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The Impact of Different Permissible Exposure Limits on Hearing Threshold Levels Beyond 25 dBA

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Background: Development of noise-induced hearing loss is reliant on a few factors such as frequency, intensity, and duration of noise exposure. The occurrence of this occupational malady has doubled from 120 million to 250 million in a decade. Countries such as Malaysia, India, and the US have adopted 90 dBA as the permissible exposure limit. According to the US Occupational Safety and Health Administration (OSHA), the exposure limit for noise is 90 dBA, while that of the US National Institute of Occupational Safety and Health (NIOSH) is 85 dBA for 8 hours of noise exposure.
Objectives: This study aimed to assess the development of hearing threshold levels beyond 25 dBA on adoption of 85 dBA as the permissible exposure limit compared to 90 dBA.
Patients and Methods: This is an intervention study done on two automobile factories. There were 203 employees exposed to noise levels beyond the action level. Hearing protection devices were distributed to reduce noise levels to a level between the permissible exposure limit and action level. The permissible exposure limits were 90 and 85 dBA in factories 1 and 2, respectively, while the action levels were 85 and 80 dBA, respectively. The hearing threshold levels of participants were measured at baseline and at first month of postshift exposure of noise. The outcome was measured by a manual audiometer. McNemar and chi-square tests were used in the statistical analysis.
Results: We found that hearing threshold levels of more than 25 dBA has changed significantly from pre-intervention to post-intervention among participants from both factories (3000 Hz for the right ear and 2000 Hz for the left ear). There was a statistically significant association between participants at 3000 Hz on the right ear at 'deteriorated' level ($\chi^2(1) = 4.08$, $\varphi = -0.142$, $P = 0.043$), whereas there was worsening of hearing threshold beyond 25 dBA among those embraced 90 dBA.
Conclusions: The adoption of 85 dBA as the permissible exposure limit has preserved hearing threshold level among participants at 3000 Hz compared to those who embraced 90 dBA.

Keywords: Effects 85 or 90 dBA; Noise; Noise-Induced Hearing Loss; Threshold Shift

1. Background

Occupational noise-induced hearing loss is the development of hearing loss because of exposure to high levels of noise (1). There are different views with regard to the levels of noise leading to this slow and irreversible malady. According to the US Occupational Safety and Health Administration (OSHA), the permissible exposure limit is 90 dBA; an employee should not be exposed beyond this level for more than 8 hours (2). The US National Institute of Occupational Safety and Health (NIOSH), recommends 85 dBA (2).

The lower level recommended by the NIOSH was based on a study (2) where the occurrence of material hearing impairment was lower upon adoption of 85 dBA (as the permissible exposure limit) compared to 90 dBA. Countries such as Malaysia, India and the US adopted 90 dBA as the permissible exposure limit. The occurrence of noise-induced hearing loss has doubled from 120 million in 1995 to 250 million in 2004 worldwide (3). Millions of workers in the US are exposed to noise levels above the permissible exposure limit. There were a total of 663 cases of occupational diseases who had been investigated in Malaysia in 2010. Around 70% of them were diagnosed to have noise-induced hearing loss, making it the most common occupational disease (4). However, there are few studies in the literature comparing the effectiveness of adopting these permissible exposure limits on noise.

2. Objectives

The hearing threshold beyond 25 dBA affects the hearing sensitivity for speech (5), both mid and high frequencies. The purpose of this study was to assess the development of hearing threshold levels beyond 25 dBA on adoption of

85 dBA (as permissible exposure limits) compared with 90 dBA. It is of utmost importance to determine scientifically adoption of the permissible exposure limit as a legal limit, since it will impose cost and enforcement issues.

