The Impact of Hearing Protection Devices (HPDs) on Blood Pressure in Workers Exposed to Noise: A Cross-sectional Study in a Textile Industry

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ABSTRACT
Many studies have reported that exposure to workplace noise leads to increase in blood pressure. The aim of this study was to investigate the effect of hearing protection devices (HPDs) including ear plug and ear muff on the systolic and diastolic blood pressures of workers exposed to workplace noise in a textile industry. A total of 120 male workers that exposed to 95 dB noise were investigated in this study. The systolic and diastolic blood pressures of the workers were measured for three situations of earplug, earmuff and earplug along earmuff applications. Data analyses were conducted through SPSS software (version 20) and statistical tests of ANOVA and Independent Sample Tests. The comparison of mean blood pressure in three situations showed that using ear muff had a significant effect on the systolic and diastolic blood pressures in the workers. Furthermore, the use of ear plug only had an effect on the systolic blood pressure. But, the application of ear muff caused to decrease in the systolic and diastolic blood pressures only in the third stage of the study. With regard to the results in this study, in order to control the blood pressure changes of the workers, it is recommended to use ear muff in the textile industry.

Key words: Noise, Hearing Protection Devises (HPDs), Blood Pressure, Textile Industry

INTRODUCTION
Noise is one of the most hazardous factors in work environment which has adverse effects on human health. National Institute of Occupational Safety and Health (NIOSH) reports that about 30 million workers are exposed to dangerous noise levels in their workplaces [1]. Furthermore, it has been estimated that around 50% of American industrial work environments exposed to noise levels of 85-95 dB [2]. Exposure to noise in a workplace leads to increase in glucocorticoid release, heart rate and peripheral hypertension. The increment of these mechanisms also effects on blood pressure [3]. Many studies have reported systolic and diastolic hypertension as a result of exposure to noise at workplace environment [4-7]. Hypertension is considered as a risk factor of cardiovascular diseases and also brain stroke. In addition, the systolic hypertension is associated with some diseases such as brain stroke, ischemic heart disease and Cardiomegaly [8]. So, applying various interventions to control hypertension can prevent brain stroke and also can reduce the damages to other target organs including congestive heart failure or renal failure [9]. Although, the genetic agents are the main risk factors for hypertension, but, the environmental factors such as noise have substantial role to control of hypertension [3]. Therefore, in point of management and health view, control of the environmental factors such as workplace noise to maintain workers' health is necessary. To prevent noise-induced hearing loss (NIHL) and other adverse effects of noise, the application of noise management and its engineering controls are considered as the preferred methods [10]. But, in some conditions, it is difficult to manage these control methods due to many reasons including high cost of the controls and lack of requirements and appropriate management. In these conditions, the application of hearing protection devices (HPDs) is the only control method to diminish the workplace noise [11, 12]. The Occupational Safety and Health Administration (OSHA) have forced employers to provide HPDs for their employees for an 8-hour TWA

(Time-weighted average) noise level of 85 dB or above if the engineering control methods are not enough [13]. A study by Kalantari *et al.* on the use of HPDs and the changes at the cortisol level among the workers exposed to excessive noise greater than 85 dB in a textile industry showed that there was a statistically significant difference between the cortisol levels in people who used and did not use of HPDs [14].Sbihi *et al.* surveyed the effectiveness of the earplug protection device in the workers exposed to excessive sound pressure more than standard rate; they concluded that the urine cortisol level in the workers was more than of the control group exposed to noise with lower the permissible limit [15]. Lee *et al.* studied on the workers equipped with simultaneous earplug and earmuff in high noise place (greater than 85 dB); they reported that the hypertension rate was higher in the groups only used one of these devices [3]. It has been proved that the use of HPDs can be recommended as a short-term solution for preventing NIHL if it is carefully planned, evaluated and monitored [10]. To the best of our knowledge, no studies have been carried out on the blood pressure changes in workers who use the hearing protection devices so far. Therefore, this study was conducted to investigate the effect of using HPDs on the systolic and diastolic blood pressures changes in workers exposed to workplace noise in a textile industry.

