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Estimate of the Percent Reduction of the Workers Hearing Loss by Doing a Training Intervention Based on BASNEF Pattern

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If we want to provide the efficient training intervention to increase the duration of using hearing protection devices (HPDs) by workers, we need a tool that can estimate the person's hearing threshold taking into account noise exposure level, age, and work history, and compare them with audiometry to find out the percent reduction of workers hearing loss.

First, the workers noise exposure level was determined according to ISO 9612, then 4000 Hz audiometry was done to find age and work history. On basis of ISO 1999 the hearing threshold was estimated and if the hearing protection device was not used continuously and correctly, the hearing protection device's actual performance was reduced adjusted with person's audiometry. After training intervention, the estimate was done again and was compared with the adjusted audiometry.

According to ISO 1999 standard estimation results, the percent reduction of the workers hearing loss level was 6.48 dB in intervention group. This level remained unchanged in control group. The mean score of hearing threshold estimation (standard ISO 1999) was statistically more significant than mean score of hearing threshold (p-value ¡ 0.001). The results show not significant change in control group due to lack of changing of noise exposure level.

In regards to the results of hearing threshold estimation based on ISO 1999 and comparing with workers audiometry, it can be seen that BASNEF training intervention increases the duration of using the HPDs and it could be effective in reducing hearing threshold related to noise.

Keywords: hearing loss; hearing protective devices; ISO 1999; BASNEF.

1. Introduction

Noise is one of the most common causes of hearing loss in the industries, and noise induced hearing loss (NIHL) is one of the most commonly reported occupational diseases (Lie *et al.*, 2016). In a study conducted on workers exposed to non-permissible noises, it was found that these sounds lead to decreased job performance and safety of people, interfere in conversation, fatigue and stress, and the using of hearing protective devices (HPDs) reduces these effects (Morata *et al.*, 2005). In various studies, the relationship between the hearing Standard Threshold Shift (STS) with the time of using HPDs in each ear has been proved (Melamed *et al.*, 1996; Rabinowitz, 2000; Toppila, 2000; Ologe *et al.*, 2005; Pourabdiyan *et al.*, 2009). Occupational hearing loss due to noise is completely preventable and using the hearing protection devices is one of the noise exposure control methods (Choobine, Amirzadeh, 2003). The last way of controlling noise is using HPDs (Monazzam *et al.*, 2016). Obviously, if the hearing protection device is not used continuously and correctly, the hearing protection device's actual performance will be reduced, for example, according to Fig. 1, if a HPD with an Noise Reduction Rate (NRR) of 20 dB is not worn for just 15 minute in an 8 hours' work shift, its effective NRR is reduced by 5 dB (time Corrected NRR would be only 20 dB) (Else, 1973; Berger, 1983).

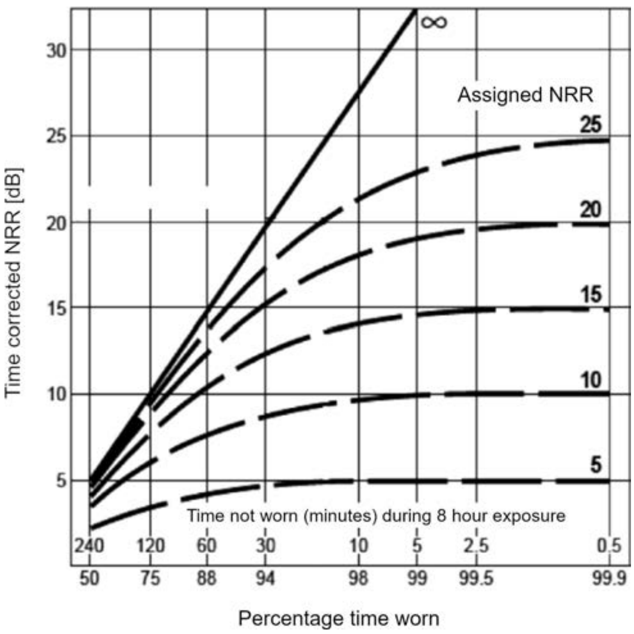

Fig. 1. Time Corrected Noise Reduction Rating (NRR) as a function of the percentage of time that the HPDs are worn in the noise