3. Patients and Methods

3.1. Design and Setting

We conducted an intervention study by comparing two factories adopting different permissible exposure limits in an automobile industry in Selangor, Malaysia. This intervention consisted of using appropriate hearing protection devices among participants from both factories. Participants of factory 1 were exposed to a permissible exposure limit of 90 dBA, and those from factory 2 were exposed to the level of 85 dBA. Upon enrolment into the study, hearing threshold levels of the participants were measured at baseline and then followed up one month later. These hearing threshold levels were measured before the participants began to work at baseline, where they should not be exposed to noise levels above 80 dBA for a period of 14 hours (6). At the first month, the hearing threshold levels were measured one hour before the end of a shift. A shift lasts for 8 hours. This study was conducted from March 2012 to April 2012.

3.2. Subjects

Recruitment of the study area was initiated through online requests to the safety and health officers, and the details of study information were explained. Upon approval to conduct the study, relevant information was provided to the participants. The participation of employees was voluntary and upon obtaining written informed consent. Universal sampling was applied in this study. The eligible participants were those exposed to noise level above the action level. The action level is defined as a sound level of 85 dBA in factory 1 and 80 dBA in factory 2, where the daily noise doses were equal to 0.5 in both factories (6). The amount of exposure is half the dose of the permissible exposure limits. The exclusion criteria were subjects who refused to participate, contract workers (since they were not continuously employed), lorry drivers, those having ear diseases, experienced physical trauma to the ear, or undergone ear surgeries.

These particulars were obtained from a questionnaire. 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 working in PC resin, QC resin, kaizen and painting departments. There were 260 workers exposed to noise levels above the action level. Of them, 203 agreed to participate in the study. The non-respondents' excuses were their busy work schedule, or simply not willing to participate in the study. Based on the outcome a previous study (7), the required sample size was 43 respondents for each factory based on a 2-sided significance level of 0.05 and power of 80% (Table 1). The calculation of sample size was done by a calculation software based on the power (8). Taking into account the 20% drop out, the minimum required sample size was 52 in each factory. The sample size limitation was addressed by calling the employees through phone call and provided them incentives (food) to participate.

3.3. Measures

3.3.1. Noise Area and Personal Exposure Noise Measurement

Noise area measurement was measured using sound level meter (6), 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 of more than 90 dBA, between 85 and 90 dBA, and below 85 dBA, whereas in factory 2, the zones comprised areas more than 85 dBA, between the range of 80 and 85 dBA, and below 80 dBA. Sound level meters were calibrated just before and after the noise measurement. Noise exposure among employees was measured by a personal exposure noise dosimeter (6), calibrated and approved by the DOSH (Larson Davis, model Spark 706 RC and Spark 703 +).

The measurement was done in each job area, exceeding the action level. One employee represented a group of employees from the same job area for the measurement of noise exposure (6). The noise dosimeters were worn by the participants for the entire shift and were switched off during breaks. The average noise exposure was recorded too. The exchange rate of 5 dB was applied during measurement of noise. The dosimeters were calibrated just before and after noise measurement. We categorized workers calculated for the area and not the individual. This method was practiced, because within individuals, sound levels fluctuate from day to day (9). The instrument which showed a higher measured level of noise (thus causing more damage to hearing) is used for calculating noise reduction rate (NRR).

3.4. Hearing Threshold Level

A manual audiometer was used to collect data on hearing threshold levels of the participants in factories 1 and 2, calibrated and approved by the DOSH (model as 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 (6). Initial audiometry assessments were taken as baseline audiograms and subsequent audiometry tests were taken after one month for all participants of both factories. The test frequencies measured were 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz for both ears. To increase the reliability of the measurements, two consistent readings were taken before entering them in the audiogram. There were two trained audiometric technicians (single observer for each worker) at a time carrying out the measurement of hearing thresholds. The measurements were done randomly on the subjects. They 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 process. The same technicians carried out the assessment at the outset of the intervention and one month later.

3.5. Intervention

3.5.1. Hearing Protective Device

Hearing protection devices (6) were used to reduce noise exposure levels among participants to the levels which ranged between the permissible exposure limit and action level. These devices were distributed by the safety and health officers to participants after the initial audiometry assessments. The hearing protection devices were made-up of synthetic and corded types of ear plugs, 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 the 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. Then, the obtained figures were multiplied by 50% (50% derating). NRR is calculated as follows:

Exposure of noise level in the specific job area = Measured noise level – [(NRR - 7) × 50%] (10) (factory 1 or factory 2).

