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Comparing Standard Threshold Shift among Employees Adopting 85 and 90 dBA as Permissible Exposure Limits over Six Months

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Abstract: The development of temporary threshold shifts among employees due to noise may lead to noise-induced hearing loss over time. The aim of this study is to explore occurrence of temporary standard threshold shifts on adopting different permissible exposure limits, 90 and 85 dBA. Countries such as Malaysia and US are adopting 90 dBA as permissible exposure limit. 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 where 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 standard threshold shifts were measured using manual audiometer. Hearing protection devices with appropriate noise reduction rate were used to reduce noise exposure among participants. According to National Institute of Occupational Safety and Health recommended standard, there was statistically significant association between participants from both factories and standard threshold shift at 1000 Hz. This change was noted on left ear at 6th month, $\chi^2(1) = 3.93$, $\varphi = -0.211$, $p = 0.047$ as per-protocol analysis. There were more threshold shifts on subjects adopting 90 dBA compared with 85 dBA. These temporary threshold shifts may progress to permanent threshold shifts over time. The prevalence of noise-induced hearing loss may be reduced on adoption of 85 dBA as permissible exposure limit.

Key words: Effects 85 or 90dBA, noise, threshold shift, noise-induced, over time

INTRODUCTION

The cochlea has organ of Corti which is embedded with sensory and non-sensory cells. The sensory cells appear to be hair-like structures, i.e., outer and inner cells. The outer sensory cells are not only more abundant but arranged in three rows compared to the inner cells with only one row (Rutka, 2011). The outer hair cells are more prone to damage due to noise and ototoxic drugs. 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 >8 h of duration (Franks *et al*., 1996). The US National Institute of Occupational Safety and Health (NIOSH) recommends an exposure limit of 85 dBA (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 Malaysia (Laws of Malaysia, 2010), India and the US (Madison, 2007) are adopting 90 dBA as the permissible exposure limit. There were a total of 663 cases of occupational diseases had been investigated in Malaysia for the year 2010. From this total, around 70% of them were diagnosed to have noise-induced hearing loss, making it as the most common occupational disease (DOSH, 2013). The present study is conducted with the aim of exploring occurrence of temporary standard threshold shifts upon adoption of different permissible exposure limits. It is of utmost importance to determine adoption of permissible exposure

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limit scientifically as legal limit, since it will impose cost and enforcement issues besides introducing the necessity of hearing protection among workers.

MATERIALS AND 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 of one factory (Factory 1) were exposed to permissible exposure limits of 90 dBA while the other (Factory 2) exposed to 85 dBA. Upon enrolment into the study, hearing threshold level was measured at baseline and then followed-up at the 6th month. These hearing threshold levels were measured before participants began to work at baseline and 6th month where they should not be exposed to noise levels beyond 80 dBA for a period of 14 h (Laws of Malaysia, 2010). This study was conducted from February-August 2012.

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 was provided about this study to the participants and written consent was obtained. The participation of employees was voluntary and included after obtaining written informed consent.

All subjects in each factory exposed to noise level above action level were recruited into this study. The action level is defined as sound level of 85 dBA in the first factory and 80 dBA in the second factory. The daily noise doses were = 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. The exclusion criteria were subjects who refused to participate, contract workers since, they were not permanently employed, lorry drivers since, they were not stationed in the factory, those having diseases of the ear such as chronic suppurative otitis media or malignancy, employees who had experienced physical trauma to ear due to penetrating injury or fall and those who had undergone ear surgery. This information was obtained from a questionnaire.

