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Assessment of Role of Job Components and Individual Parameters on the Raised Blood Pressure in a Noisy Industry

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The present study aimed to determine the role of job components and individual parameters on the raised blood pressure among male workers of textile industry who were exposed to continuous high noise level. Information of all eligible subjects including demographic and individual characteristics, medical history and job characteristics were obtained by direct interview and referring to the medical records. All blood pressure measurements were done using mercury sphygmomanometer in the morning before work. The 8-hours equivalent A-weighted sound pressure level, the level of blood cholesterol and triglyceride, and noise annoyance was determined for each worker. As the result of weighted regression in path analysis (direct effect), only the work shift did not have a significant effect on blood pressure among the studied variables. It can be seen that variables including the level of triglyceride, cholesterol, and noise exposure have the most direct effects on blood pressure. The results of total effects showed that variables, including using the hearing protection device, age, work experience and visibility of sound source, did not have a significant effect on blood pressure. The results of this study indicate that occupational noise exposure alone and combined with other job components and individual parameters is associated with raised blood pressure. However, noise exposure was probably a stronger stressor for increased blood pressure.

Keywords: noise exposure; noise annoyance; noise sensitivity; triglyceride; cholesterol; raised blood pressure.

1. Introduction

Keeping the blood pressure (BP) under control is extremely important since having abnormally high blood pressure (≥ 120 mmHg systolic) can be considered a risk factor for many diseases and life-threatening problems (Lawes *et al.* 2008; MacGregor, He, 2005). Raised blood pressure is a health risk for the heart and circulatory system (the cardiovascular system) worldwide. Raised BP is responsible for 62% of stroke and 49% of ischemic heart disease and approximately 7% global disability and also about 9.4 million deaths per year worldwide (He *et al.*, 2014). Approximately one billion people, or 15% of the world's population, suffer from raised blood pressure, and are at increased risk of cardiovascular disease, atherosclerosis, plaque-rupture problem, cerebral hemorrhage, small vessel disease and kidney disease (MacGregor, He, 2005).

Employees exposed to high levels of noise at work are considered one of the groups at risk for raised BP (Foraster *et al.*, 2014). Studies have repeatedly indicated that noise exposure increases systolic and diastolic blood pressure (Babisch, 2011). Especially workers in the textile industry are exposed to high levels of noise due to outdated machinery, poor design and construction and crowding of the workplace, especially in developing countries (Ashraf *et al.*, 2009), so it is expected that they are linked with a risk of high BP (Ni *et al.*, 2007). An exposure-response relationship between prevalence of hypertension and noise exposure as a persistent occupational and environmental problem was indicated in previous studies (Jarup *et al.*, 2008; Rosenlund *et al.*, 2001; Osadad, Yamamotoa, 2004). Exposure to high level of noise can cause increase in stress levels leading to adrenalin augmentation, increase in cortisol level, superficial vascular constriction, and as a result, raised blood pressure (Dehghan *et al.*, 2017; Bigert *et al.*, 2005; van Kempen *et al.*, 2002).

The assessment of noise annoyance using subjective ratings can assign a more useful estimator of noise exposure level for tracing its effects on blood pressure (Lercher *et al.*, 1993; Soares *et al.*, 2017; Abbasi *et al.*, 2015). Moreover, some researchers have indicated that the level of noise annoyance can also be affected by the visibility of the sound source, so it has been suggested to hide the source of sound in order to decrease the levels of noise annoyance (Bangjun *et al.*, 2003; Krogh *et al.*, 2012; 2018).

Progress in industrialization has created the need for continuous operations; this is because shift work was known as a significant risk factor for the beginning of hypertension (Suwazono *et al.*, 2008). The combined effects of shift work and exposure to noise on blood pressure have also been investigated by Attarchi *et al.* (2012). They reported that doing shift work and exposure to noise have an additive effect on occurrence of hypertension (Attarchi *et al.*, 2012).