In factory 1, the perceived noise levels were reduced to intensities between 85 and 90 dBA. In factory 2, the levels were reduced to intensities between 80 and 85 dBA.

3.6. Compliance

The continuous use of ear plugs among participants was insured by providing a checklist to the supervisors of both factories. We also monitored that by conducting regular spot checks to these factories on the use of these hearing protection devices.

3.7. Blinding

The participants and the safety and health officers were blinded to the adoption of levels of permissible exposure limits. The outcome assessors were also blinded to participants from either factory, during hearing threshold levels measurement. The statistician who analyzed the data was also blinded to factories that had embraced 85 dBA or 90 dBA as permissible exposure limits. However, we were not blinded as the NRR was needed in each job area of both factories.

3.8. Statistical Analyses

The data analyses were performed using SPSS version 20 for Windows. Data from the participants who missed the follow-up were imputed by baseline values using the intention-to-treat analysis. An independent t test, chi-square test and Fisher exact test were used in the statistical analysis. A McNemar test was conducted to detect any change over hearing threshold levels beyond 25 dBA among participants over one month. These changes were temporary threshold shifts.

If there were changes, a chi-square test for association would be conducted among participants. Hearing threshold levels would be said to be 'preserved' if the levels were at or below 25 dBA after intervention. Before intervention, these participants had hearing threshold levels beyond 25 dBA. If the hearing threshold levels among subjects before and after intervention were at or below 25 dBA, the intervention would be said to have 'maintained preservation'. On the other hand, hearing threshold levels would be considered 'deteriorated', if the hearing threshold levels among subjects were beyond 25 dBA after intervention. Before intervention, these subjects had hearing threshold levels at or below 25 dBA. If the hearing threshold levels among subjects before and after intervention were remained unchanged, beyond 25 dBA, then adoption of the permissible exposure limit would result in 'continue deteriorated' of hearing threshold levels. A P value of less than 0.05 was considered statistically significant.

3.9. Ethical Considerations

Written authorization was obtained from the relevant personnel to conduct this study in the automobile factories. 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 intervention.

4. Results

The mean age of the participants was 27.1 ± 6.6 y. The majority of the participants were Malay male (> 90%). Most of these workers were single, and more than 60% of them had never smoked. About 3% of these subjects had never consumed alcohol. More than one-third of these employees had only secondary or primary school education and hence, most of them earned less than RM 3000. Almost 90% of them have worked for less than 5 years. More than one-third were exposed to hobbies which may contribute to hearing loss such as listening to loud music, scuba diving, or shooting. More than one-third of them were exposed to hand-arm vibration. There were 106 participants from factory 1 and the remaining 97 of them were from factory 2. There were more than a-fifth of subjects in each department of both factories. The basic socio-demographic characteristics and risk factors for hearing loss were compared, as shown in Table 2. All the independent variables between the participants of two factories were not statistically different.

A chi-square test for association were conducted between factories and hearing threshold level beyond 25 dBA at 500 to 8000 Hz over right and left ear at baseline. All expected cell frequencies were greater than five. There were no statistically significant associations were seen at all baseline frequencies (Table 3). A McNemar test was conducted between participants in both factories with the hearing threshold level beyond 25 dBA. These associations were conducted to both right and left ears of the subjects at 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. The hearing threshold levels more than 25 dBA has changed significantly from pre-intervention to post-intervention among participants from factory 1 and factory 2 at 3000 Hz of the right ear and 2000 Hz of the left ear, respectively (Tables 4 and 5).