Knowing the duration of using the hearing protection device is surely affective on hearing protection programme (Williams, 2009). Therefore, needs for a comprehensive review is essential. According to the Occupational Health and Safety (OHS) Act, all employers are required to provide employees with proper PPE as required by the Act and monitor the employees' use of PPE ((OHS) October 2011, revised June 2014). The important thing is how the employer trains workers (3071 2002). If workers are just familiar with how to use the HPD and being forced into using it (by motivation and punishment); the question arises whether the workers willingly use their HPDs appropriately and all the time when they are exposed to encounter the unallowable noise. According to studies, the training program is considered as a prevention strategy on occupational health and safety learn that enhances workers use of PPE (Cohen *et al.*, 1998; Ologe *et al.*, 2005). Education and training can be used as a method to increase of compliance (Hon *et al.*, 2008; Gershon *et al.*, 2009; Verbeek *et al.*, 2016). Insufficient training on the correct techniques of the HPDs usage, and lack of motivation have been reported as the other causes of irregular use of the HPDs in the workplace with dangerous level of noise (Ologe *et al.*, 2005). Educational theories and models can help researchers to pay attention to the most suitable areas for changing behaviour (Saghafipour *et al.*, 2017). One of the useful models in health education is beliefs, attitudes, subjective norms and enabling factors (BASNEF) model (Salehi *et al.*, 2004). This model focuses on the impact of knowledge and attitude on behaviour, and is assisted by other factors such as enabling factors and subjective norms. The aim of this study was to evaluate the effectiveness of BASNEF training course on increasing the time that workers use HPDs, using the method of estimating the reduction of prevalence of hearing loss based on ISO 1999:2013 method: "Acoustics – Estimation of noise-induced hearing loss, International Organization for Standardization (ISO)" (ISO 1999:2013). The ISO published the relationship between noise exposure and noise induced permanent threshold shift (NIPTS) that allows to compare hearing status of subjects of different age and noise exposure (ISO 1999:2013). The ISO 1999 model uses four parameters: gender, age, duration of employment and noise exposure level (ISO 1999:2013).

2. Methodology

In this cross-sectional study, the research population includes workers in the tile industry based on this Eq. (1) ($a = 95\%$, $P = 80\%$, $Z = 1.96$)

$$n = \left(\frac{Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}}{d} \right)^2 . \tag{1}$$

A total of 100 workers (50 in intervention and 50 in control group) were selected from employees of these units as the sample group. Inclusion criteria were exposure to occupational noise, at least 1 year of exposure to noise and no history of ear diseases, no co-exposure to noise and chemical materials. Exclusion criteria included the history of head injury or otologic surgery and family history of hearing loss. First, the noise exposure of workers was determined according to the dosimetry based on standard

No. ISO 9612 (Monazzam Esmaielpour *et al.*, 2017; ISO 9612:2009). In the next stage, the demographic information like age and experience were collected. For determining the threshold, audiometry test for each of the cases and controls were carried out, and after collecting the information of the audiogram, hearing threshold level (HTL) was recorded at a frequency of 4000 Hz. To estimate the HTL associated with age and noise, ISO 1999:2013 method was used. So that first hearing threshold level associated with age (HTLA) was calculated in accordance with the ISO 1999:2013 method (Table 1) for each employee according to their age and at the frequency of 4000 Hz (ISO 1999:2013).

Table 1. HTLA from ISO-1999 (2013), Table A.3 (database A).

Frequency [Hz]	Age [year]			
	30	40	50	60
500	1	2	4	6
1000	1	2	4	7
2000	1	3	7	12
3000	2	6	12	20
4000	2	8	16	28
6000	3	9	18	32
8000	3	11	23	39

At the next stage, the noise-induced permanent threshold shift (NIPTS) was calculated in accordance with the ISO 1999:2013 method (Table 2) for each employee according to the duration of noise exposure (work experience) for frequencies (4000 Hz) (ISO 1999:2013). Also to get the level of noise exposure, the ISO 9612 standard, was used according to the duration of using the HPD.

Table 2. NIPTS from ISO-1999 (2013), Table D.l and D.2.

Exposure time [year]		10		20		30		40	
LEX, 8hr [dB]		90	85	90	85	90	85	90	85
Frequency [Hz]	500	0	0	0	0	0	0	0	0
	1000	0	0	0	0	0	0	0	0
	2000	2	1	4	1	5	1	6	2
	3000	8	3	10	4	11	4	12	5
	4000	11	5	13	6	14	6	15	7
	6000	7	3	8	3	9	3	10	4

The calculations of the age-related hearing threshold level (HTLA) were taken into reference population (database A) and the mean values of the change of the noise threshold constant (NIPTS) according to ISO 1999 (Eq. (2)). In the next stage, by using the Eq. (2) the hearing threshold level associated with age and noise (HTLAN) was estimated for each of the individuals in two groups in the frequency of 4000 Hz

$$\text{HTLAN} = \text{HTLA} + \text{NIPTS} - \frac{\text{HTLA} \cdot \text{NIPTS}}{120} \text{ [dB]} \quad (2)$$

HTLAN is the hearing threshold level, associated with age and noise, expressed in decibels [dB]; HTLA is the hearing threshold level, associated with age, expressed in decibels [dB]; NIPTS is the actual or potential noise-induced permanent threshold shift (PTS), expressed in decibels [dB].