MATERIALS AND METHODS

Study population

This analytical cross-sectional study was performed on 120 male workers employed in a textile industry (Isfahan, IRI) in 2013. The studied laborers worked in two different weaving (40 workers) and spinning (80 workers) units. The workers were selected in different sectors of the weaving and spinning units like ring, weaving, carding, Auto Kenner, twisting etc. Inclusion criteria of the study for worker participation consisted of the following: lack of hearing loss more than 20 dB, lack of cardiovascular diseases, diabetes, obesity and other influencing diseases reported by individual. The workers with a systolic blood pressure of greater than 150mm Hg were excluded from the study.

Environmental conditions

To determine environmental conditions of the above mentioned two units, workplace temperature, relative humidity and noise were measured. The temperature and relative humidity in the spinning and weaving units were 26.0°C and 40.0% and 23.7°C and 67.3%, respectively. Furthermore, the rates of these two variables in weaving unit were 23.7°C and 67.3%. Noise measurement (on the basis of dB) in the workplace environments of the units were quantified by a noise measurement device, Nor-132 (UK). In order to frequency analysis, two networks of A and C were used to determine noise levels of the workplace environments and network C was also applied to measure high level noise. The noise measurement device was calibrated using a calibrator (Nor-1252) before noise measurement. The total means results of noise measurement of the studied stations (weaving and spinning units) in different frequencies are shown in Table 1.

Table 1: The means of Equivalent Sound Level (Leq) in network A, C and in Frequency Analysis of octave band

Section	A	C	Octave Band Analysis Data						
			250	500	1000	2000	4000	8000	*16000*
Weaving	95	97	93	90	91	93	88	84	*80*
spinning	95	96	89	91	92	90	87	80	*73*

Hearing Protection Devices (HPDs)

The participants were divided into three groups of 40 people. The first, second and third groups were given Earmuff (JSP Ltd, England), Earplug (ELEVEX, Iran) and both Earmuff and Earplug protection devices, respectively. The technical specifications of the hearing protection devices (HPDs) are presented in Table 2.

The Noise Reduction Rating (NRR) for simultaneous use of Earplug and Earmuff is generally 5 dB higher than the highest NRR used instruments [16, 17]. So, earmuff had the highest NRR was for the Earmuff and the value of NRR for simultaneous use of HPDs in this study was 31 dB (High=36, Medium=28, Low=21, and NRR=31dB).

Table 2: Noise Reduction Rating (NRR) in different frequencies for the used ear plug and Earmuff

Device Type	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
Earplug							
Mean Attenuation (dB)	29.4	30.8	31.8	32.1	33.1	36.8	39.5
Standard Deviation	4.3	4.0	3.9	3.3	2.6	3.3	2.8
High = 32, Medium = 29, Low = 28, NRR = 25 dB							
Earmuff							
Mean Attenuation (dB)	14.5	16.6	22.1	35.3	32.4	38.4	35.9
Standard Deviation	3.9	3.9	2.9	2.9	3.0	2.8	3.0
High = 31, Medium = 23, Low = 16, NRR = 26 dB							

Design of research

Firstly, the voluntary participation form was given to the people according to the Helsinki Accord and the process of participation was explained. Then, the individuals' hearing and cardiovascular health conditions were evaluated and the healthy people were selected in this study. The hearing protection devices were delivered to the participants and the systolic and diastolic blood pressures were measured three times (each 10 minutes) by a Mercury sphygmomanometer after 30 min exposure to noise. The mean values of these three times of the systolic and diastolic blood pressures were recorded as the first-stage of systolic blood pressure (SBP1) and diastolic blood pressure (DBP1), respectively. Then, the systolic and diastolic blood pressures of the participants were measured three times after 30 min exposure to noise in the absence of the hearing protection devices. During this period, the mean values of the systolic and diastolic blood pressures were recorded as the second-stage SBP (SBP2) and DBP2, respectively. Finally, the individuals were asked to use the hearing protection devices and the mean values of three times the systolic and diastolic blood pressures measurement after 30 min exposure to noise were also recorded as the third-stage SBP (SBP3) and DBP3, respectively. This process was conducted for every studied participant during 20 days. The final score of blood pressure changes, based on mean systolic and diastolic pressures during 20 days, for every individual in three stages of the study (including use of HPDs, not use of these devices and reuse of them) were reported.

