kirchner et al., 2012; Occupational Safety & Health Administration, 2013), the shift is said to occur if there is a change of 10 dB and more over 2000 to 4000 Hz. As for NIOSH, the threshold shift is said to occur if the alteration is more than 15 dB at all frequencies, ranged from 500 to 8000 Hz(National Institute for Occupational Safety and Health, 1998).A p-value of less than 0.05 was considered statistically significant.

Ethical considerations

Written authorization was obtained from the relevant personnel to conduct this study in the automobile industry. Ethical approval was then obtained from the Research and Ethics Committee, University of Malaya (MEC Ref. No: 848.37). Participant information sheets were distributed to the participants, the objectives were specified, and maintenance of confidentiality was provided for, and that the participants were assured that they were free to opt out at any time during the study. The contact details were given in the event the participants intend to clarify any doubts pertaining to the study. The written informed consents were collected before participants were allowed to take part in this study.

Results

With reference to Table 1, mean age of the participants was 27.1 ± 6.56 years. The majority of the participants are males, and Malays accounted for more than 90% of the participants in this study. Most of these workers are single and more than 60% have ever smoked and hardly 3% of them ever consumed alcohol. More than one third of these employees have only secondary or primary school education and hence, most of them earned less than RM 3000. The mean duration of employment of the participants in the automobile industry was 2.4 ± 2.05 years More than a third had hobbies which could expose them to hearing loss such as listening to loud music, scuba diving and shooting. More than a third has been exposed to hand-arm vibration. Of the 203 subjects, 106 of them were from Factory 1, exposed to noise levels 90 dBA as the permissible exposure limit while 97 from Factory 2, have been exposed to 85 dBA. In Factory 1, employees work in the Production Control (PC) Press, Quality Control (QC) Press, welding and maintenance departments while in Factory 2, the workers were in the PC Resin, QC Resin, kaizen and painting departments. There are more than a fifth of subjects in each department. The basic socio-demographic characteristics and risk factors were compared between the two factories as shown in Table 1. All the independent variables between factories were not statistically significantly different.

Table 1: *Comparison of independent variables between participants from Factory 1 and Factory 2*

Characteristics/ Risk factors	Factory 1	Factory 2	*p* value
Age (years), mean (SD)	27.94 (7.25)	26.22 (5.60)	0.060*
Smoking, n (%)			
Ever smoked	74 (69.8)	64 (66.0)	0.559**
No smoking	32 (30.2)	33 (34.0)	
Alcohol consumption, n (%)			
Ever consumed alcohol	3 (2.8)	4 (4.1)	0.712***
Not consumed alcohol	103 (97.2)	93 (95.9)	
Duration of work (years), mean (SD)	2.45 (2.11)	2.37 (2.00)	0.798*
Exposure to hand-arm vibration, n (%)			
Exposed	83 (78.3)	66 (68.0)	0.098**
Not Exposed	23 (21.7)	31 (32.0)	
Exposure to hobbies risk for hearing loss, n (%)			
Exposed	40 (37.7)	33 (34.0)	0.582**
Not exposed	66 (62.3)	64 (66.0)	

*Statistical significance is based onIndependent t test; ** Statistical significance is based onChi-square test for independence; *** Statistical significance is based on

Fisher's exact test

Generally, noise measurement using sound level meter showed a higher level of noise exposure than average noise exposure of personal exposure noise dosimeter. Hence, noise levels that of sound level meter were used as noise exposure of the participants for calculating NRR. The mean noise exposure of participants from each department is shown in Table 2. There was no difference of noise exposure between participants from the two factories, [0.275 (95% CI, -0.42 to 0.97) dBA, t (164) = 0.78, p = 0.436].