Noise is probably the most prevalent physical stressor in the workplaces; and for underestimating the real health effects, it is necessary to evaluate its adverse effects in the presence of other risk factors (Lercher *et al.*, 1993, Azadboni *et al.*, 2018). There is now a sparse literature regarding this approach, so the present study aimed to determine the role of job components (including noise exposure level, noise source visibility, noise annoyance, using hearing protection device and work shift) and individual parameters (including age, body mass index (BMI), years of employment, level of triglyceride and cholesterol, smoking status) on the raised blood pressure among male workers of textile industry who are exposed to high levels of noise. In the present study, direct and indirect effects of continuous noise on the raised blood pressure of workers engaged in a noisy industry were modeled.

2. Subjects and methods

This cross-sectional study was carried out in Savad-Kouh textile industry in 2017. Workers who had at least ten years of duration of employment were recruited into this study. Participating in this study was entirely voluntary. Subjects were asked to fill out a consent form. Participants who had healthy and balanced diet, and regular exercise behaviour were found to be eligible for study enrollment.

Information of all subjects including demographic and individual characteristics (age, work experience, body mass index, and smoking habit), medical history (history of high blood pressure, diabetes, heart disease or kidney disease, and the use of drugs that have an effect on blood lipids) and job characteristics (shift work, noise source visibility, and use of hearing protection) were obtained by direct interview and referring to their medical records. Participants were excluded if they received any drugs that affect blood pressure such as Corticosteroids, and or had overt diabetes, hypertension, cardiovascular and kidney diseases. Referring to audiometric test results of the workers, those with a hearing loss greater than 30 decibels (dB) and history of hearing impairment were excluded from the study. In the studied industry, workers wear hearing aids under uniform attenuation earmuffs and in this regard, the required training about the instructions for proper fit, correct use, and maintenance of hearing protectors was provided for them.

Blood pressure was measured using mercury sphygmomanometer (ALPK2, Japan) after providing necessary training to participants in the morning before work after 5 minutes of seated rest. All blood pressure measurements were done at least 30 minutes after eating, physical activity, or smoking (Nikolic *et al.*, 2014). To determine the level of cholesterol and triglyceride, after 8 hours of fasting the blood samples were taken and then the samples were transferred to the biochemistry laboratory of Savad-Kouh and analyzed by cholesterol oxidase – phenol + aminophenazone and (CHOD-PAP) and glycerol-3-phosphate oxidase – phenol + aminophenazone (GPO-PAP) methods (Chiu *et al.*, 2006). For 1 day prior to test day, participants were asked to refrain from consumption of alcohol, fatty foods, lipid-modifying drugs, and doing extreme sports (Cox, Garcia-Palmieri, 1990; Fadaei *et al.*, 2017). All above mentioned variables were measured at least three times in one month during the work.

Subjects have being exposed to a variety of noise level but the type of noise was similar as it was produced by weaving and spinning machines, thus personal measurement was conducted. Based on ISO 9612: 2009 consideration since noise was steady in most stations the equivalent A-weighted sound pressure level was measured over 15 minutes in all their work stations by a Bruel and Kjaer Type 2236 noise analyzer. In the cases where noise was fluctuated more than 5 dB, measurement time was equal to working time at that station. The noise measurement was done in every potential place where workers may be present along a working day. The location of a microphone of sound level meter was determined by taking into account the location of subjects in a routine work. Noise measurements were conducted for each person separately and finally, 8-hour time-weighted average sound pressure level was obtained according to the standard ISO 9612: 2009 (ISO, 2009; Dehghan *et al.*, 2013).

Noise annoyance was assessed through the questionnaire "Acoustics – Assessment of noise annoyance by means of social and socio-acoustic surveys" which is defined by ISO/TS 15666:2003 (ISO, 2003). The reliability and validity of its Persian translation was investigated by Alimohammadi *et al.* (2013). This questionnaire uses a numerical scale ranging from 0 to 10 to describe the level of noise annoyance in five scales including not at all, slightly moderately, very and extremely (Abbasi *et al.*, 2015; Monazzam *et al.*, 2018).

The statistical method used in this study is the pathway analysis which includes 6 endogenous variables (work experience, noise annoyance, body mass index (BMI), cholesterol level, triglyceride level, and blood pressure) and 6 exogenous variables (using hearing protection equipment, sound source visibility, noise exposure, smoking status, work shift, and age). Normality of the collected data was tested by Skewness and Kurtosis indices in single-variable mode as well as Mardia test in multivariate mode (Mardia, 1970). In order to achieve robust results, the bootstrapping method was used to calculate confidence intervals as well as significant level with 2000 repeat times (Bollen, Stine, 1992; Efron, 1987).