Hence there were differences on adopting different permissible exposure limits at the first month on the hearing threshold level beyond 25 dBA at these frequencies on right and left ears. A chi-square test was conducted to compare the association between participants from both factories and the change on hearing threshold level beyond 25 dBA over one month. These associations were conducted on both right and left ears of the participants on frequencies that showed statistically significant differences in McNemar test. Fisher exact test was performed if the assumptions of chi-square were not met. There was statistically significant association between participants from both factories and change on hearing threshold level beyond 25 dBA for the frequency of 3000 Hz on right ear at 'deteriorated' level (χ^2 (1) = 4.08, φ = -0.145, P = 0.043). The finding indicated that there was a weak association between the adoption of different permissible exposure limits and the worsening of hearing threshold levels. There were more participants who showed deteriorated hearing threshold levels beyond 25 dBA despite using hearing protection devices in factory 1 adopting 90 dBA compared to factory 2 adopting 85 dBA at 3000 Hz (Table 6). On other frequencies, no statistically significant associations were noted.

Table 1. Estimated Required Sample Size [a,b]

	Frequency, kHz					
	1	2	3	4	6	8
Full day 90 dBA, [c]	5.54 4.13	7.88 6.27	12.56 6.81	15.73 6.94	13.57 7.71	5.57 6.51
Full day 85 dBA [c]	2.92 4.37	2.39 4.79	5.17 9.7	7.31 12.18	8.84 12.1	10.96 9.51
Required sample size, *n*	40	13	14	19	43	24

[a] kHz, kilohertz.
[b] SD, Standard Deviation.
[c] All the values are presented as Mean ± SD.

Table 2. Comparison of Independent Variables Between Participants From Factory 1 and Factory 2 [a,b,c,d]

Characteristics/Risk Factors	Factory 1 (n = 106)	Factory 2 (n = 97)	P Value
Age, y	27.94 ± 7.25	26.22 ± 5.60	0.060 [a]
Duration of work	2.45 ± 2.11	2.37 ± 2.00	0.798 [a]
Smoking			0.559 [b]
Ever smoked	74 (69.8)	64 (66.0)	
No smoking	32 (30.2)	33 (34.0)	
Alcohol consumption, n (%)			0.712 [c]
Ever consumed Alcohol	3 (2.8)	4 (4.1)	
Not consumed alcohol	103 (97.2)	93 (95.9)	
Exposure to hand-arm vibration			0.098 [b]
Exposed	83 (78.3)	66 (68.0)	
Not Exposed	23 (21.7)	31 (32.0)	
Exposure to risky hobbies for hearing loss			0.582 [b]
Exposed	40 (37.7)	33 (34.0)	
Not exposed	66 (62.3)	64 (66.0)	

[a] Statistical significance is based on independent t test.
[b] Statistical significance is based on chi-square test for independence.
[c] Statistical significance is based on Fisher exact test.
[d] Data are presented as mean ± SD or No.(%).

Table 3. Factories Associated With Hearing Threshold Level Beyond 25 dBA at Baseline [a,b]

Frequency Hz	Factory 1 (n = 106), Factory 2 (n = 97)	> 25 dBA	≤ 25 dBA	χ^2 Statistic (df)	P Value [a]
		Ear Right			
500				0.09 (1)	0.769
	1	18 (17.0)	88 (83.0)		
	2	18 (18.6)	79 (81.4)		
1000				0.33 (1)	0.569
	1	10 (9.4)	96 (90.6)		
	2	7 (7.2)	90 (92.8)		
2000				0.53 (1)	0.467
	1	6 (5.7)	100 (94.3)		
	2	8 (8.2)	89 (91.8)		
3000				0.91 (1)	0.341
	1	7 (6.6)	99 (93.4)		
	2	10 (10.3)	87 (89.7)		
4000				2.73 (1)	0.098
	1	25 (23.6)	81 (76.4)		
	2	14 (14.4)	83 (85.6)		
6000				0.12 (1)	0.724
	1	43 (40.6)	63 (59.4)		
	2	37 (38.1)	60 (61.9)		
8000				0.56 (1)	0.456
	1	17 (16.0)	89 (84.0)		
	2	12 (12.4)	85 (87.6)		
		Ear Left			
500				0.03 (1)	0.874
	1	6 (5.7)	100 (94.3)		
	2	5 (5.2)	92 (94.8)		
1000				0.02 (1)	0.903
	1	7 (6.6)	99 (93.4)		
	2	6 (6.2)	91 (93.8)		
2000				0.19 (1)	0.662
	1	7 (6.6)	99 (93.4)		
	2	5 (5.2)	92 (94.8)		
3000				< 0.001 (1)	0.987
	1	11 (10.4)	95 (89.6)		
	2	10 (10.3)	87 (89.7)		
4000				0.44 (1)	0.509
	1	13 (12.3)	93 (87.7)		
	2	15 (15.5)	82 (84.5)		
6000				1.22 (1)	0.269
		36 (34.0)	70 (66.0)		
		26 (26.8)	71 (73.2)		
8000				0.41 (1)	0.523
	1	14 (13.2)	92 (86.8)		
	2	10 (10.3)	87 (89.7)		

