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ORIGINAL ARTICLE

Field Validation of a Standard Hearing Loss Prediction Model in an Iranian Textile Industry

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ABSTRACT

Noise is the most frequent physical agent in workplace that effects on hearing loss. This study aimed to investigate the value of noise exposure in different jobs along with noise induced permanent threshold shift of workers, prediction of hearing threshold alteration in relation to job and work experience using ISO 1999 standard and comparing with measured hearing loss. This study was performed among 138 Iranian workers in a Yazd spinning factory in 2014. Noise exposure level was measured using ISO 1999 method in any work conditions. An audiometric test was done in a standard soundproof room by an experienced audiologist. Noise induced hearing loss was identified after reduction of age related hearing loss. Necessary program for hearing loss prediction of workers was prepared using the ISO method. Finally, data were analyzed by SPSS16 software. Mean age and employment duration of participants were 36.58 ± 6.76 yr and 11.08 ± 5.47 yr, respectively. Mean noise exposure in office, spinning, baling, carding, combing and other parts was 45, 94, 95.5, 90, 85 and 88dBA, respectively. Mean measured hearing threshold was 16.69 ± 7.82dB in right ear and 17.59 ± 8.55 dB in left ear. The duration of employment and noise are two important factors in work-related hearing loss. There was a significant difference between the measured noise induced hearing loss and its predicted values ($P<0.05$). Better surveillance and prevention programs are recommended to reduce the prevalence of work-related hearing loss, such as perform pre-employment medical and periodic occupational health examinations.

KEYWORDS: *Audiometry, Hearing loss, ISO 1999 standard, Noise exposure, Textile*

INTRODUCTION

Noise is one of the most important harmful exposures in occupational settings, which affects human health, considered as an important occupational hazard [1-6].

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Noise, a physical agent, is the most frequent occupational exposure in the workplace [7-11]. The harmful effects of the exposure to high levels of noise have been identified from many years ago [12-15]. When noise level exceeds allowable thresholds, it can affect many organ systems in the body, such as ear and circulation and it can influence productivity at the workplace [16-

17]. There is some evidence that workers exposed to high levels of noise are in the higher risk of accidents [18, 9. The most important health effect of noise is hearing loss [20-23]. Hearing loss due to high levels of noise (Noise-Induced Hearing Loss: NIHL) and due to age (presbycusis) is the most frequent types of hearing loss which is irreversible and considerably affect human's quality of life. Nowadays noise is considered as the most frequent cause of permanent hearing loss in adults [24].

NIHL is a sensor neural hearing loss, which develops after exposure to noise and is a preventable but irreversible disorder [25-27]. This loss brings some problems for the worker, his/her coworkers and family [28].

Recently, some efforts have been done to evaluate the problems due to exposure to noise in different industries. NIOSH (National Institute for Occupational Safety and Health) considers textile industry as the second industry (after wood industry) in which the workers are exposed to high levels of noise [29].

Evaluation of the workers' hearing loss and its association with employment duration and noise level can be used to identify the intervals between hearing assessments in periodic evaluations, to recommend preventive measures at the workplace and to control the workers' exposure to noise [30-32].

International standard of ISO 1999 was introduced by International Organization for Standardization (ISO) technical committee 43 to identify the relationship between noise exposure and noise-induced permanent threshold shift (NIPTS) in different ages by a statistical formula. This standard describes the combined and separate effects of age and noise on hearing among populations, which are different according to age, gender, and duration of exposure to noise. Using the experimental equation of the standard method, hearing threshold is calculated in relation to age and noise [33-34].

The hearing loss diagrams of the workers were analyzed and were compared with the predicted diagrams of the proposed method. They were not consistent with each other, i.e. real measures were less than predicted ones [33-34].

The relationship between hearing loss and noise level and employment duration were assessed and overall, 4000 Hz the frequency with the highest hearing loss was found. Hearing loss had a direct linear relationship between noise exposure and work history [31].

The susceptibility of individuals to noise was assessed to find a proper method for categorization of workers to noise-susceptible and noise-resistant. They categorized workers according to the ISO method, so that 10% of workers with the worst hearing threshold and 10% of workers with the best hearing threshold were categorized as noise-resistant and noise-susceptible, respectively. In other methods, all workers were divided into subgroups according to age, employment duration, and noise level, then 10% of individuals susceptible and resistant to noise was selected. The first categorization resulted in an appropriate separation of susceptible and resistant subjects. The susceptible sub group included younger subjects with lower employment duration and lower noise exposure than resistant subgroup. Other methods showed a weaker separation. Using the ISO method for identification of susceptible and resistant subjects to noise is the most reliable method [26].

