RESEARCH ARTICLE

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Oxidative Stress Assessment of Noise Exposure in the Workers Using Hearing Protection in a Pressing Industry

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Abstract

Background and objective: Exposure to noise by generation of free radicals causes oxidative stress in body. The aim of this study was the evaluation of oxidative stress in workers who have used hearing protection devices during working time. **Material and Method:** Pressing workers (n=24) of a home appliance industry were studied using hearing protection devices to reduce noise exposure. Twenty two office staff (without exposure to noise) were considered as a control group. Two groups were matched for age, work experience and smoking. Exposure to noise was measured by dosimeter method at workstations. By obtaining 3 ml blood sample, Malondialdehyde levels, Thiol groups and total antioxidant capacity were evaluated in all subjects. **Results:** Exposure to sound pressure level in pressing workers by considering the noise reduction factor of the earplug was observed in 77.65 dB with minimum 75.1 dB and Maximum 81.22 dB. Plasma thiol groups (0.076 (0.041-0.119) vs (0.110 (0.076-0.197), mmol/l P =0.0001) and total antioxidant capacity (361.33± 54.65 vs 414.14± 96.82, µmol/ml P = 0.026) in pressing workers significantly decreased than control group. Pearson correlation showed significant results between exposure to noise and oxidative stress parameters. **Conclusion:** Exposure to noise wave cause oxidative stress in different site of body. Oxidative stress is an intermediate way for different disease due to noise exposure. Reducing of noise exposure by earplug in pressing workers is not efficient protection for oxidative stress generation. Therefore, hearing protection devices are not a barrier to the harmful effects of noise in occupational exposure.

Keywords: Hearing Protection Devices- Oxidative stress- noise- pressing industry

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Introduction

Noise is one of the most common physical harmful factors in workplace [1]. In Iran, the permissible limit of exposure to sound in industry according to the standard provided by NIOSH and the American Conference of Governmental Industrial Hygienists Professionals (ACGIH) is 85 dB with the rule of 3 dB for 8 hours of work per day [2]. Considering the working population of Iran and according to the statistics of the Center for Environmental and Occupational Health of the Ministry of Health, Golmohammadi et al. have reported that more than 2 million workers are exposed to harmful occupational noise [3].

In metal pressing there are devices that produce a percussive sound with a sound pressure level exceeding the permissible limit [4]. Noise exposure has auditory and non-auditory effects on human health, which has been reported in many studies [5]. Among the auditory effects of sound, we can mention noise-induced hearing loss (NIHL) [6], which has been introduced as one of the 10 most important work-related diseases in the world [7]. Among the non-auditory effects of noise exposure, we can mention the effect on the balance system, headache, anxiety, nausea, walking disorder, nervous effects, sleep disorder, cognitive function disorder, stress, and increase the risk of cardiovascular and metabolic diseases such as blood pressure [6, 8, 9]. Research shows that in many of these cases, sound acts through the mechanism of oxidative stress [10]. When oxidative stress occurs, many macromolecules in the body are damaged, including lipid peroxidation, DNA oxidation, protein oxidation, enzyme deactivation, and dysfunction of various membranes [11]. The best and most common method to measure oxidative stress is to determine the products resulting from the reaction of free radicals with biological molecules of the body [12]. Malondialdehyde (MDA), plasma thiol groups (TTG) and total plasma antioxidant capacity (TAC) can

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be measured as indicators of oxidative stress in the human body.

Studies show that acute and chronic exposure to noise causes the production of additional free radicals and can cause irreversible damage to the auditory system through oxidative stress [5]. These effects are not only limited to the hearing system, but also cause non-auditory disorders such as neurological, endocrine and cardiovascular disorders [13, 9, 14]. Damage to the hair cells of the cochlea can lead to noise-induced hearing loss [6, 5, 14].