Sample size: Population of this research was participants from two factories in an automobile industry, exposed to noise levels beyond action level. The participants of the two factories were exposed to different noise levels which ranged from 80-98 dBA upon conducting initial noise area measurement. All of them worked in a shift of 8 h. The total population exposed to noise levels above the action level was 260. Of the eligible participants, 203 of them had participated in this study. The nonrespondents were those who were involved in very busy work procedures and who had the predilection not to participate in the study. Based on the results of an earlier study (Yates *et al*., 1976), the sample size required was 43 respondents for each factory based on a two-sided significance level of 0.05 and power of 80%. The calculation of sample size was based on the Power and Sample Size Calculations software (Dupont and Plummer, 1990; Pearson and 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 providing them with incentives to participate (food).

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 >90 dBA, between 85 and 90 dBA and below 85 dBA whereas areas were divided into levels of >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. 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).

Standard threshold shifts: A manual audiometer was used to collect data on standard threshold shifts of the participants from Factory 1 and 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 6th month to all participants of the two factories. The test frequencies measured were 500, 1000, 2000, 3000, 4000, 6000 and 8000 on both ears of participants. To increase the reliability of measurements, two similar readings were taken before entering in the audiogram.

Intervention

Hearing protective device: Hearing protection devices (earplugs) (Laws of Malaysia, 2010) were used to reduce noise exposure levels among participants to levels between permissible exposure limit and action level. These devices were distributed by the safety and health officers to participants of the two factories after the initial audiometry assessments. Hearing protection devices were given to participants who were exposed 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 were taken into calculation for noise exposure reduction. The hearing protection devices were made-up of synthetic and corded types of earplugs which are reusable. To ensure continuous usage of these devices, the participants were supervised at all times during work.

Noise levels of each job area were achieved by determining appropriate Noise Reduction Rate (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 (Factory 1 and 2):

$$\text{Exposure of noise level in the specific job area} = \{\text{Measured noise level} - [(\text{NRR}-7)\times 50\%]\}$$

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 (Berger *et al*., 2003).

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

Blinding: The participants and safety and health officers were blinded to the adoption of levels of permissible exposure limits. The outcome assessor was blinded to the allocation arm during the measurement of hearing threshold levels of the subjects. The statistician who analyzed the data was blinded to which factories had embraced 85 dBA or 90 dBA as permissible exposure limits. We were not blinded as the NRR needed to be considered in each job area for the two factories.

Statistical analyses: The data analyses were performed using SPSS version 20 for Windows. Data for participants who were lost to follow-up were imputed by baseline values using intention-to-treat principle and as per-protocol analysis. An independent t-test was used to analyze a difference in mean for continuous characteristics such as age between subjects who adopted 85 and 90 dBA. 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 from the two factories. A Fisher's exact test was used to detect differences in the frequencies of alcohol consumption among the two groups. A Gamma test was used to detect differences in the frequencies of duration of employment between the two groups exposed to different permissible exposure limits. Finally, a Chi-square test for association was conducted between participants from the two factories and standard threshold shift for 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 presence of more than 10 dB shift over 2000-4000 Hz relative to baseline audiogram. According to the OSHA regulations (Berger *et al*., 2003; Kirchner *et al*., 2012; Occupational Safety and Health Administration, 2013), the shift is said to occur if there is a change of 10 dB and more over 2000-4000 Hz. As for NIOSH, the threshold shift is said to occur if the alteration is more than 15 dB at all tested frequencies, ranged from 500-8000 Hz (National Institute for Occupational Safety and Health, 1998). A $p<0.05$ 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). The participants' information sheets were distributed to the participants, specifying the objectives, maintenance of confidentiality and that the participants were free to opt-out at any time during the study. Contact details were given in the event the participants needed to clarify any doubts pertaining to the study. The written informed consent forms were collected before participants were allowed to take part in this study.

RESULTS

Mean age of the employees was about 27.1±6.56. The majority of these participants were Malays males accounted for >95%. Most of these workers were single and >60% had ever smoked and hardly 3% of them ever consumed alcohol. More than one third of these employees had only secondary or primary school education and hence, most of them earned <RM3000. Almost 90% of them worked <5 years in these factories. More than a third was exposed to hobbies which may contribute to hearing loss such as hearing loud music, scuba diving and shooting. More than a third had 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 had been exposed to 85 dBA. In Factory 1, employees were working 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 were >5th of subjects in each department. The basic socio-demographic characteristics and risk factors for hearing loss were compared between the two factories as shown in Table 1. All the independent variables between factories were not statistically significantly different.