This is the first study in Iran designed to predict the hearing loss of workers by the standard method and validate them in a textile industry.

MATERIALS AND METHODS

This is a cross-sectional study conducted in 2014 in a textile industry in Yazd, a central province of Iran. Subjects were selected by simple randomized sampling. A questionnaire about demographic data (age, gender, education, present job, previous jobs, history of hearing disorders, drug history, smoking, alcohol consumption, participation in the war and hearing protection devices) was filled for each participant. Subjects with the history of alcohol consumption, diabetes, exposure to ototoxic substances, ototoxic drug consumption and using hearing protection devices were excluded from the study.

An informed consent form was obtained from each participant. The study was approved by the university.

Totally, 138 subjects entered the study based on a census of different sectors. Considering the exclusion criteria, 14 participants were excluded. The level of worker's exposure to noise was determined using ISO 9612 standard method by a calibrated noise dosimeter in an 8-h work shift [35]. The worker's jobs in the factory were categorized according to the noise exposure level and tasks performed in each part. All jobs were categorized in 6 main categories including office, spinning, baling, carding, combing, and others (comprising flier, autoconner and ginning). At each job category, noise dosimetry was performed for a worker as the representative of any category. Then the measured noise dose (in percent) was transformed to the 8-h exposure level decibels (LAeq) and the results were generalized to other workers in each category. Audiometric test was also performed by an audiologist using an audiometer (AC 40, Intracoustic, made in Denmark) in an acoustic chamber after 16 h noise avoidance. Hearing threshold was measured at frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz in each ear separately.

In order to identify noise induced hearing loss, the effect of age called presbycusis loss was omitted by following formula, in which "N" is the subject's age and "K" derives (Table 1) [36].

Equation 1:

$$Presbycusis\ loss = \frac{k}{1000}\left(N-20\right)^2$$

Table 1. K at different frequencies

K	4	4.3	6	8	12	14
Frequency	500	1000	2000	3000	4000	6000

Then the overall noise induced hearing loss was identified in each ear as mean hearing loss at frequencies of 500, 1000, 2000 and 4000 Hz [1, 37]. In the next step, using ISO 1999 standard, potential permanent hearing loss due to noise or N_{50} (i.e. 50% of the population suffer from hearing loss more than this measure) was predicted using following formula [33].

Equation 2:

$$N_{50}=[u+ v \log \Theta]\ [L_{Aeq,8h}-Lo]^2$$

in which:
N_{50}: Mean NIPTS (noise-induced potential threshold shift) in dB
L_0: Noise pressure level as a function of audiometric frequency and is found from Table 2
Θ: History of exposure to noise in year
u, v: Parameters which are functions of frequency and are found from Table 2
L_{Aeq}: 8-hour noise exposure level in dBA

Table 2. The measures of coefficients u, v and L_0

Frequency	U	v	L_o
500	-0.033	0.11	93
1000	-0.02	0.07	89
2000	-0.045	0.066	80
3000	0.012	0.037	77
4000	0.025	0.025	75
6000	0.019	0.024	77

Finally, the gathered data was analyzed by SPSS (ver. 15) (Chicago, IL, USA) using t-test, paired t-test, Pearson's correlation and ANOVA.

RESULTS

Overall, 124 subjects entered the study and were divided into 6 job categories. Tables 3 and 4 shows descriptive statistics of age and work experience in different job groups, respectively.

Table 3 shows min, max and average age of participants in different occupational groups in which the min and max age are 19 and 52 yr respectively and the average age for most occupational groups are under 38 yr.

Table 3. Descriptive statistics of age (years) in different job categories

Job category	**Minimum**	**Maximum**	**Mean**	**Standard deviation**
Office	25	48	35.90	7.50
Spinning	24	47	37.30	5.00
Baling	19	51	34.60	8.60
Carding	24	44	35.00	5.70
Combing	31	49	41.00	6.20
Others	28	52	38.50	5.70
Total	19	52	37.05	6.45

According to Table 4, the min and max experiences of workers are 1 and 18 yr respectively while the average of work experience within groups is not very high.