The expression (HTLA · NIPTS)/120 starts to modify the result significantly only when HTLA + NIPTS is greater than 40 dB. Finally, with regard to age, work experience and exposure to noise, the threshold of hearing (audiometry) of each person in the frequency 4000 Hz was compared with ISO 1999:2013 method for validation. The difference (Δ) between actual individual measured HTL (HTL_m) and standard HTL (HTL_s) in the population of the same age and noise exposure is a measurement describing the state of the auditory system of a given person. The delta is expressed by subtracting HTL_s from HTL_m

$$\Delta = \text{HTL}_m - \text{HTL}_s \text{ [dB]}. \quad (3)$$

After the intervention, to assess the reduction of prevalence of hearing loss in the intervention group, the estimation is run again based on the age and work experience of people by considering reduced exposure to noise based on the standard; then we compare it with audiometric test results to estimate the effect of using HPDs in hearing loss. Educational intervention was performed in six sessions (practical-theoretical), each held once a week for 30 to 45 minutes (six weeks long) (Khan *et al.*, 2018). Also, additional educational training such as texting, face to face training in the workplace and design of posters were done. All classes were held based on the BASNEF model in terms of knowledge, personal attitude and enabling factors; behavioural intention, planning, and design performance with appropriate training methods (lectures, practical displays, videos, providing pamphlets). The workers of control group have not received any training in this study. In this study, the BASNEF intervention was used to increase workers' awareness about the sound and change their attitude towards the use of HPDs and provide the enabling factors such as knowledge about harmful noise and HPDs and access to them, as well as involving the occupational physician and head of the unit, so that workers who are exposed to excessive noise use protection headset throughout their shift. Data related to estimating the level of HTL using SPSS 19 was compared before and after intervention using UNIANOVA procedure. The χ^2 testing was again used to look for a difference in diversity scores between the HTL_m and HTL_s groups. The standard criterion for statistical significance for all tests was set at a $p = 0.05$.

3. Results

The study involved 100 workers in tile industry, 50 cases and 50 controls, aged 21–50 years, (mean 30.30 ± 4.27 years). Duration of exposure to noise ranged from 1 to 18 years (mean 10.12 ± 2.96 years). The results of measuring noise exposure of workers in conformance with ISO 9612 and the time of using the HPDs are presented in Table 3. According to Table 3, it is obvious that before the intervention the time of using HPDs in both groups was 0.5 hour, and the noise exposure was 89 dBA. Also, after the intervention the time of using HPDs was increased in intervention group, the noise exposure was 80 dBA, and for the control group that had not received treatment the same amount of time spent on the HPD was found as 89 dBA (Table 4). In order to estimate the threshold of the hearing before increased duration of use of the HPD in the intervention and control groups, HTLAN for both groups is presented in Table 4.

The results show that according to audiometric measures, HTL at the frequency of 4000 Hz was obtained about 21.20 dB for the intervention group and 20.30 dB for the control group (Table 3). In order to estimate HTL after increased duration of HPD use in the intervention and control groups, HTLAN for both groups is shown in Table 4. The Daily Exposure Measurement (LEX, 8h) was modified to use HPDs according to the previous study (Monazzam Esmaielpour *et al.*, 2017).

After reducing exposure to noise, HTL estimation results (standard and adjust) were about 14.72 dB and 19.30 dB for the intervention and control groups, respectively. To compare the two groups HTL in the frequency of 4000 Hz was used and its results are presented in Table 5.

Results in Table 5 show that the average score of estimating the threshold of hearing (standard unit) in the intervention group was statistically significant compared to the mean threshold of hearing (audio-

Table 3. Validating the threshold of hearing in accordance with ISO 1999 in the intervention and control groups (before the intervention).

Study Group	Mean of age [year]	Exposure to noise [years]	Exposure LEx,8h [dBA]	Using of HPD [hr]	HTL in 4000 Hz (measured) [dB]	HTLAN in 4000 Hz (standard units) [dB]	*Δ
	Mean ± SD						
Intervention ($n = 50$)	31.00 ± 4.45	10.14 ± 3.56	89.80 ± 0.34	0.56 ± 0.65	21.20 ± 6.66	16.32 ± 4.19	4.88 ± 2.47
Control ($n = 50$)	29.60 ± 4.00	10.10 ± 2.26	89.67 ± 0.42	0.67 ± 0.82	20.30 ± 6.65	16.52 ± 5.41	3.78 ± 1.24
p-value	0.102	0.947	0.095	0.461	0.771	0.891	0.180

*Δ – difference between actual individual measured HTL (HTL_m) and standard HTL (HTL_s).