The use of hearing protection devices as a temporary and complementary solution can be used to reduce the exposure of workers exposed to noise [15]. Although the use of hearing protection devices should be considered as a temporary solution, however, in industries for various economic and cultural reasons, it is considered as a permanent solution in most cases [1, 15, 16]. One of the main features of hearing protection devices (earplugs and earmuffs) is the noise reduction rate (NRR), which is actually an important indicator for protection efficiency regardless of the type and level of ambient sound pressure. This index is recommended by the American National Standards Institute (ANSI) and accepted in most countries of the world [16]. The point of view of using hearing protection devices is to reduce the impact of sound on the auditory system by modulating the emission through the airway. On the other hand, the purpose of this study is to answer the question of what effect the use of hearing protection devices has on the oxidative stress caused by exposure to sound in the body. Therefore, the present study was conducted with the aim of determining some biomarkers of oxidative stress in press workers of an industry who use hearing protection devices.

Materials and Methods

This cross-sectional study was conducted on press machine operators in a home appliance industry located in Tehran. The studied subjects were selected by census method from press machine operators (30 people), and according to the entry criteria, 24 people were included in the study. Also, 22 employees of the office unit were selected as the control group. Demographic information of people, including age, work experience, smoking, diseases such as diabetes, blood pressure, hearing loss, and special diseases such as immunodeficiency diseases, epilepsy, and cancer, were collected through the workers' demographic profile sheet. Also, the general health of people was examined using the GHQ questionnaire. Obtaining a score of 22 and below was the criteria for entering people in the public health evaluation. Also, not having any of the above diseases, general health and not taking medication and work experience of at least 1 year were considered as other entry criteria. People were matched in terms of age, work experience and smoking in two control and exposed groups.

Noise measurement

First, the required information about the workplace, such as the number of sources of sound generation, the number of people working in the unit, work shifts and working hours, how the worker is exposed in terms of the variability of sound with time, its pattern and frequency in terms of the type of sound (percussive) and other workplace information related to the workers were collected. There were 10 press machines, one bending machine and one scissor machine in the industrial press hall (Figure 1). Table 1 shows the number of workers exposed to different press machines.

The dosimetry method was used to measure the worker's exposure. In this study, dosimeter model 4444 made by B&K company and calibrator made by B&K company and model 4231 were used. Due to the fact that the workers' exposure pattern was certain, dosimetry was done in a short period. For this purpose, dosimetry was done for 2 hours when workers were present at the work site. According to ISO 9612 standard, the microphone of the dosimeter device was placed at a distance of 10 to 30 cm from the external ear canal of the workers and on the collar of their clothes. Considering that the workers were present in the press hall for 7 hours and 15 minutes, after reading the two-hour dose on the device, the two-hour dose was converted to the 7.25-hour dose (real exposure time) through the Equation 1:

$$\frac{D_2}{D_1} = \frac{T_2}{T_1} \qquad \text{Eq. (1)}$$

Which:

T_1 = dosimetry duration (2 hours)

T_2 = actual exposure time of the worker (7.25 hours)

D_1 = 2-hour measured dose (percentage)

D_2 = dose calculated for working time 7.25 hours (percentage).

Then, the level of exposure equivalent to 7.25 hours in decibels was calculated from the 7.25 hours dose using the Equation 2:

$$\text{equivalent exposure level to 7.25 hours} = 10\log\left(\frac{Dose \times 8}{100 \times \text{actual exposure time}}\right) + 85 \qquad \text{Eq. (2)}$$

Which:

Standard sound pressure level = 85 dB

Daily work scale = 8 hours

Actual exposure time = 7.25 hours.

Finally, the resulting value and sound pressure level measured at rest were used, and the 8-hour sound pressure level was calculated using the Equation 3:

$$L_{eq\,8} = 10\,Log\,\frac{1}{8}\sum_{i=1}^{n} t_i \times 10^{\frac{Lp_i}{10}} \qquad \text{Eq. (3)}$$

Which:

Leq_8= Equivalent Continuous Sound Pressure Level to 8-hour sound (dB)

LP_i = sound pressure level measured at the work site (dB)

T_i = exposure times (hours).