3. Results

Among 220 workers, 159 volunteers were in full compliance with the inclusion criteria and participated in the study. The results of demographic and individual characteristics showed that 74 subjects (46.5%) wore hearing protection device (HPD), 78 people (49.1%) were able to see the source of sound, 97 participants (61%) were smokers, and 67 people (42.1%) worked in the morning shift. Some of descriptive statistics of the research variables are presented in Table 1.

Table 1. Mean (SD) of the studied variables among the study population.

Variable	Mean ± SD
Age [year]	46.78 ± 5.25
Work experience [year]	24.92 ± 6.42
BMI [kg/m^2]	26.29 ± 0.63
Triglyceride [mg/dl]	181.25 ± 2.87
Cholesterol [mg/dl]	187.31 ± 3.24
Noise exposure level [dBA]	84.72 ± 2.01
Score of noise annoyance	8.15 ± 0.76
Systolic Blood pressure [mmHg]	150.28 ± 2.1

Results of normality tests indicate that the variables in the multivariate mode did not get a normal distribution (Kurtosis = −9.78); so, the statistical analysis was carried out based on bootstrapping method with 2000 repetitions.

The hypothesized model of research is presented in Fig. 1. Fitness for hypothesized model due to gathered data showed acceptable fit on five measures: Chi-square (24.05, df = 43, p = 0.949), Chi-square over degree of freedom (0.676 < 3), Comparative Fit Index (CFI = 1.00), Goodness of Fit Index (GFI = 0.971), and Root Mean Square Error of Approximation (RMSEA < 0.001).

Table 2 shows the standardized regression weights along with their bootstrap confidence intervals. As the result of regression weights (direct effects) in path analysis, among the research variables that their effect on blood pressure based on the hypothesized model was evaluated, only the work shift did not have a significant effect (p = 0.445). It can be seen that among the variables that have a significant effect on blood pressure, variables including triglyceride (95% CI 0.400, 0.511), cholesterol (95% CI 0.353, 0.462), and noise exposure (95% CI 0.448, 0.531) have the most effects.

In the present model of path analysis, there is also an estimation of indirect effects in fact each of them is result of the effect of an exogenous variable through another exogenous variable on the dependent variable (Kline, 2015). Estimating the indirect effects as well as estimating the direct and indirect effect on a variable (total effect) was reported using bootstrap method in Table 3.

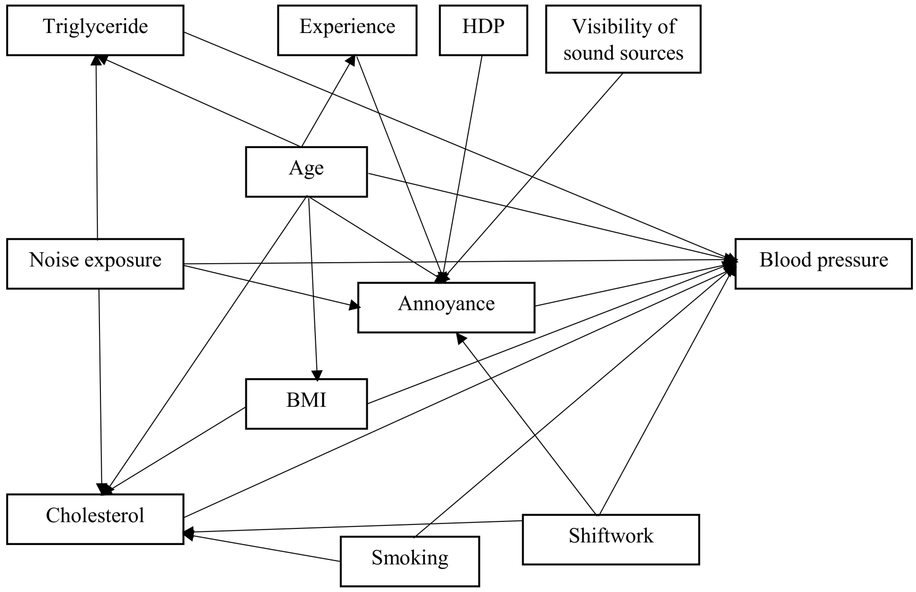

Fig. 1. Hypothesized model of the study.