According to the Factories and Machinery (Noise Exposure) Regulations 1989: Chi-square test for association was conducted to compare association between participants from the two factories and standard threshold shift. These associations were conducted to 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 shift at these frequencies on both ears as depicted in Table 2. Hence, there was no

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

Characteristics/Risk factors	Factory 1	Factory 2	p-value
Age, 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 (n, %)			
0-12 months	34 (32.1)	28 (28.9)	0.909****
1-<5years	58 (54.7)	59 (60.8)	
5 years and more	14 (13.2)	10 (10.3)	
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 on Independent t test, Chi-square test, Fisher's exact test and Gamma test

Table 2: Comparison on association between standard threshold shift and participants according to the factories and machinery (noise exposure) Regulations 1989

Variable (Factory)	Frequency (Ear)	Based on intention-to-treat analysis Factory 1 and 2 n = 106, 97 STS*n (%)	No STSn (%)	χ^2 statistic* (df)	p-value*	As per-protocol analysis Factory 1 and 2 n = 48, 40 STS n (%)	No STS n (%)	χ^2 statistic* (df)	p-value*
Factory 1	2000	17 (16.0)	89 (84.0)	1.44 (1)	0.230	17 (35.4)	31 (64.6)	2.55 (1)	0.110
Factory 2	(Right)	10 (10.3)	87 (89.7)			8 (20.0)	32 (80.0)		
Factory 1	2000	16 (15.1)	90 (84.9)	0.62 (1)	0.431	16 (33.3)	32 (66.7)	0.73 (1)	0.394
Factory 2	(Left)	11 (11.3)	86 (88.7)			10 (25.0)	30 (75.0)		
Factory 1	3000	16 (15.1)	90 (84.9)	0.02 (1)	0.894	16 (33.3)	32 (66.7)	0.11 (1)	0.738
Factory 2	(Right)	14 (14.4)	83 (85.6)			12 (30.0)	28 (70.0)		
Factory 1	3000	22 (20.8)	84 (79.2)	1.39 (1)	0.239	20 (41.7)	28 (58.3)	0.78 (1)	0.376
Factory 2	(Left)	14 (14.4)	83 (85.6)			13 (32.5)	27 (67.5)		
Factory 1	4000	25 (23.6)	81 (76.4)	0.77 (1)	0.381	25 (52.1)	23 (47.9)	1.28 (1)	0.258
Factory 2	(Right)	18 (18.6)	79 (81.4)			16 (40.0)	24 (60.0)		
Factory 1	4000	28 (26.4)	78 (73.6)	1.33 (1)	0.249	26 (54.2)	22 (45.8)	0.73 (1)	0.392
Factory 2	(Left)	19 (19.6)	78 (80.4)			18 (45.0)	22 (55.0)		

*Chi-square test for independence; STS: Standard Threshold Shift

Table 3: Comparison on association between standard threshold shift and participants according to the OSHA regulations