Assessment of oxidative stress

After obtaining written consent, 3 ml of blood was obtained from the workers at the end of the work shift. After blood collection, blood samples were collected separately in polyethylene tubes containing EDTA

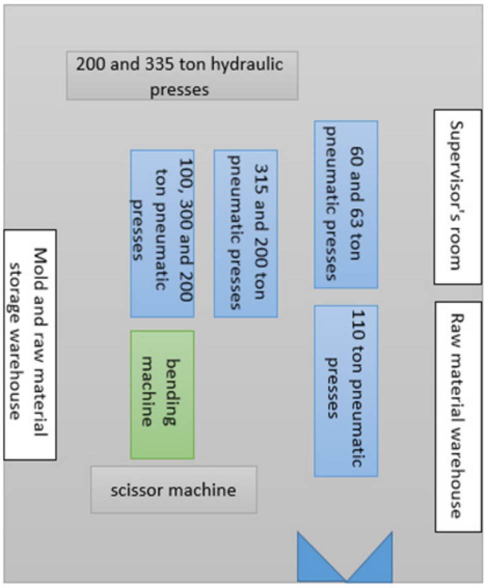

Figure 1. The Map of the Pressing Hall and the Location of the Pressing Machines

Table1. Location of Workers in the Press Hall

Type of press machines		Workers (n)
pneumatic	60 & 63 ton	4
	100 & 110 ton	5
	200 & 300 ton	5
	315 & 400 ton	6
hydraulic	200 & 335 ton	4

Table 2. Demographic Characteristics in Two Exposure and Control Groups

parameters	Exposure group	control group	p-value
Age*	40.29 ± 5.31	38.86 ± 7.05	0.439
Work experience < 15**	9	12	0.246
Work experience > 15**	15	10	
smoking**	16	14	0.829
Yes	16	14	0.829
No	8	8	

*, Standard deviation ± mean; **, Frequency

Table 3. Results of Noise Measurement in Workstations

Type of press machines		Workers (n)	Minimum LP (dB)	Maximum LP (dB)	average LP (dB)	Minimum Leq8 (dB)	Maximum Leq8 (dB)
pneumatic	60 & 63 ton	4	89.3	90.3	89.92	88.9	89.91
	100 & 110 ton	5	89	91.2	90.44	88.91	90.87
	200 & 300 ton	5	90.3	91.4	90.91	89.87	90.97
	315 & 400 ton	6	91.43	92.8	92.8	91	93.9
hydraulic	200 & 335 ton	4	85.73	98.1	87.62	85.39	88.67

anticoagulant and transported to the laboratory for analysis. In order to separate the plasma, the samples were centrifuged at 3000 rpm for 15 minutes.

In order to measure the level of lipid peroxidation, based on the method proposed by Karatas et al., the concentration of MDA in human blood plasma was measured using a high-performance liquid chromatography (HPLC) device. First, the standard solution of malondialdehyde was prepared from the acid hydrolysis of 3,3,1,1-tetraethoxypropane by hydrochloric acid, which was placed in a boiling water bath for 5 minutes and immediately cooled to a concentration of 292 µg/ml. After the preparation of functional standards in the concentration range of 17.52 to 175.2 µg/ml, the calibration curve was obtained. After preparation, the samples collected from the workers were analyzed at a wavelength of 254 nm with a mobile phase consisting of 35% methanol and 65% 30 mM phosphate buffer at a flow rate of 1 ml/min [17].