Table 2. Estimates of standardized regression weights based on hypothesized model.

Parameter I	Parameter II	Estimate (beta)	95% CI	p-value
Age	Cholesterol	–0.10	(–0.23,0.01)	0.08
Smoking	Cholesterol	0.04	(–0.09,0.18)	0.54
ShiftWork	Cholesterol	0.14	(0.004,0.28)	0.04*
NoiseExposure	Cholesterol	0.38	(0.25,0.49)	0.01**
Age	Work experience	0.60	(0.50,0.68)	0.01**
Visibility	Annoyance	0.05	(–0.09,0.21)	0.47
Age	Triglyceride	0.01	(–0.12,0.17)	0.75
WorkExperience	Annoyance	0.03	(–0.16,0.21)	0.76
Age	Annoyance	–0.03	(–0.19,0.13)	0.69
ShiftWork	Annoyance	0.12	(–0.02,0.27)	0.09
NoiseExposure	Triglyceride	0.24	(0.09,0.38)	0.01**
HPD***	Annoyance	0.02	(–0.11,0.16)	0.75
NoiseExposure	Annoyance	0.38	(0.22,0.53)	0.01**
BMI	Cholesterol	0.76	(0.69,0.82)	0.01**
Age	BMI	0.06	(–0.03,0.16)	0.18
Annoyance	Blood pressure	0.19	(0.15,0.22)	0.01**
BMI	Blood pressure	0.05	(0.02,0.08)	0.01**
Cholesterol	Blood pressure	0.40	(0.35,0.46)	0.01**
NoiseExposure	Blood pressure	0.38	(0.44,0.53)	0.01**
ShiftWork	Blood pressure	–0.00	(–0.02,0.01)	0.44
Age	Blood pressure	0.04	(0.02,0.06)	0.01**
Triglyceride	Blood pressure	0.45	(0.40,0.51)	0.01**
Smoking	Blood pressure	0.16	(0.13,0.18)	0.01**

* Significance at 5% level, ** significance at 1% level, *** HPD: hearing protection device.

The results of total effects (total direct and indirect effects) showed that HPD ($p = 0.746$), age ($p = 0.083$), work experience ($p = 0.763$) and visibility of sound source ($p = 0.467$) did not have a significant effect on blood pressure. However, smoking, working in the afternoon shift, exposure to noise in the workplace, cholesterol levels, triglyceride levels, BMI and the noise annoyance had the significant effect on blood pressure.

Table 3. Standardized indirect and total effects.

Parameter I	Parameter II	Indirect effect	*p*-value	Total effect	*p*-value
Age	Work experience	0.00	–	0.60	0.01**
Smoking	Cholesterol	0.00	–	0.04	0.54
Shift work	Cholesterol	0.00	–	0.14	0.04*
Noise exposure	Cholesterol	0.00	–	0.38	0.01**
Age	Cholesterol	0.00	–	–0.10	0.08
Noise exposure	Triglyceride	0.00	–	0.24	0.02**
Age	Triglyceride	0.00	–	0.01	0.75
Smoking	BMI	0.03	0.53	0.03	0.53
Shift work	BMI	0.11	0.04*	0.11	0.04
Noise exposure	BMI	0.29	0.01**	0.29	0.01**
Age	BMI	–0.07	0.08	–0.01	0.85
BMI	Cholesterol	0.00	–	0.76	0.01**
HPD***	Annoyance	0.00	–	0.02	0.75
Shift work	Annoyance	0.00	–	0.12	0.09
Noise exposure	Annoyance	0.00	–	0.38	0.01**
Age	Annoyance	0.02	0.75	–0.01	0.87
Visibility	Annoyance	0.00	–	0.05	0.47
Work experience	Annoyance	0.00	–	0.03	0.76
HPD	Blood pressure	0.00	0.74	0.00	0.74
Smoking	Blood pressure	0.02	0.54	0.18	0.01**
Shift work	Blood pressure	0.08	0.02*	0.08	0.04*
Noise exposure	Blood pressure	0.35	0.01**	0.74	0.01**
Age	Blood pressure	0.03	0.46	0.01	0.08
Visibility	Blood pressure	0.01	0.46	0.01	0.46
Work experience	Blood pressure	0.00	0.76	0.00	0.76
Cholesterol	Blood pressure	0.04	0.01**	0.44	0.01**
Triglyceride	Blood pressure	0.00	–	0.45	0.01**
BMI	Blood pressure	0.00	–	0.05	0.01**
Annoyance	Blood pressure	0.00	–	0.19	0.01**

* Significance at 5% level, ** significance at 1% level, *** HPD: hearing protection device.