Statistics analysis

Firstly, the difference of systolic and diastolic blood pressures values was calculated in each three groups. Then, the variations of blood pressures in the groups were compared with each other by SPSS-20 software via descriptive statistics and variance analysis. Furthermore, the results were analyzed by other statistical tests of ANOVA and Independent Sample test.

RESULTS

Demographic characteristics, workload and blood pressure

Table 3 shows the demographic characteristics of the participants and also the mean heart rate of them in three groups. As seen, the mean heart rate of the participants for both the weaving and spinning units was 88.2±12.8 beats per minute. Since, because the heart rate of the workers was less than 90 beats per minute, therefore, the activity of the studied individuals is classified in easy workload class [18]. The results of ANOVA statistical test also showed a significant difference between work experience and heart rate in variables in three studied groups.

Table 3: Demographic characteristics of the participants in this study.

Variables	Ear plug		Ear muff		Combined		Total		P-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Age (year)	35.6	7.5	33.5	6.8	32.2	8.2	33.8	7.6	**0.131**
Body mass (Kg)	70.1	11.6	69.8	12.6	68.1	11.9	69.4	12.0	**0.721**
Height (cm)	173.0	4.5	172.5	7.4	171.8	6.8	172.5	6.3	**0.695**
BMI ($kg.m^{-2}$)	23.4	3.6	23.4	3.8	23.0	3.3	23.3	3.5	**0.838**
Experience (year)	12.8	6.8	9.2	6.8	7.8	7.8	10.0	7.4	**0.007**
Heart rate $beats.min^{-1}$)	87.6	14.2	85.2	10.1	92.1	13.3	88.2	12.8	**0.046**

Effects of hearing protection devices (HPDs) on blood pressure

The comparison of the systolic and diastolic pressures mean values, in every group, was performed and the results are shown in Table 4. As can be seen, the results demonstrated the significant difference between mean systolic blood pressure in the various stages of the group used ear muff (P=0.005). But, on the other hand, there was no significant difference between the systolic blood pressure in three stages of the groups that used ear plug and ear plug with ear muff (P=0.121-0.261). The comparison of mean diastolic blood pressure values, in three stages of the groups also showed that the significant difference in diastolic blood pressure were only found in the group that used air muff (P<0.001). The results of Table 4 also presented no significant statistically difference among the diastolic blood pressure of the groups (P=0.195).

Table 4: The mean systolic blood pressure (SBP) and Diastolic blood pressure (DBP) values in the groups.

Blood Pressure (mmHg)	Ear plug		Ear muff		Combined		*P* (Comparison Groups)
	Mean	SD	Mean	SD	Mean	SD	
SBP1	128.40	13.2	129.25	11.2	137.43	15.3	
SBP2	130.47	13.2	132.69	13.2	134.05	17.9	
SBP3	127.32	12.2	126.53	12.3	132.33	15.7	
***P* (Changes in three steps)**	*P*=0.261		*P*=0.005		*P*=0.121		***P*=0.050**
DBP1	83.82	11.2	82.67	8.0	86.02	10.0	
DBP2	82.15	10.4	82.95	10.0	85.51	14.7	
DBP3	80.92	10.8	78.13	9.3	82.84	10.3	
***P* (Changes in three steps)**	*P*=0.086		*P*<0.001		*P*=0.250		***P*=0.195**