Variable (Factory)	Frequency (Ear)	Based on intention-to-treat analysis Factory 1 and 2 n = 106, 97				As per-protocol analysis Factory 1 and 2 n = 48, 40			
		STSn (%)	No STS n (%)	χ^2 statistic* (df)	p-value*	STS n (%)	No STS n (%)	χ^2 statistic* (df)	p-value*
Factory 1	2000	41 (38.7)	65 (61.3)	1.73 (1)	0.189	39 (81.2)	9 (18.8)	2.98 (1)	0.084
Factory 2	(Right)	29 (29.9)	68 (70.1)			26 (65.0)	14 (35.0)		
Factory 1	2000	34 (32.1)	72 (67.9)	0.98 (1)	0.323	32 (66.7)	16 (33.3)	1.83 (1)	0.176
Factory 2	(Left)	25 (25.8)	72 (74.2)			21 (52.5)	19 (47.5)		
Factory 1	3000	36 (34.0)	70 (66.0)	0.02 (1)	0.883	32 (66.7)	16 (33.3)	0.01 (1)	0.934
Factory 2	(Right)	32 (33.0)	65 (67.0)			27 (67.5)	13 (32.5)		
Factory 1	3000	34 (32.1)	72 (67.9)	0.25 (1)	0.620	32 (66.7)	16 (33.3)	1.25 (1)	0.263
Factory 2	(Left)	28 (28.9)	69 (71.1)			22 (55.0)	18 (45.0)		
Factory 1	4000	43 (40.6)	63 (59.4)	0.04 (1)	0.840	40 (83.3)	8 (16.7)	0.48 (1)	0.490
Factory 2	(Right)	38 (39.2)	59 (60.8)			31 (77.5)	9 (22.5)		
Factory 1	4000	44 (41.5)	62 (58.5)	0.41 (1)	0.522	39 (81.2)	9 (18.8)	0.50 (1)	0.478
Factory 2	(Left)	36 (37.1)	61 (62.9)			30 (75.0)	10 (25.0)		

Table 4: Comparison on association between standard threshold shift and participants according to the NIOSH recommended standard

Variable (Factory)	Frequency (Ear)	Based on intention-to-treat analysis Factory 1 and 2 n = 106, 97				As per-protocol analysis Factory 1 and 2 n = 48, 40			
		STS n (%)	No STS n (%)	χ^2 statistic* (df)	p-value*	STS n (%)	No STS n (%)	χ^2 statistic* (df)	p-value*
Factory 1	500	11 (10.4)	95 (89.6)	0.00 (1)	0.987	11 (22.9)	37 (77.1)	0.00 (1)	0.963
Factory 2	(Right)	10 (10.3)	87 (89.7)			9 (22.5)	31 (77.5)		
Factory 1	500	5 (4.7)	101 (95.3)	1.05 (1)	0.305	10 (20.8)	38 (79.2)	0.50 (1)	0.48
Factory 2	(Left)	8 (8.2)	89 (91.8)			6 (15.0)	34 (85.0)		
Factory 1	1000	22 (20.8)	84 (79.2)	0.60 (1)	0.437	22(45.8)	26 (54.2)	0.30 (1)	0.582
Factory 2	(Right)	16 (16.5)	81 (83.5)			16 (40.0)	24 (60.0)		
Factory 1	1000	19 (17.9)	87 (82.1)	3.18 (1)	0.074	19 (39.6)	29 (60.4)	3.93 (1)	0.047
Factory 2	(Left)	9 (9.3)	88 (90.7)			8 (20.0)	32 (80.0)		
Factory 1	2000	17 (16.0)	89 (84.0)	1.44 (1)	0.23	17 (35.4)	31 (64.6)	2.55 (1)	0.11
Factory 2	(Right)	10 (10.3)	87 (89.7)			8 (20.0)	32 (80.0)		
Factory 1	2000	16 (15.1)	90 (84.9)	0.62 (1)	0.431	16 (33.3)	32 (66.7)	0.73 (1)	0.394
Factory 2	(Left)	11 (11.3)	86 (88.7)			10 (25.0)	30 (75.0)		
Factory 1	3000	16 (15.1)	90 (84.9)	0.02 (1)	0.894	16 (33.3)	32 (66.7)	0.11 (1)	0.738
Factory 2	(Right)	14 (14.4)	83 (85.6)			12 (30.0)	28 (70.0)		
Factory 1	3000	22 (20.8)	84 (79.2)	1.39 (1)	0.239	20 (41.7)	28 (58.3)	0.78 (1)	0.376
Factory 2	(Left)	14 (14.4)	83 (85.6)			13 (32.5)	27 (67.5)		
Factory 1	4000	25 (23.6)	81 (76.4)	0.77 (1)	0.381	25 (52.1)	23 (47.9)	1.28 (1)	0.258
Factory 2	(Right)	18 (18.6)	79 (81.4)			16 (40.0)	24 (60.0)		
Factory 1	4000	28 (26.4)	78 (73.6)	1.33 (1)	0.249	26 (54.2)	22 (45.8)	0.73 (1)	0.392
Factory 2	(Left)	19 (19.6)	78 (80.4)			18 (45.0)	22 (55.0)		
Factory 1	6000	21 (19.8)	85 (80.2)	0.00 (1)	0.968	20 (41.7)	28 (58.3)	0.03 (1)	0.874
Factory 2	(Right)	19 (19.6)	78 (80.4)			16 (40.0)	24 (60.0)		
Factory 1	6000	18 (17.0)	88 (83.0)	0.44 (1)	0.507	17 (35.4)	31 (64.6)	0.46 (1)	0.497
Factory 2	(Left)	20 (20.6)	77 (79.4)			17 (42.5)	23 (57.5)		
Factory 1	8000	13 (12.3)	93 (87.7)	0.74 (1)	0.39	12 (25.0)	36 (75.0)	1.05 (1)	0.306
Factory 2	(Right)	16 (16.5)	81 (83.5)			14 (35.0)	26 (65.0)		
Factory 1	8000	11 (10.4)	95 (89.6)	1.64 (1)	0.2	10(20.8)	38 (79.2)	1.54 (1)	0.215
Factory 2	(Left)	16 (16.5)	81 (83.5)			13 (32.5)	27 (67.5)		