The most significant effects on blood pressure were related to noise exposure (beta = 0.743), triglyceride level (beta = 0.456), and cholesterol level (beta = 0.447), respectively.

4. Discussion

The present study indicated that among all studied job components and individual parameters, the most significant factor affecting raised blood pressure was noise exposure. Moreover, noise exposure had the individual and total significant effects on level of cholesterol and triglyceride and score of annoyance, and all of them had the individual and total significant effect on the blood pressure.

In general, effects of occupational noise exposure as the most common physical stressor in the workplace can be categorized into auditory or non-auditory, including hearing impairment and permanent hearing loss as the auditory effects and stress, related physiological and behavioural effects and increased blood pressure as the non-auditory effects (Ismaila, Odusote, 2014; Zamanian *et al.*, 2012; Abbasi *et al.*, 2015; 2016; Mohammadi *et al.*, 2016).

Kelsey *et al.* (1999) concluded that the release of stress hormones such as steroids and activation of the sympathetic nervous system along with release of epinephrine are the main reasons for the raised blood pressure among workers who are exposed to noise (Kelsey *et al.*, 1999). As reported in the study by Chang *et al.* (2003), two possible mechanisms including sympatheticotonia-induced endothelial lesion and stress-induced hormone release have been suggested for initiating hypertension. The current study confirmed that exposure to noise significantly increases the diastolic blood pressure among textile workers, and this finding is in line with the results of the previous studies (Neghab *et al.*, 2009; Ising, Braun, 2000; Motamedzade, Ghazaiee, 2003; van Kempen *et al.*, 2002); however, it did not support some other studies (Ismaila, Odusote, 2014; Attarchi *et al.*, 2012) that observed no significant correlation between noise exposure and raised blood pressure.

According to our results, level of triglyceride and cholesterol also has a strong significant effect on raised blood pressure. Several epidemiological studies have pointed out that arterial hypertension is frequently associated with serum lipid abnormalities (Ferrara *et al.*, 2002; Marotta *et al.*, 1995; Laurenzi *et al.*, 1990; MacMahon *et al.*, 1984). It has been suggested by some authors that endothelium plays an important role in the regulation of systemic blood pressure and local vascular tone, in the sense that, the same factors which can affect the endothelium are able to influence blood pressure levels. Therefore, lipoproteins, which are atherogenic, might contribute to the pathophysiology of arterial hypertension (Ferrara *et al.*, 2002; Vallance *et al.*, 1989; Resink *et al.*, 1994; Creager *et al.*, 1990; Clarkson *et al.*, 1996). Moreover, it has been shown that high cholesterol can impair endothelium-dependent dilation (Creager *et al.*, 1990).

In the present study, it has been shown that there are significant positive correlations between noise exposure and blood level of cholesterol and triglyceride. The effect of occupational noise exposure on increased cholesterol and triglyceride levels has been reported in a couple of studies (Melamed *et al.*, 1997; Mohammadi *et al.*, 2016). Brandenberger *et al.* (1980) have drawn a conclusion that the levels of cortisol will be increased as a result of noise exposure, which subsequently leads to increased total cholesterol, low-density lipoprotein (LDL), triglycerides, decreased cholesterol high-density lipoprotein (HDL), and impaired insulin secretion (Melamed *et al.*, 1997).