Table 4. Work experience in each job groups

Job category	**Minimum**	**Maximum**	**Mean**	**Standard deviation**
Office	2	18	9	6.3
Spinning	3	18	13.4	3.7
Baling	1	17	8.7	6.1
Carding	1	15	8.3	5.3
Combing	9	17	14.7	2.6
Others	3	18	13.1	4.1
Total	1	18	11.2	4.68

Table 5 shows the noise frequency analysis at locations of different job categories. The highest sound pressure level is at frequencies below 250 Hz so the noise in these groups can be categorized as low frequency.

Although this is a common noise characteristic finding among different job location, the noise character of three locations of spinning, combing and others relatively differ from those of the baling and carding. At the first three groups, the noise levels were decreased by increasing octave band frequencies above 250 Hz, while it is not true within the latter two groups. In these groups, the lowest noise levels occur at 500 Hz and it is increased with frequency. By averaging the findings in each frequency, there were significant differences between noise levels at the frequencies below 2000 Hz, explained the interaction effects of different present noise sources.

Table 5. Noise frequency characteristics at locations of different job categories in dB (linear) along with their 8-h equivalent noise exposure levels L_{Aeq} (dBA)

Job Category	Octave band center frequency (Hz)							L_{Aeq}
	125	250	500	1000	2000	4000	8000	
Spinning	85.8	89.2	88.2	87.7	86.7	85	79.8	93.2
Baling	92.3	89.8	89.8	92	91.3	91.3	89.2	98
Carding	89.9	86.8	84	84.7	84	82.5	80.3	90.6
Combing	77.8	81.5	81.5	80.3	79.7	77.3	67	85.9
Others	80.1	83.8	83.5	83.2	81.2	80.5	71.5	88.3

Table 6 shows the min, max and mean hearing loss at each frequency both in right and left ears. Hearing loss in left ear was more than right ear in most frequencies. The highest average hearing loss was related to the frequency 4000 Hz and the average hearing loss in left ear was higher than that of right ear.

Table 6. Mean hearing loss at each frequency in right and left ears

Hearing loss	Octave band center frequency (Hz)													
	500		1000		2000		3000		4000		6000		8000	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Minimum	2.1	2.1	1.9	3.1	0.6	2.4	0.8	1.5	3.7	0.0	0.0	0.0	5.0	5.0
Maximum	54.0	39	43.9	47.1	48.7	55.9	58.0	54.6	56.9	51.9	55.5	53.8	50.0	60.0
Mean	14.3	13.7	14.6	13.8	16.2	15.6	20.0	18.9	25.2	23.7	19	20.4	18.6	18.7
SD	8.5	6.6	7.7	7.7	8.7	8. 9	11.1	10.4	12.4	11.7	11.5	10.9	9.9	10.5

The noise induced hearing losses at each frequency were compared between right and left ears. The difference was only significant at 4000 Hz (*P*=0.02)

Pearson's correlation test showed a significant correlation between total hearing loss and duration of employment in all age groups (*P*=0.019). This test also showed a significant association between 8-h equivalent A-weighted noise exposure levels and total hearing loss (*P*<0.001).

Fig. 1 shows the predicted hearing loss using the ISO method among all job categories. Increasing noise levels in different occupations, predicted levels of hearing loss also increased that the highest loss was related to Baling, which had the highest noise level and the lowest loss was related to combing which had the lowest noise level. The effect of work experience was significantly increased, as the amount of noise exposure raised in different jobs. According to the prediction, the max overall noise induced hearing loss for workers with highest considered noise exposure is less than 7 dB.