Table 2: *Comparison of noise exposurebetween participants from Factory 1 and Factory 2*

Factory	Departments	Frequency (%) *n* = 203	Mean (SD) dBA
Factory 1	PC and QC Press	41 (20.2)	90.8 (0.75)
	Welding and Maintenance	65 (32.0)	87.2 (1.60)
Factory 2	PC Resin and QC Resin	44 (21.7)	88.6 (1.62)
	Kaizen and Painting	53 (26.1)	90.1 (2.50)

According to the Factories and Machinery (Noise Exposure) Regulations 1989

A Fisher's exact test for association was conducted to compare association between participants from the two factories andstandard threshold shifts. These tests for associations were conducted on both right and left ears at 2000, 3000 and 4000 Hz. All expected cell frequencies were not greater than five for both ears. Based on intention-to-treat analysis and as per-protocol analysis, there were no statistically significant associations between participants from the two factories and standard threshold shiftsat these frequencies on both ears as depicted in Table 3. Hence, there is no difference in terms of adopting different permissible exposure limits on standard threshold shift at these frequencies according to the Factories and Machinery (Noise Exposure) Regulations 1989 on right and left ears.

According to the OSHA regulations

A Chi-square test for association was conducted to compare association between participants from the two factories andstandard threshold shifts. These associations were conducted on both right and left ears at 2000, 3000 and 4000 Hz. All expected cell frequencies were greater than five for both ears. Based on intention-to-treat analysis and as per-protocol analysis, there were no statistically significant associations between participants from the two factories and standard threshold shiftsat these frequencies on both ears as depicted in Table 4. Hence, there was no difference in terms of adopting different permissible exposure limits on standard threshold shifts at these frequencies according to the OSHA regulationson right and left ears.

According to the NIOSH recommended standard

A Chi-square test of association was conducted to compare the association between participants from the two factories andstandard threshold shifts when all the expected cell frequencies were greater than five for both ears. These associations were conducted on both right and left ears at 500, 1000, 2000, 3000, 4000, 6000 and 8000

Hz. A Fisher's exact test of association was conducted to compare the association between participants from the two factories andstandard threshold shifts, when all of the expected cell frequencies were not greater than five for both ears. Based on intention-to-treat analysis and as per-protocol analysis, there were no statistically significant associations between participants from the two factories and standard threshold shiftsat these frequencies on both ears as shown in Table 5. Hence, there was no difference in adopting different permissible exposure limits on standard threshold shift at these frequenciesaccording to the NIOSH recommended standardon right and left ears.

Discussion

One of the causes of hearing loss is exposure to high levels of noise in industries (Haboosheh & Brown, 2012; Kirchner, et al., 2012).Exposure to sound level at or above 85 dBA(Rabinowitz, 2000) may result in permanent threshold shifts. The hair cells within the cochlea are damaged by high noise levels; results in permanent and irreversible damage (Rutka, 2011). Participants who followed-up were 62.6% at the first month of study. This was due to their busy schedules and the requirement to achieve daily productivity target. There were no differences in terms of occurrence of temporary standard threshold shifts between participants from the two factories, based on intention-to-treat analysis and as per-protocol analysis. The dissimilarities in standard threshold shifts were not noted according to the Factories and Machinery (Noise Exposure) Regulations 1989, OSHA regulations and NIOSH recommended standard. These findings were consistent with a cross-sectional study conducted in New Zealand. McBride et al. (McBride et al., 2004) revealed that employees exposed either below 85, 85 to 90 or more than 90 dBA in the workplace showed no statistically significant differences in threshold shifts between these three groups.

Variable (Factory)	Frequency (Ear)	Based on intention-to-treat analysis Factory 1 *n* = 106 Factory 2 *n* = 97				As per-protocol analysis Factory 1 *n* = 62 Factory 2 *n* = 65			
		STS n (%)	No STS n (%)	χ^2 statistic (df)	p value*	STS n (%)	No STS n (%)	χ^2 statistic (df)	p value*
Factory 1 Factory 2	2000 (Right)	0 (0.0) 4 (4.1)	106 (100.0) 93 (95.9)	-	0.050	0 (0.0) 4 (6.2)	62 (100.0) 61 (93.8)	-	0.119
Factory 1 Factory 2	2000 (Left)	1 (0.9) 2 (2.1)	105 (99.1) 95 (97.9)	-	0.607	1 (1.6) 2 (3.1)	61 (98.4) 63 (96.9)	-	1.000
Factory 1 Factory 2	3000 (Right)	1 (0.9) 3 (3.1)	105 (99.1) 94 (96.9)	-	0.350	1 (1.6) 3 (4.6)	61 (98.4) 62 (95.4)	-	0.619
Factory 1 Factory 2	3000 (Left)	3 (2.8) 1 (1.0)	103 (97.2) 96 (99.0)	-	0.623	3 (4.8) 1 (1.5)	59 (95.2) 64 (98.5)	-	0.357
Factory 1 Factory 2	4000 (Right)	5 (4.7) 3 (3.1)	101 (95.3) 94 (96.9)	-	0.723	5 (8.1) 3 (4.6)	57 (91.9) 62 (95.4)	-	0.485
Factory 1 Factory 2	4000 (Left)	5 (4.7) 2 (2.1)	101 (95.3) 95 (97.9)	-	0.448	5 (8.1) 2 (3.1)	57 (91.9) 63 (96.9)	-	0.266