The FRAP assay (Ferric Reducing Antioxidant Power) was used to measure the total antioxidant capacity of plasma. In this method, the ability of plasma to regenerate ferric ion ($Fe+3$) is measured. By reducing ferric ion and converting it to ferrous ion ($Fe+2$) in acidic conditions and with the presence of specific reagent, TPTZ, a blue colored complex is created which can be measured at 593 nm wavelength by spectrophotometer [18]. Thiol in plasma was determined using the Hu method. In this method, dithionitrobenzoic acid (DTNB) solution reacts with thiol groups. By reducing this reagent, thiol groups create a yellow complex that can be measured at a wavelength of 412 nm [19].

Statistical Analysis

SPSS software version 21 was used for statistical data analysis. Kolmogorov-Smirnov test was used to check the distribution of data. Parametric tests were used for normal data and non-parametric tests were used for non-normal data.

Results

The data distribution of age, work experience and smoking was analyzed using the Kolmogorov-Smirnov statistical test. The distribution of normal age data was evaluated ($P = 0.612$) and the average age of the workers in the exposed and control groups was 40.29 ± 5.31 and 38.86 ± 7.05, respectively. The independent t-test was used to compare age and the chi-square test was used to compare work history and smoking. The results of statistical tests confirmed the similarity of the two groups in terms of age, work experience and smoking (Table 2).

The sound measurement results show that the highest equivalent continuous sound pressure level to 8-hour can be seen for the operator of the 400 ton pneumatic press at the rate of 93.9 dB and the lowest value for the operator of the 200 ton hydraulic press at the rate of 85.39 dB (Table 3).

The measurement results show that exposure to noise in all workstations is more than the permissible limit. Press workers used JSP model of earplug hearing protectors. According to the recommendation of the National Institute of Occupational Safety and Health (1998), the amount of sound reduction for earplugs was considered to be 50% of the reduction power recommended by the manufacturer, which is equivalent to 12.5 dB. Due to the fact that all personnel were using hearing protectors, the average individual exposure to noise was 77.65 dB with a minimum and maximum of 75.1 and 81.22 dB, respectively .Further, after calculating the noise exposure by considering hearing protection devices, the exposure level of all workers has been reduced to below the permissible limit of 85 dB, but it is still in the caution zone of 65 to 85 dB.

In the case of MDA, the results show that there is no significant difference in plasma MDA level between the exposure and control groups (p=0.086). Also, the statistical test showed that there is a significant difference in plasma TAC level between press workers and office workers (p=0.026), so that TAC concentration in plasma for press workers was lower than the control group. The results of Pearson's correlation showed that there is a significant relationship between noise exposure and plasma TAC (r = -0.337 and p = 0.022).

The results also showed that, there is a significant difference in plasma TTG level between the press workers and the control group (P=0.0001). So that the plasma TTG concentration in the group exposed to noise is lower than office workers. The results of the Pearson correlation analysis showed that there is a significant relationship between the noise exposure and the plasma TTG concentration (r = -0.610 and p = 0/0001).

Discussion

In the studied industry, earplugs were used to reduce exposure to noise. In the product catalog, the amount of noise reduction at the frequency of 2000 Hz was reported as 25 dB. OSHA has recommended the effective reduction rate of earplugs to be 50% of the NRR value [20]. The American National Institute of Occupational Safety and Health has stated the suggested percentage for the ratio of operational reduction to the nominal reduction provided by the manufacturer, 75% for earmuff, 50% for earplugs, and 30% for Flanged earplugs [20]. So, according to the reduction of 50%, in this study, the actual amount of sound reduction by earplugs was considered to be 12.5 dB. Usually the last way to noise control (using hearing protection equipment) is chosen. Since the highest Leq8 equal to 93.9 dB has been reported, assuming that the reduction factor of 12.5 dB is considered, it can be concluded that the use of earplugs in this industry has reduced the level of noise exposure.