[a] Statistical significance is based on chi-square test for independence.
[b] Data are presented as No.(%).

Table 4. Comparison of Change on Hearing Threshold Levels Beyond 25 dBA Among Participants From Factory 1 [a,b]

Frequency	Pre-intervention	Post-intervention (n = 106)		P Value [a]
		≤ 25dB	> 25dB	
Ear Right				
500				0.267
	≤ 25dBA	84 (95.5)	4 (4.5)	
	> 25dBA	9 (50.0)	9 (50.0)	
1000				1.000
	≤ 25dBA	91 (94.8)	5 (5.2)	
	> 25dBA	4 (40.0)	6 (60.0)	
2000				0.219
	≤ 25dBA	95 (95.0)	5 (5.0)	
	> 25dBA	1 (16.7)	5 (83.3)	
3000				0.021
	≤ 25dBA	90 (90.9)	9 (9.1)	
	> 25dBA	1 (14.3)	6 (85.7)	
4000				1.000
	≤ 25dBA	76 (93.8)	5 (6.2)	
	> 25dBA	4 (16.0)	21 (84.0)	
6000				0.167
	≤ 25dBA	50 (79.4)	13 (20.6)	
	> 25dBA	6 (14.0)	37 (86.0)	
8000				1.000
	≤ 25dBA	86 (96.6)	3 (3.4)	
	> 25dBA	4 (23.5)	13 (76.5)	
Ear Left				
500				0.500
	≤ 25dBA	100 (100.0)	0 (0.0)	
	> 25dBA	2 (33.3)	4 (66.7)	
1000				1.000
	≤ 25dBA	96 (97.0)	3 (3.0)	
	> 25dBA	3 (42.9)	4 (57.1)	
2000				0.687
	≤ 25dBA	97 (98.0)	2 (2.0)	
	> 25dBA	4 (57.1)	3 (42.9)	
3000				1.000
	≤ 25dBA	90 (94.7)	5 (5.3)	
	> 25dBA	5 (45.5)	6 (54.5)	
4000				1.000
	≤ 25dBA	90 (96.8)	3 (3.2)	
	> 25dBA	2 (15.4)	11 (84.6)	
6000				0.424
	≤ 25dBA	61 (87.1)	9 (12.9)	
	> 25dBA	5 (13.9)	31(86.1)	
8000				0.625
	≤ 25dBA	89 (96.7)	3 (3.3)	
	> 25dBA	1 (7.1)	13 (92.9)	

[a] McNemar test.
[b] Data are presented as No.(%).