*Chi-square test for independence; STS: Standard Threshold Shift

difference on adopting different permissible exposure limits on standard threshold shift at these frequencies 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 factories and standard threshold shift. These associations were conducted to 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 shift at these frequencies on both ears as depicted in Table 3. Hence, there was no

difference on adopting different permissible exposure limits on standard threshold shift at these frequencies on right and left ears.

According to the NIOSH recommended standard: A Chi-square test for association was conducted to compare association between participants from the two factories and standard threshold shift. These associations were conducted to both right and left ears at 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. All expected cell frequencies were >5 for both ears. Based on intention-to-treat analysis, there were no statistically significant associations between participants from the two factories and standard threshold shift at these frequencies on both ears as depicted in Table 4. However as per-protocol analysis, there was statistically significant association between participants from the two factories and standard threshold shift at 1000 Hz on left ear at the 6th month, χ^2 (1) = 3.93, φ = -0.211, p = 0.047. The finding indicated there was a moderate association between adoption of 90 dBA and worsening of temporary threshold shifts seen among participants from Factory 1. Hence, there was a difference on adopting different permissible exposure limits on standard threshold shift at this frequency on left ear. At other frequencies, there were no statistically significant associations between participants from the two factories and standard threshold shift at these frequencies on both ears as shown in Table 4.

DISCUSSION

One of the causes of hearing loss is exposure to high noise levels in industries (Haboosheh and Brown, 2012; Kirchner *et al*., 2012). The hair cells within the cochlea are damaged due to high noise levels, resulting in permanent and irreversible damage (Rutka, 2011). In this population, as per-protocol analysis, 39.6% of subjects showed temporary threshold shifts on adoption of 90 dBA as the permissible exposure limit at 1000 Hz on left ear in Factory 1, compared to 20% over Factory 2. These findings were consistent with that of Lawton (2001) as temporary threshold shifts may progress to permanent threshold shifts (Lawton, 2001) over time if exposed to noise levels beyond 85 dBA. These significant changes on the threshold shifts were seen conferring to the NIOSH recommended standard (National Institute for Occupational Safety and Health, 1998) as all frequencies were tested, ranging from 500-8000 Hz. On the contrary, there were no statistically significant changes noted among participants from the two factories based on intention-to-treat analysis. This may be explained as only 43.3% of the subjects had turned-up for follow-up audiometry assessment at the 6th month.