Noise-induced hearing loss affects initially the high frequencies, followed by low frequencies. For the threshold shift to occur in these frequencies, one has to be exposed to high noise levels for at least 5 years (Rutka, 2011). In this study sample, majority of them were exposed to noise for less than 5 years. Due to the shorter duration of exposure to noise, significant changes in threshold shifts among participants were not observed, as occupational noise-induced hearing loss is a long-latency disease (Meyer, et al., 2002).

There was a possibility of cross-over effect of employees from the two factories where the participants may be placed in the other factory during the study. This was avoided by informing the occupier that the duration of this study was carried out for one month and that the participants should be placed in the same department and factory during this study period. The measurement of personal noise exposure level was done only for one subject in each work area. The measurement was done as such since all workers in a job area were exposed to similar levels of noise intensities. This is also in accordance to regulations for noise in Malaysia (Laws of Malaysia, 2010), where not all workers in a job area are required to undergo personal noise exposure measurement.

Table 3: *Comparison of association between standard threshold shifts and participants from the two factories according to the Factories and Machinery (Noise Exposure) Regulations 1989*
Statistical test is based on Fisher's exact test

Table 4: *Comparison of association between standard threshold shifts and participants from the two factories according to the OSHA regulations*

Variable (Factory)	Frequency (Ear)	Based on intention-to-treat analysis Factory 1 *n* = 106 Factory 2 *n* = 97				As per-protocol analysis Factory 1 *n* = 62 Factory 2 *n* = 65			
		STS n (%)	No STS n (%)	χ^2 statistic* (df)	p value*	STS n (%)	No STS n (%)	χ^2 statistic* (df)	p value*
Factory 1 Factory 2	2000 (Right)	4 (3.8) 7 (7.2)	102 (96.2) 90 (92.8)	1.17 (1)	0.279	4 (6.5) 7 (10.8)	58 (93.5) 58 (89.2)	0.75 (1)	0.387
Factory 1 Factory 2	2000 (Left)	5 (4.7) 7 (7.2)	101 (95.3) 90 (92.8)	0.57 (1)	0.451	5 (8.1) 7 (10.8)	57 (91.9) 58 (89.2)	0.27 (1)	0.602
Factory 1 Factory 2	3000 (Right)	10 (9.4) 11 (11.3)	96 (90.6) 86 (88.7)	0.20 (1)	0.656	10 (16.1) 11 (16.9)	52 (83.9) 54 (83.1)	0.01 (1)	0.904
Factory 1 Factory 2	3000 (Left)	8 (7.5) 10 (10.3)	98 (92.5) 87 (89.7)	0.48 (1)	0.489	8 (12.9) 10 (15.4)	54 (87.1) 55 (84.6)	0.16 (1)	0.689
Factory 1 Factory 2	4000 (Right)	13 (12.3) 12 (12.4)	93 (87.7) 85 (87.6)	0.00 (1)	0.982	13 (21.0) 12 (18.5)	49 (79.0) 53 (81.5)	0.13 (1)	0.723
Factory 1 Factory 2	4000 (Left)	11 (10.4) 12 (12.4)	95 (89.6) 85 (87.6)	0.20 (1)	0.654	11 (17.7) 12 (18.5)	51 (82.3) 53 (81.5)	0.01 (1)	0.916