In addition, the existence of significant positive correlation between noise exposure and annoyance score has been confirmed in current study. Annoyance is one of the common health problems caused by noise exposure and it has been confirmed in numerous studies that there is a positive exposure-response relationship between noise exposure and annoyance (Héritier *et al.*, 2014; Öhrström *et al.*, 2006; Brink, Wunderli, 2010). Dehghan *et al.* (2013) concluded that the annoyance score "highly annoyed" was obtained by 42% of workers who were exposed to sound pressure level higher than 85 dBA. Noise annoyance as a negative feeling such as disturbance dissatisfaction, displeasure, irritation and nuisance, may evoke emotions and cause the reaction which is tightly related to the individual affective experience regarding the noise source (Ouis, 2002). Several publications suggested that the noise level and the noise annoyance were equally good indicators for assessing the adverse health effect of noise exposure (Rylander, 2004; Lercher *et al.*, 1993; Bluhm *et al.*, 2004). Lercher *et al.* (1993) by Crude analysis showed that the effect of noise annoyance is 2.1 mmHg for systolic and 3.5 mmHg for diastolic blood pressure. Babisch *et al.* (2013) introduced noise annoyance as a modifier of the association between noise level and cardiovascular health. They concluded that subjects who are more annoyed by noise are at a higher risk of raised blood pressure (Babisch *et al.*, 2013).

According to the noise reaction model (Babisch, 2002), one of the principal pathways which is related to adverse health effects of noise is indirect route. It usually refers to the cognitive perception of the sound and its cortical activation and related emotional responses (Ndrepepa, Twardella, 2011). Noise exposure can initiate physiological stress reactions including hypothalamus, the limbic system, the autonomous nervous system, the pituitary and the adrenal gland, and so it can lead to dysregulation of these systems as a result of long-term health effects (Babisch *et al.*, 2013; Rylander, 2004).

At the workplace, one of the non-acoustical factors that contributes to noise annoyance is visibility of sound source (Passchier-Vermeer, Passchier, 2000). In the present study, the effect size of the sound source visibility on noise annoyance was found to be 0.052.

According to above statement, high level of blood cholesterol and triglycerides, noise exposure, and noise annoyance can cause high blood pressure. Our findings indicate the amount of total effect (direct + indirect) of cholesterol and triglycerides level, noise exposure and noise annoyance on blood pressure were 0.447, 0.456, 0.743, and 0.192, respectively. Noise exposure had the total effect of 0.380, 0.243, and 0.387 on cholesterol and triglycerides level and annoyance score, respectively. However, for comparison purposes, there have been no studies conducted on investigating the joint effects of these parameters on blood pressure. The present results are consistent with the above mentioned studies in case of individual effect of studied parameters on blood pressure.

Our results indicate that the variables age, BMI, and smoking have the significant individual effects on blood pressure with total effect of 0.010, 0.054, and 0.181, respectively and there was no significant individual relationship between blood pressure and shift work of participants (total effect: 0.081). It has been demonstrated that the prevalence of hypertension increases with aging (Pinto, 2007; Hart *et al.*, 2012). Increase in blood pressure with aging is associated with several reasons including: a decrease in vascular resistance, reduced elasticity of the blood vessel, changes in blood volume and decreased kidney function (Kovacic *et al.*, 2011; Greenwald, 2007; Lakatta, 1999). The body mass index has a major influence on blood pressure (Brown *et al.*, 2000). Jones *et al.* (1994)

found that the relationships between BMI and systolic and diastolic blood pressure were almost linear. It seems that weight gain stimulates sympathetic activation which inhibits insulin and leptin secretion. Moreover, linking between body weight and elevated blood pressure can be due to activation of the renin-angiotensin system as well as physical compression of the kidney (Drřyvold *et al.*, 2005; Masuo *et al.*, 2000; Hall *et al.*, 2000). Epidemiological studies have demonstrated that cigarette smoking is associated with changes in blood pressure (Neaton, Wentworth, 1992; Sung *et al.*, 2016; Jain *et al.*, 2016), since smoking releases sympathetic neurotransmitters which increase blood pressure (Abtahi *et al.*, 2011). However, some studies confirm that smoking decreases blood pressure, because of the cotinine (a metabolite of nicotine) loosens vascular muscle and widens blood vessels and it leads to decreased BP (Borzelleca *et al.*, 1962; Dominiak *et al.*, 1985). Shift work disrupts sleep patterns and physiological circadian rhythms (Ĺkerstedt, 2003). Shift work is a systemic stressor which can be related to blood pressure dysregulation and hypertension. Sleep deprivation increases the activity of sympathetic nervous system and adrenocortical excitation, and in that way it can lead to blood pressure dysregulation (McCubbin *et al.*, 2010; Chang *et al.*, 2006).