Table 4. Estimation of hearing threshold of intervention and control groups after increasing the duration of use of HPDs (after the intervention).

Study Group	Exposure LEx, 8h [dBA]	Using of HPD [hr]	HTLAN in 4000 Hz (standard units) [dB]	*Adjusted of HTL in 4000 Hz [dB]
	Mean ± SD			
Intervention ($n = 50$)	80.61 ± 8.76	6.66 ± 1.40	9.84 ± 4.21	14.72 ± 6.68
Control ($n = 50$)	89.58 ± 0.46	0.83 ± 0.85	15.52 ± 5.41	19.30 ± 6.65
p-value	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$

* $HTL_s + \Delta$.

Table 5. Comparing the mean of hearing threshold in the intervention group and control group.

Study Group	HTL in 4000 Hz (measured) [dB] before the intervention	Adjusted of HTL in 4000 Hz [dB] after the intervention	p-value
	Mean ± SD		
Intervention ($n = 50$)	21.20 ± 6.66	14.72 ± 6.68	$p < 0.001$
Control ($n = 50$)	19.30 ± 6.65	20.30 ± 6.65	0.104

metry) (p-value < 0.001). Results also show that in the control group hearing threshold (HT) value didn't change due to no change in noise exposure (p-value > 0.05). According to this study, the mean of estimated hearing threshold in intervention group was reduced by 6.48 dB in Adjusted audiometry and was statistically significant (p-value < 0.001).

4. Discussion

According to the studies of noise-induced hearing loss, the minimum time that hearing loss occurs and can be examined is 10 years or more (Pankova, Podol'skaia, 1990; Gijbels *et al.*, 2006; Zare *et al.*, 2007; Mirmohammadi, 2008; Neitzel, Fligor, 2017). Due to the limited time of this study, audiometry before and after the study cannot be done and compared with each other, so as to study the efficacy of educational interventions and increase the duration of using HPDs by workers. Therefore, we have decided to use hearing threshold estimate calculations of ISO 1999:2013 method. This standard takes into account noise exposure, as well as age and work experience, because according to studies, hearing loss has a significant relationship with age and work experience (Mizoue *et al.*, 2003; Ghamari *et al.*, 2009; Loukzadeh *et al.*, 2011; Belachew, Berhane, 2017). According to this study, the mean of estimated hearing threshold in intervention group was reduced by 6.48 dB. Study by Davies *et al.* (2008), showed that by continuous use of hearing protection, the risk for STS was reduced by 30%. Neitzel and Seixas (2005) demonstrated that the irregular use of hearing protection with regard to their noise reduction level and duration of use can considerably reduce the noise reduction level of hearing protection to > 3 dB. According to previous studies, a continued use of the HPD can help in lowering the threshold of hearing, because the results of a study by Pourabdiyan *et al.* (2009) and Oloqe *et al.* (2005) also showed that the relationship between changing standard threshold of hearing with the duration of using the HPD in each of the ears is significant. Rabinowitz (2000) reported that NIHL can be prevented using internal and external guards, that can be achieved with proper planning. Toppila (2000) studied hearing conservation programs (HCP) in different jobs and concluded that the use of personal protective headset is a relatively good controlling method against the hearing loss. We tried to improve the knowledge of intervention group toward harmful noise and its complications using BASNEF model, then compare their hearing test with previous years and explain the loss of hearing progress to change their attitude. During training we tried to use an influential figure such as the head of the workshop to explain the importance of education to workers. The occupational physician was asked to train workers in terms the harmful noise side effects and occupational deafness steps. Health professionals were also asked to teach the types of HPDs, how to use them properly and testing them in terms of being fit, and maintenance and cleaning of headsets. One of the workers (colleagues) that almost entirely used the HPDs was asked to speak of the advantages of the HPD. Also, the enabling factors such as time, cost, training facilities and access to HPDs, that is another component of BASNEF model, helped us in the training. The four parameters of BASNEF model (knowledge, attitude, influential individuals, enabling factors) lead to behavioural intention and finally behaviour, i.e. using the HPDs in a full time manner. Since estimation of hearing threshold using BASNEF educational intervention was carried out in short time, longer duration study in future is recommended.

5. Conclusion

The results showed that increasing the using duration of hearing protection device had significant effect on increasing the performance of protective devices. Also as the duration of using the hearing protection device increases, hearing threshold shift remains constant. All of these positive results were achieved by BASNEF training intervention.

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