DISCUSSION

The application of hearing protection devices (HPDs) is a simple solution to control noise exposure in workplace due to economic and practical reasons [19]. The aim of this study was to investigate the effect of using HPDs of ear plug, ear muff and ear plug along with ear muff on blood pressure in the persons exposed to noise in a textile industry. Hypertension is defined as systolic and diastolic blood pressures equal or more than or equal to 140 mmHg and 90 mmHg, respectively [20]. Since the means of systolic and diastolic blood pressures among the participants in this study showed that the studied groups did not suffer from high blood pressure. Furthermore, the values of the systolic and diastolic blood pressures changes of the workers over using HPDs were less than 140 and 90 mmHg, respectively in each three stages. In this study, the effect of HPDs on the blood pressure changes of the workers was investigated in three stages of use, lack of use and reuse of the HPDs. The results of three stages in the studied groups showed that ear muff decreased the systolic and diastolic blood pressures more than other HPDs (ear plug and combined ones). The effect of ear muff on the reduction of the systolic blood pressure value was significantly more than of the diastolic blood pressure. Moreover, the decrease of mean value of the systolic blood pressure in three stages was greater in the group that used ear muff compared to other HPDs. Sbihi *et al.* investigated the effect of ear plug on the physiological and psychological responses of the workers; they expressed that using ear plug decreased the frequency of the mental fatigue signs and also the urine catecholamine level [15]. Furthermore, Hu *et al.* expressed that using ear plug and face mask increased the hormonal balance and sleeping [21]. The results of this study showed that the combined use of ear plug and ear muff decreased the systolic and diastolic blood pressure only after the second stage (lack of use of HPDs) and in the third stage (use of them). The reduction of the diastolic blood pressure mean values were more significant as a resulted of the combined use of ear plug and ear muff. It was found in that the systolic and diastolic blood pressures were decreased in each three groups in the third stage compared to the second stage. Moreover, the decrease of the systolic and diastolic blood pressures mean values for the workers equipped with ear muff was more than of other groups. Although most workers prefer to use ear plug compared to ear muff, due to provide a more realistic feel of the outer environment [22], but the results of this study showed that ear muff had more efficiency in decreasing blood pressure than other HPDs. Various studies have been conducted on the effectiveness and usability of HPDs in industries [23-27]. In these studies, the hearing protection and also peoples' understanding about using the HPDs have been considered as an affected factor. However, the changes in blood pressure value of the workers used HPDs have been considered as a dependent variable in the present study. Although, the previous studies have reported that the combine use of ear plug and ear muff was more effective for reduce noise [16, 28, 29], but, our study showed that ear muff was more effective protector for blood pressure changes compared to other HPDs. So, this device (ear muff) had more efficiency in decreasing systolic and diastolic blood pressures of the workers.

With regard to this fact that old age is considered as a risk factor of hypertension [30], therefore, industries, especially with relatively old aged workers, can be used ear muff as more effective HPDs to control of workplace noise and blood pressure.

CONCLUSION

In this study, the effect of hearing protection devices (HPDs) on the systolic and diastolic blood pressures was studied among workers exposed to workplace noise. According to the results, the use of ear muff significantly decreased the systolic and diastolic blood pressures. The decrease in the systolic blood pressure values for the workers that used ear muff was more than of the diastolic blood pressure. Also, the comparison of mean systolic and diastolic blood pressures in three study stages showed that the pattern of systolic blood pressure decrease was more considerable than of the diastolic blood pressure. Although the use of ear plug decreased the systolic blood pressure value in the workers used ear plug, but, it did not decrease the diastolic blood pressure in the highly noisy environments. Finally, it was proved that combined use of the ear plug and ear muff was less efficient to decrease the blood pressure. On the other hand, combined use of ear plug and ear muff did not decrease the systolic and diastolic blood pressure in all three stages of the study. With regard to the obtained results in this study, in industries that HPDs are applied to control the blood pressure changes in order to maintain the workers' health, it is recommended to use ear muff instead of ear plug.

ETICAL ISSUES

Ethical issues such as plagiarism have been observed by the authors.

CONFLIC OF INTERSEST

Authors have no conflict of interests.

AUTHORS' CONTRIBUTIONS

All authors equally help to write this manuscript.

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