So far only a few studies have dealt with the combined effect of noise exposure and the above mentioned parameters in present study on raised blood pressure. Some epidemiological studies suggest that long-term exposure to noise causes the increased risk of high blood pressure in middle-aged and older subjects (Eriksson *et al.*, 2007; Rhee *et al.*, 2008). It has been shown that for the workers engaged in a noisy environment, there was an additive effect of exposure to noise and shift working on occurrence of hypertension (Ismaila, Odusote, 2014). Also, Lercher *et al.* (1993) concluded that workers who experience noise annoyance have significantly higher BMI, and usually work on nightshifts. In their study, it was reported that age and BMI showed larger contributions on blood pressure than smoking, which is inconsistent with our results. They have shown that shift workers are more annoyed by noise than day workers.

5. Conclusions

The results of this study indicate that individual and combined effect of occupational noise exposure with job components and individual parameters is associated with increased blood pressure. Noise exposure may be a stronger stressor for blood pressure that other studied parameters. So far only a few studies have dealt with the combined effect of noise exposure and the studied variables on raised blood pressure and such findings can expand the current knowledge of direct and indirect effects of noise exposure on blood pressure. Although, future field and laboratory studies with larger sample sizes, more potential confounding factors and long follow-up are needed to confirm our findings on this issue.

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Competing interests

The authors declare that they have no competing interests.

References

1. Abbasi M., Monazzam M.R., Akbarzadeh A., Zakerian S.A., Ebrahimi M.H. (2015), *Impact of wind turbine sound on general health, sleep disturbance and annoyance of workers: a pilot-study in Manjil wind farm, Iran*, Journal of Environmental Health Science and Engineering, **13**, 1, 71.
2. Abbasi M., Monazzam M.R., Ebrahimi M.H., Zakerian S.A., Dehghan S.F., Akbarzadeh A. (2016), *Assessment of noise effects of wind turbine on the general health of staff at wind farm of Manjil, Iran*, Journal of Low Frequency Noise, Vibration and Active Control, **35**, 1, 91–98.
3. Abbasi M., Monnazzam M.R., Zakerian S., Yousefzadeh A. (2015), *Effect of wind turbine noise on workers' sleep disorder: a case study of Manjil wind farm in northern Iran*, Fluctuation and Noise Letters, **14**, 2, 1550020, 15 pages.
4. Abtahi F. *et al.* (2011), *Correlation between cigarette smoking and blood pressure and pulse pressure among teachers residing in Shiraz, Southern Iran*, Iranian Cardiovascular Research Journal, **5**, 3, 97–102.
5. Ĺkerstedt T. (2003), *Shift work and disturbed sleep/wakefulness*, Occupational Medicine, **53**, 2, 89–94.
6. Alimohammadi I., Soltani R., Sandrock S., Azkhosh M., Gohari M.R. (2013), *The effects of road traffic noise on mental performance*, Iranian Journal of Environmental Health Science & Engineering, **10**, 1, 18.
7. Ashraf H.D., Younus M., Kumar P., Siddiqui M.T., Ali S.S., Siddiqui M.I. (2009), *Students' Corner-Frequency of hearing loss among textile industry workers of weaving unit in Karachi, Pakistan*, JPMA The Journal of the Pakistan Medical Association, **59**, 8, 575–579.
8. Attarchi M., Dehghan F., Safakhah F., Nojomi M., Mohammadi S. (2012), *Effect of exposure to occupational noise and shift working on blood pressure*

in rubber manufacturing company workers, Industrial Health, **50**, 3, 205–213.