*Statistical test is based on Chi-square test for independence

Table 5: *Comparison of association between standard threshold shiftsand participants from the two factories according to the NIOSH recommended standard*

Variable (Factory)	Frequency (Ear)	Based on intention-to-treat analysis Factory 1 *n* = 106 Factory 2 *n* = 97				As per-protocol analysis Factory 1 *n* = 62 Factory 2 *n* = 65			
		STS n (%)	No STS n (%)	χ^2 statistic (df)	p value	STS n (%)	No STS n (%)	χ^2 statistic (df)	p value
Factory 1 Factory 2	500 (Right)	0 (0.0) 3 (3.1)	106 (100.0) 94 (96.9)	-	0.107*	0 (0.0) 3 (4.6)	62 (100.0) 62 (95.4)	-	0.244*
Factory 1 Factory 2	500 (Left)	0 (0.0) 1 (1.0)	106 (100.0)	-	0.478*	0 (0.0) 1 (1.5)	62 (100.0)	-	1.000*

			96 (99.0)				64 (98.5)		
Factory 1 Factory 2	1000 (Right)	-	106 (100.0) 97 (100.0)	-	1.000*	-	62 (100.0) 65 (100.0)	-	1.000*
Factory 1 Factory 2	1000 (Left)	0 (0.0) 1 (1.0)	106 (100.0) 96 (99.0)	-	0.478*	0 (0.0) 1 (1.5)	62 (100.0) 64 (98.5)	-	1.000*
Factory 1 Factory 2	2000 (Right)	0 (0.0) 4 (4.1)	106 (100.0) 93 (95.9)	-	0.050*	0 (0.0) 4 (6.2)	62 (100.0) 61 (93.8)	-	0.119*
Factory 1 Factory 2	2000 (Left)	1 (0.9) 2 (2.1)	105 (99.1) 95 (97.9)	-	0.607*	1 (1.6) 2 (3.1)	61 (98.4) 63 (96.9)	-	1.000*
Factory 1 Factory 2	3000 (Right)	1 (0.9) 3 (3.1)	105 (99.1) 94 (96.9)		0.350*	1 (1.6) 3 (4.6)	61 (98.4) 62 (95.4)	-	0.619*
Factory 1 Factory 2	3000 (Left)	3 (2.8) 1 (1.0)	103 (97.2) 96 (99.0)	-	0.623*	3 (4.8) 1 (1.5)	59 (95.2) 64 (98.5)	-	0.357*
Factory 1 Factory 2	4000 (Right)	5 (4.7) 3 (3.1)	101 (95.3) 94 (96.9)	-	0.723*	5 (8.1) 3 (4.6)	57 (91.9) 62 (95.4)	-	0.485*

*Statistical test is based on Fisher's exact test, **Statistical test is based on Chi-square test for independence Table 5, continued

Variable (Factory)	Frequency (Ear)	Based on intention-to-treat analysis Factory 1 *n* = 106 Factory 2 *n* = 97				As per-protocol analysis Factory 1 *n* = 62 Factory 2 *n* = 65			
		STS n (%)	No STS n (%)	χ^2 statistic (df)	p value	STS n (%)	No STS n (%)	χ^2 statistic (df)	p value
Factory 1 Factory 2	4000 (Left)	5 (4.7) 2 (2.1)	101 (95.3) 95 (97.9)	-	0.448*	5 (8.1) 2 (3.1)	57 (91.9) 63 (96.9)	-	0.266*
'Factory 1 Factory 2	6000 (Right)	10 (9.4) 6 (6.2)	96 (90.6) 91 (93.8)	0.74 (1)	0.391**	10 (16.1) 6 (9.2)	52 (83.9) 59 (90.8)	1.37 (1)	0.242**
Factory 1 Factory 2	6000 (Left)	3 (2.8) 5 (5.2)	103 (97.2) 92 (94.8)	-	0.483*	3 (4.8) 5 (7.7)	59 (95.2) 60 (92.3)	-	0.718*
Factory 1	8000	4 (3.8)	102 (96.2)	-	0.739*	4 (6.5)	58	-	1.000*