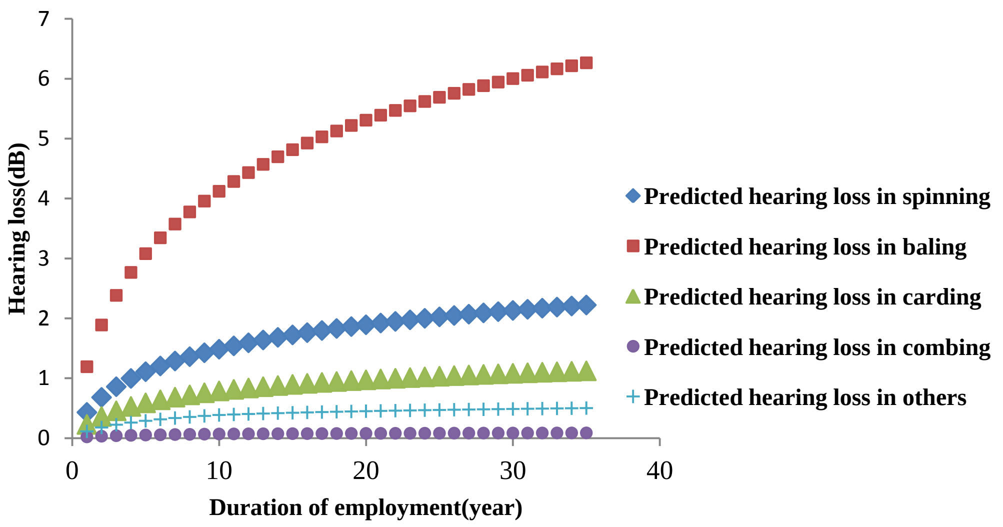

Fig. 1. Comparison of mean predicted hearing loss by ISO 1999 method according to duration of employment among all job categories

Fig. 2 shows the predicted hearing loss at 4000 Hz at all job categories. In this diagram, the highest level of hearing loss was related to Baling with the highest sound pressure level at 4000 Hz and minimal hearing loss was related to combing with the lowest sound pressure level at frequency 4000. Therefore, the direct relation of frequency effectiveness of noise character could be explained. Again, the same trend for 4000 Hz compared with the overall hearing loss was seen. The noise level effect was dominant over exposure time except early stages of work. The slope of the diagrams decreases by noise level reduction. Almost after 10 yr of noise exposure, the noise effect was not increased so gently with noise levels less than 93 dB.

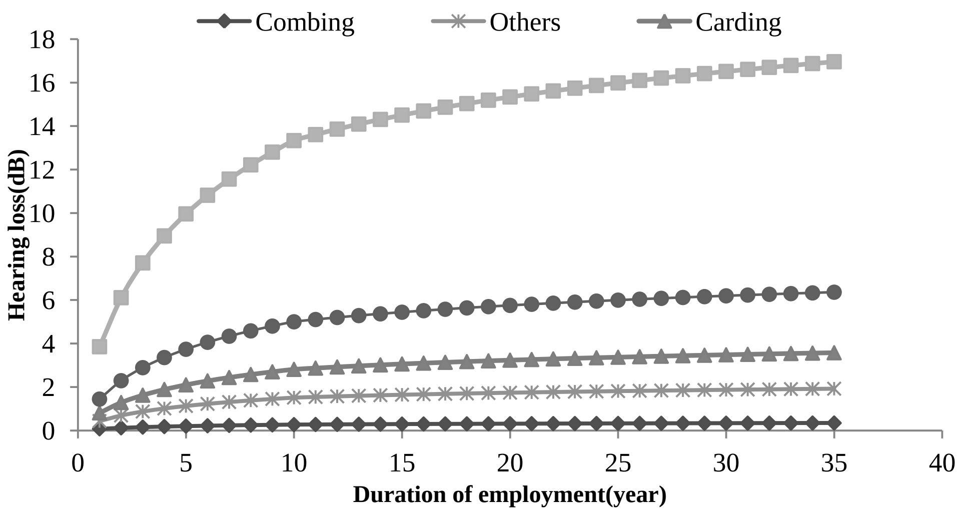

Fig. 2. Comparison of mean predicted hearing loss at 4000 Hz according to duration of employment in all job categories

Fig. 3 compares the measured and predicted hearing loss in spinning workers**.** The measured values of noise induced hearing loss in the studied population are much more than the predicted hearing loss in each occupational group. Although, with increasing noise pressure levels, both measured and predicted hearing loss show an increasing trend but the two values do not match. A similar trend was seen for all other groups. The graphs are omitted for shortening.