In a study, Jurban et al. classified workers in terms of work experience (years) into three groups: 2-8 years, 9-19 years, and more than 19 years, and examined the serum level of malondialdehyde in each group. The serum level of malondialdehyde in the first, second, third and control groups was reported as 1.646 ± 0.5, 2.401 ± 0.7, 2.808 ± 0.6 and 0.6 ± 0.3 (µmol/l), respectively. ±0.6. They reported that the serum level of malondialdehyde of workers exposed to noise pollution in power stations is significantly higher than the control group ($P \leq 0.05$). They also stated that the increase in the serum level of malondialdehyde is due to the increase in the production of free radicals caused by exposure to noise pollution in the workplace. The use of personal protective equipment was not investigated in this study [21].

The results of the present study are consistent with other studies investigating the effect of noise exposure on oxidative stress. One of the characteristics of this study is the use of personal protective equipment in all the studied workers one month before the measurement. The results of this study showed that thiol groups and total plasma antioxidant capacity were significantly lower in press workers compared to the control group. These results show that resistance to oxidative stress is reduced in workers exposed to noise. Also, the evaluations revealed a negative correlation between noise exposure and TAC and TTG levels. Total plasma antioxidant capacity and thiol plasma decrease with increasing exposure to sound, because these two indicate the state of the body's antioxidant defense system.

When the body is exposed to an oxidant agent, the production of free radicals in the body is abnormally increased, which leads to the stimulation of the body's antioxidant defense system. In this condition, the total antioxidant capacity of plasma and the concentration of thiol groups in plasma, which are sensitive to oxidative damage, decrease. The results of this study are also in line with the reduction of plasma thiol groups and the antioxidant capacity; and are consistent with the creation of oxidative stress by noise exposure. It should be noted that many factors cause oxidative stress, but in this study, the control group was matched as much as possible with the exposed workers, such as age, work history, and smoking. Doing this made it more reliable to attribute oxidative stress to noise exposure. In addition, establishing a statistical relationship between oxidative stress parameters and noise exposure emphasizes that the studied workers suffered from oxidative stress due to noise exposure. Since in this study, personal protective equipment has reduced noise exposure, it is expected to reduce hearing effects caused by noise, but the evaluations showed that hearing protective equipment is not effective in reducing oxidative stress in noise exposure, and as a temporary and complementary solution in line with other controls can be used.

Studies have evaluated the effect of noise on oxidative stress [21, 20] and no study has reported the occurrence of oxidative stress while using hearing protection devices. Studies show that air transmission is not the only route of noise transmission. Noise can also penetrate solids. The contact of the body with vibrating objects is also one of the ways of structural transmission of noise that can affect the organs and tissues of the body [18]. Therefore, it seems that noise exposure exists in other parts of the body in addition to the auditory path. This study shows that noise exposure, despite the use of hearing protection devices, has a significant difference in the level of oxidative stress parameters between press workers and non-exposed workers.

In conclusion, Oxidative stress is an intermediary pathway for the occurrence of various diseases, which is considered as one of the side effects of noise exposure. Noise control using hearing protection devices is considered as one of the most common ways used in industries. Since the earplugs limit the transmission of noise only through the auditory path, the effects of these waves still exist in different parts of the body. From the results of this study, it can be concluded that earplugs have reduced the noise exposure through hearing, but did not protect against oxidative stress. In general, it can be said that the results of this study will emphasize that the use of personal protective equipment should be considered as the last occupational health approach in facing harmful factors.

Author Contribution Statement

Zahra Moradpour: investigation, project administration, writing original draft, and writing—review and editing. Behjat Jafari Tehrani: Methodology and writing - Original Draft. Fatemeh Ravannakhjavani: conceptualization, writing the original draft. Seyed Husein Naziri: project administration, writing and editing. Mojgan Tansaz: Software, writing and review. Mansoureh Hamidi: Methodology and writing - Original Draft. Rezvan Zendehdel: Supervision, methodology, writing original draft, and writing—review and editing.

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Approval Ethics

This work was done with the code of ethics issued by the Faculty of Safety and Public Health of Shahid Beheshti University of Medical Sciences [No.: IR.SBMU.PHNS.REC.1398.011].

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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