Factory 2	(Right)	5 (5.2)	92 (94.8)			5 (7.7)	(93.5)		
							60		
							(92.3)		
Factory 1	8000	3 (2.8)	103 (97.2)	3.79 (1)	0.052**	3 (4.8)	59	3.01 (1)	0.083**
Factory 2	(Left)	9 (9.3)	88 (90.7)			9 (13.8)	(95.2)		
							56		
							(86.2)		

*Statistical test is based on Fisher's exact test, **Statistical test is based on Chi-square test for independence

Sound waves from external sources are heard through air conduction and bone conduction (Henry & Letowski, 2007). In air conduction, these sound waves travel via external auditory canal. Air conduction is affected once there is damage either in outer or middle ear. In bone conduction, the sound waves are transmitted directly to the cochlea through skull bones. Therefore, if there is any damage to inner ear or auditory nerve, the bone conduction is affected. Bone conduction is used to distinguish sensorineural from conductive hearing loss (Gelfand, 2009).Only air conduction was used to measure hearing threshold levels in this study. To ensure no damage to outer or middle ear, ear assessmentwas performed on all participants. The assessment was done using otoscopy examination at baseline and first month. Only participants who have no damage to ear were allowed to undergo audiometry assessment.

There were no differences on possible confounding factors between participants from the two factories such as smoking (Carmelo, et al., 2010),consumption of alcohol(Upile, et al., 2007) and exposure to hand-arm vibration (Pettersson, 2013). Differences among participants from the two factories on hobbies risk for hearing loss such as listening to loud music (Levey, et al., 2012), shooting(Pawlaczyk-Luszczynska, et al., 2004) and scuba diving (Newton, 2001) were not significant. No significant difference in threshold shifts among participants from the two factories in terms of age and employment duration.

Several preventive measures could be taken to control and prevent high levels of noise (Franks, et al., 1996; Kirchner, et al., 2012; Timmins, et al., 2010). One of the measures is to reduce emission of noise from the source (Concha-Barrientos, et al., 2004; World Health Organization, 1997). If engineering measures fail to reduce high levels of noise, then administrative methods are advocated (Franks, et al., 1996). In this approach, job rotation is encouraged so that duration of exposure to these high level noises is shortened among these employees. Both approaches above incurred cost. Finally, the last alternative to prevent hearing loss due to exposure to noise is by wearing hearing protection devices (Concha-Barrientos, et al., 2004). Though this is the last option, it is the cheapest solution for reducing noise exposure adopted by most in the industries, and is also adopted in this study.

Noise level is measured using sound level meter and noise dosimeter. The former would measure noise at the point of time, whereas the latter measures average exposure of an employee to noise in the job area (Levey, et al., 2012). The instrument which showed higher level measurement of noise would be taken for calculation of NRR as it was more damaging to hearing.

There were no differences between the respondents and nonrespondents in age (mean age was 27.1 ± 6.6 and 27.7 ± 7.0 among the respondents and nonrespondents respectively), gender, ethnicity and duration of work variables. A total of 62.6% followed-up till end of the study. However, the total number of subjects who participated from the two factories was more than the minimum sample size required and hence, the power of study was not affected. There were no differences between the participants who followed-up and those who had loss to follow-up in age (the mean age was 26.8 ± 6.4 and 27.6 ± 6.8 among those responded and loss to follow-up respectively), gender, ethnicity, education level and duration of work variables.

Universal sampling was adopted within these two factories. Findings in this study are arrived at based on data collected in the automobile industry and thus should not be generalized. More studies in future are required to be conducted on different types of industries to confirm the findings. This study was only conducted for a month and hence, the differences on threshold shifts on adoption of different permissible exposure limits were not substantial. More studies are required to confirm the current findings on employees. These studies should be carried out for a longer duration on these employees.

Conclusions

This study concludes that there were no differences in standard threshold shifts among employees based on adoption of 90 or 85 dBA as the permissible exposure limits. Based on the current findings, countries adopting 90 dBA as permissible exposure limit need not review their policies on lowering the limit, but rather ensure compliance in the use of hearing protection devices.

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