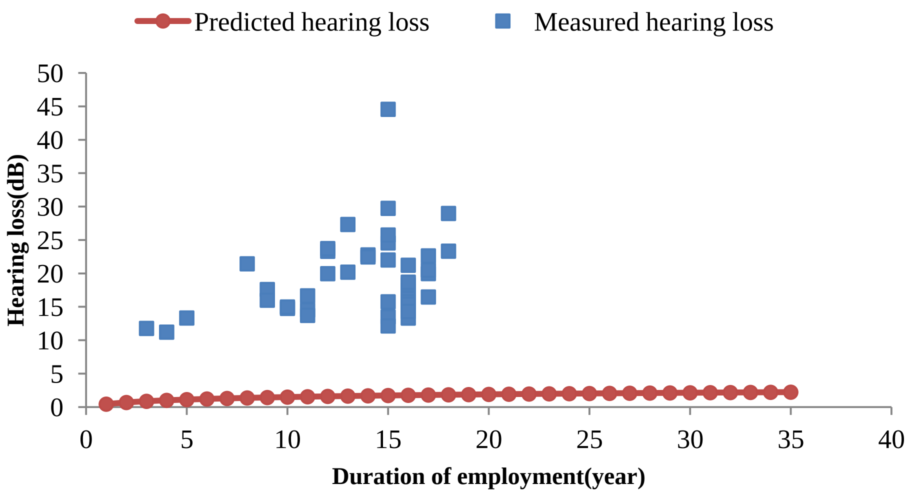

Fig. 3. Comparison of the measured and predicted hearing loss according to duration of employment in spinning

DISCUSSION

Hearing loss, a preventable but irreversible disorder, is one of the most common occupational disorders in all industrial settings. In this study, the measured and predicted noise induced hearing loss among the workers of an Iranian textile industry was compared. From overall 8-h equivalent A-weighted noise exposure levels in different jobs, one can conclude that all 5-task groups were exposed to the levels above American Conference of Governmental Industrial Hygienists (ACGIH) TLVs. Although the workers in combing section are exposed to noise levels very close to the standard levels.

A positive association between hearing loss and duration of employment was consistent in some studies [10, 38-40]. Moreover, similar result was observed and showed above relationship is direct, positive and linear [41-42].

Exposure to noise was well above ACGIH standard in all job categories except for office [37]. A significant relationship between noise level and hearing loss was also found in this investigation. This finding was consistent with many other studies [2, 43-45].

Overall, 4000 Hz to be the frequency with the highest level of risk of hearing loss and the 500 Hz the frequency with the lowest level [8]. Noise induced hearing loss begins around the frequency of 4 kHz and slowly progresses within this frequency region and continuation of exposure to noise may lead to the involvement of other adjacent frequencies, some this is achieved in this investigation both in experimental or theoretical findings [12, 46, 47]. While the amount of Noise Induced Hearing Loss and the frequencies involved depending on the acoustic parameters of noise and the length of exposure. Besides, there are some subjective factors such as general health, genetics, medication and susceptibility to noise [12].

Noise induced hearing loss in right and left ears were also compared, a significant difference at 4 kHz was found which was consistent [12]. Mean hearing loss right and left ear was 17.59 and 15.99 dB, respectively and *t*-test analysis showed that left ear is more sensitive to noise than right ear ($P<0.001$). This result is consistent with the most recent studies [31, 48-50].

The job with the highest level of hearing loss is caring and most of the hearing loss is seen in the first 10 yr of the employment, which is consistent with some studies [25, 51].

For field validation of ISO 1999 method, the predicted and measured values of hearing loss were compared. The measured hearing loss is much higher than predicted hearing loss according. These results were completely against the results of another study [33]. Nonetheless, in some other studies, the reliability of this method was doubtful as well [33, 52]. This difference may be due to insufficient hearing assessment in pre-employment evaluations and other sources of noise exposure outside the workplace. Another reason for this difference is probably different sensitivity of ears of the tested population in comparison to other populations.

There are many factors other than occupational noise, which may affect hearing status of workers, e.g. smoking, ototoxicity and diseases such as diabetes. It is necessary to evaluate all factors affecting the hearing during hearing assessments. Some of these factors are ototoxic drug consumption, smoking, ototoxic substance exposure, familial hearing loss, non-occupational noise exposure and acoustic trauma can affect workers hearing status, therefore, considering only age and occupational noise exposure for predicting hearing loss is not sufficient and may cause underestimation of the level of hearing loss.

This study was the first study for predicting hearing loss by ISO 1999 method In Iran [34], therefore, identification of its validity and reliability needs future studies.

This study had some limitations. For example, we measured the noise level at a specific time, but it is probable that noise at the workplace has been changed during past years. Some exposures (e.g. second job) may not have been mentioned by some workers.

CONCLUSION

The effect of evaluating the efficiency of predictive models and effective factors of noise-induced hearing loss in a study population is very important. Increasing noise and the duration of employment on noise-induced hearing loss has a significant impact. There was a significant difference between the measured noise induced hearing loss and its predicted values. It can be due to inaccurate audiometry. Audiometry was done in the industry and has many errors that need to be reviewed and corrected.

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