Table 5. Comparison of Change on Hearing Threshold Levels Beyond 25 dBA Among Participants From Factory 2 [a,b]

Frequency	Pre-intervention	Post-intervention ($n = 97$)		P Value [a]
		≤ 25dBA	> 25dBA	
Ear Right				
500				0.454
	≤ 25dBA	73 (92.4)	6 (7.6)	
	> 25dBA	10 (55.6)	8 (44.4)	
1000				1.000
	≤ 25dBA	88 (97.8)	2 (2.2)	
	> 25dBA	3 (42.9)	4 (57.1)	
2000				0.727
	≤ 25dBA	84 (94.4)	5 (5.6)	
	> 25dBA	3 (37.5)	5 (62.5)	
3000				0.500
	≤ 25dBA	85 (97.7)	2 (2.3)	
	> 25dBA	0 (0.0)	10 (100.0)	
4000				0.289
	≤ 25dBA	77 (92.8)	6 (7.2)	
	> 25dBA	2 (14.3)	12 (85.7)	
6000				1.000
	≤ 25dBA	51 (85.0)	9 (15.0)	
	> 25dBA	10 (27.0)	27 (73.0)	
8000				0.687
	≤ 25dBA	81 (95.3)	4 (4.7)	
	> 25dBA	2 (16.7)	10 (83.3)	
Ear Left				
500				1.000
	≤ 25dBA	89 (96.7)	3 (3.3)	
	> 25dBA	4 (80.0)	1 (20.0)	
1000				1.000
	≤ 25dBA	91 (100.0)	0 (0.0)	
	> 25dBA	1 (16.7)	5 (83.3)	
2000				0.031
	≤ 25dBA	86 (93.5)	6 (6.5)	
	> 25dBA	0 (0.0)	5 (100.0)	
3000				0.070
	≤ 25dBA	80 (92.0)	7 (8.0)	
	> 25dBA	1 (10.0)	9 (90.0)	
4000				1.000
	≤ 25dBA	78 (95.1)	4 (4.9)	
	> 25dBA	4 (26.7)	11 (73.3)	
6000				1.000
	≤ 25dBA	64 (90.1)	7 (9.9)	
	> 25dBA	7 (26.9)	19 (73.1)	
8000				0.774
	≤ 25dBA	80 (92.0)	7 (8.0)	
	> 25dBA	5 (50.0)	5 (50.0)	

[a] McNemar test.
[b] Data are presented as No.(%).

Table 6. Comparison of Change on Hearing Threshold Levels Beyond 25 dBA Among Participants of Factory 1 and Factory 2 [a,b,c]

Frequency	Ear	Hearing Threshold Level	Factory 1 (n = 106)		Factory 2 (n = 97)		χ^2 Statistic [a] (df)	P Value [a]
			Yes	No	Yes	No		
3000	Right						-	1.000 [b]
		Preserved	1 (0.9)	105 (99.1)	0 (0.0)	97 (100.0)		
		Maintained Preservation	90 (84.9)	16 (15.1)	85 (87.6)	12 (12.4)	0.32 (1)	0.574
		Deteriorated	9 (8.5)	97 (91.5)	2 (2.1)	95 (97.9)	4.08 (1)	0.043
		Continue Deteriorated	6 (5.7)	100 (94.3)	10 (10.3)	87 (89.7)	1.51 (1)	0.219
2000	Left							0.123 [b]
		Preserved	4 (3.8)	102 (96.2)	0 (0.0)	97 (100.0)	-	
		Maintained Preservation	97 (91.5)	9 (8.5)	86 (88.7)	11 (11.3)	0.46 (1)	0.496
		Deteriorated	2 (1.9)	104 (98.1)	6 (6.2)	91 (93.8)	-	0.155 [b]
		Continue Deteriorated	3 (2.8)	103 (97.2)	5 (5.2)	92 (94.8)	-	0.483 [b]

[a] Statistical significance is based on chi-square test for independence.
[b] Statistical significance is based on Fisher exact test.
[c] Data are presented as No.(%).