The findings indicated that mid-frequency may be involved on threshold shifts which is consistent with a study conducted by Idota *et al.* (2010). As for NIOSH, the threshold shift is said to occur if the alteration is >15 dB at all the tested frequencies, 500-8000 Hz (National Institute for Occupational Safety and Health, 1998). However, we observed no statistically significant changes among participants adopted 90 or 85 dBA as the permissible exposure limits when the Factories and Machinery (Noise Exposure) Regulations 1989 (Laws of Malaysia, 2010) and OSHA regulations (Berger *et al*., 2003; Kirchner *et al*., 2012; Occupational Safety and Health Administration, 2013) were anticipated. According to the Factories and Machinery (Noise Exposure) Regulations 1989 (Laws of Malaysia, 2010) and OSHA regulations (Berger *et al*., 2003; Kirchner *et al*., 2012; Occupational Safety and Health Administration, 2013), standard threshold shift is considered only when shifts occurred over 2000-4000 Hz. Hence, all frequencies should be tested to recognize temporary threshold shifts early as recommended by the NIOSH (National Institute for Occupational Safety and Health, 1998) in order to prevent noise-induced hearing loss.

There is an experimental study (Takagi *et al*., 1988) conducted on noise-induced temporary threshold shifts in Japan. The exposure group, three to five subjects were exposed to noise levels between 65 and 86 dB for 24 h. The control group was not exposed to noise. The hearing threshold levels were measured on right ear for both these groups. There were no statistically significant changes on threshold levels among control group. However, among exposure group, temporary threshold shifts increased as noise levels increased. The study was accentuated by Yates *et al.* (1976) where the findings showed that the damaging effects on threshold shift of subjects exposed to full-day noise of 85 dBA was equivalent with 90 dBA half-day. Hence, it would be more appropriate to institute hearing conservation program (Kirchner *et al*., 2012) at 80 dBA where action can be taken to reduce noise exposure among employees, also known as action level and to adopt 85 dBA as the permissible exposure limit.

There was a possibility of cross-over effect of employees from 2 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 6 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.

Sound waves from external sources are heard through air conduction and bone conduction (Henry and 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 that there was no damage to outer or middle ear, ear assessment was performed for all participants. The assessment was done using otoscopy examination at baseline and 6th month. Only participants who have no damage to ear were allowed to undergo audiometry assessment.

There were no differences on possible confounding factors among participants of 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). There were also no significant differences noted 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). Age and employment duration among employees in both factories were also not significantly different.

There are a few measures which may be taken in order 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; WHO, 1997). The employer may need to reduce noise emitted from vibration of the machines by damping process or by controlling noise at path such as creating barriers. If engineering measures fail to reduce high levels of noise, then administrative methods are advocated (Franks *et al*., 1996). In this approach, job rotation was encouraged so that duration of exposure to these high level noises was shortened among these employees. Both approaches above incurred cost. Finally, the last alternative to prevent hearing loss due to noise is by wearing hearing protection devices (Concha-Barrientos *et al*., 2004). Though, it is the last option, it is the cheapest solution for reducing noise exposure adopted by most of the industries and was also adopted in this study.

Noise level was 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 over 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 is more damaging to hearing.

Universal sampling was adopted within these two factories. The findings were limited to the automobile industry and so, more studies in future are required to be conducted on different types of industries to confirm the findings.

CONCLUSION

The findings of this study suggest that adoption of 85 dBA as the permissible exposure limit has reduced occurrence of standard threshold shifts among participants (at 1000 Hz) compared to those at 90 dBA. The results of this study, suggest that steps should be taken by countries to review their policy with regards to the permissible exposure limit in order to reduce prevalence of noise-induced hearing loss.

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