5. Discussion

Noise-induced hearing loss is an irreversible and permanent occupational disease (11). In factory 1, around 9% of participants had developed hearing thresholds above 25 dBA at 'deteriorated' level, as compared with 2% from factory 2 after one-month exposure. These changes were seen at 3000 Hz on right ear. Noise-induced hearing loss involves frequencies ranging from 3000 to 6000 Hz (11). The changes were temporary threshold shifts. This finding elucidated that hearing threshold levels were more preserved when participants embraced 85 dBA as the permissible exposure limit, instead of 90 dBA. In factory 2, at 2000 Hz, on left ear, around 6% of participants developed hearing threshold levels beyond 25 dBA as compared with 2% on those from factory 1. However, this finding was not significant compared with those embraced 90 dBA. The employees exposed to noise level adopting 90 dBA as the permissible exposure limit may result in more damaging effects on hearing compared with those embracing 85 dBA. Temporary threshold shifts may result in permanent shift of hearing thresholds over time, if continuous exposure to noise ensues (12, 13).

According to Kryter (14), the temporary threshold shifts reflected one day's exposure to noise. These mentioned temporary threshold shifts occurred two minutes after noise exposure (TTS_2). The author had also stressed that TTS_2 may result in permanent threshold shifts if one is exposed to noise continuously for a longer duration. It is hypothesized that permanent threshold shifts would occur after 10 years of continuous noise insult. Kryter (14) also reported that if TTS_2 was beyond 40 dB, the recovery period of threshold shifts would get prolonged and development of permanent threshold shifts might ensue.

There are two possible mechanisms on the pathogenesis of noise-induced hearing loss. First, the mechanical damage of stereocilia (13), and the other possible process is the metabolic damage to the hair cells in cochlea. These findings recommend countries to adopt 85 dBA as the permissible exposure limit in order to preserve hearing thresholds and prevent hearing thresholds above 25 dBA. Consequently, the prevalence of noise-induced hearing loss is reduced.

The limitation of the study is that there was a possibility of a crossover effect of employees from two factories. This was avoided by informing the occupier the duration of this study 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 on one subject in each work area. The measurement was done as such because all workers in a job area were exposed to similar levels of noise intensities. This is also in accordance with the regulations for noise in Malaysia (6), where the workers in a job area are not required to undergo personal noise exposure measurement. A total of 78.1% of employees from the two factories agreed to participate. The non-respondents' excuses were their busy work procedure or their personal predilection not to participate in the study.

There were no differences between the respondents and non-respondents regarding age (mean age was 27.1 ± 6.6 y and 27.7 ± 7.0 y among the respondents and non-respondents, respectively), gender, ethnicity, and duration of work. A total of 62.6% participants were followed up until the end of the study. However, the total number of subjects who participated from both factories was more than the minimum sample size required based on the study by Yates et al. (7) and hence, the power of study was not affected. There were no differences between the participants who followed up and those who had dropped out regarding variables of age (the mean age was 26.8 ± 6.4 y among those responded and 27.6 ± 6.8 y among those dropped out), gender, ethnicity, education level and duration of work. Only air conduction was used to measure hearing threshold levels in this study. To ensure that there were no damages to outer or middle ear, ear assessment was performed on all participants by otoscopic examination at baseline and then one month later. Only participants that have no damage to the ear were allowed to undergo the audiometry assessment. There were no differences in hearing threshold levels beyond 25 dBA between participants at baseline. Hence, any changes in the hearing thresholds at post-intervention were likely due to the effect of noise.

There were no differences on confounding factors among participants of the two factories such as smoking (15, 16), consumption of alcohol (17), and exposure to hand-arm vibration (18). Also no significant differences were noted among participants from two factories regarding risky hobbies for hearing loss such as listening to loud noise (19), shooting (20), and scuba diving (21). Age and employment duration among employees were not significantly different. The hearing loss above 25 dBA occurred more when participants adopted 90 dBA as the permissible exposure limit. Hence, the countries may need to review their policy on their permissible exposure limit for noise.

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Authors' Contributions

Sayapathi BS drafted the manuscript. Su AT obtained funding from the University. Su AT and Koh D supervised the entire process of the research. All authors made substantial contributions for design and revision of the manuscript. All authors approved the final manuscript.

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