9. Azadboni Z.D. *et al.* (2018), *Effect of occupational noise exposure on sleep among workers of textile industry*, Journal of Clinical & Diagnostic Research, **12**, 3, LC18-LC2.
10. Babisch W. (2002), *The noise/stress concept, risk assessment and research needs*, Noise and Health, **4**, 16, 1–11.
11. Babisch W. (2011), *Encyclopedia of environmentalh-Health*, Burlington, Elsevier.
12. Babisch W. *et al.* (2013), *Noise annoyance – A modifier of the association between noise level and cardiovascular health?*, Science of the Total Environment, **452**, 50–57.
13. Bangjun Z., Lili S., Guoqing D. (2003), *The influence of the visibility of the source on the subjective annoyance due to its noise*, Applied Acoustics, **64**, 12, 1205–1215.
14. Bigert C., Bluhm G., Theorell T. (2005), *Saliva cortisol – a new approach in noise research to study stress effects*, International Journal of Hygiene and Environmental Health, **208**, 3, 227–230.
15. Bluhm G., Eriksson C., Hilding A., Östenson C.G. (2004), *Aircraft noise exposure and cardiovascular risk among men – first results from a study around Stockholm Arlanda airport*, [in:] Proceedings of the 33rd International Congress and Exhibition on Noise Control Engineering. T.C.A. Society, Prague, The Czech Acoustical Society, pp. 2385–2389.
16. Bollen K.A., Stine R.A. (1992), *Bootstrapping goodness-of-fit measures in structural equation models*, Sociological Methods & Research, **21**, 2, 205–229.
17. Borzelleca J.F., Bowman E.R., McKennis H. (1962), *Studies on the respiratory and cardiovascular effects of (-)-cotinine*, Journal of Pharmacology and Experimental Therapeutics, **137**, 3, 313–318.
18. Brandenberger G., Follenius M., Wittersheim G., Salame P., Siméoni M., Reinhardt B. (1980), *Plasma catecholamines and pituitary adrenal hormones related to mental task demand under quiet and noise conditions*, Biological Psychology, **10**, 4, 239–252.
19. Brink M., Wunderli J.-M. (2010), *A field study of the exposure-annoyance relationship of military shooting noise*, The Journal of the Acoustical Society of America, **127**, 4, 2301–2311.
20. Brown C.D. *et al.* (2000), *Body mass index and the prevalence of hypertension and dyslipidemia*, Obesity, **8**, 9, 605–619.
21. Chang H.M. *et al.* (2006), *Total sleep deprivation inhibits the neuronal nitric oxide synthase and cytochrome oxidase reactivities in the nodose ganglion of adult rats*, Journal of Anatomy, **209**, 2, 239–250.
22. Chang T.-Y., Jain R.-M., Wang C.-S., Chan C.-C. (2003), *Effects of occupational noise exposure on blood pressure*, Journal of Occupational and Environmental Medicine, **45**, 12, 1289–1296.
23. Chiu C.-H., Lu T.-Y., Tseng Y.-Y., Pan T.-M. (2006), *The effects of Lactobacillus-fermented milk on lipid metabolism in hamsters fed on high-cholesterol diet*, Applied Microbiology and Biotechnology **71**, 2, 238–245.
24. Clarkson P. *et al.* (1996), *Oral L-arginine improves endothelium-dependent dilation in hypercholesterolemic young adults*, Journal of Clinical Investigation, **97**, 8, 1989–1994.
25. Cox R.A., Garcia-Palmieri M.R. (1990), *Cholesterol, triglycerides, and associated lipoproteins*, [in:] Walker H.K., Hall W.D., Hurst J.W. [Eds], *Clinical methods: The history, physical, and laboratory examinations*, 3rd ed., Butterworth, Boston.
26. Creager M.A. *et al.* (1990), *Impaired vasodilation of forearm resistance vessels in hypercholesterolemic humans*, Journal of Clinical Investigation, **86**, 1, 228–234.
27. Dehghan H., Bastami M.T., Mahaki B. (2017), *Evaluating combined effect of noise and heat on blood pressure changes among males in climatic chamber*, Journal of Education and Health Promotion, **6**, doi: 10.4103/jehp.jehp_107_15.
28. Dehghan S.F. *et al.* (2013), *Study on the noise assessment and control at a petrochemical company*, Noise & Vibration Worldwide, **44**, 1, 10–18.
29. Dominiak P., Fuchs G., von Toth S., Grobecker H. (1985), *Effects of nicotine and its major metabolites on blood pressure in anaesthetized rats*, Journal of Molecular Medicine, **63**, 2, 90–92.
30. Drřyvold W., Midthjell K., Nilsen T., Holmen J. (2005), *Change in body mass index and its impact on blood pressure: a prospective population study*, International Journal of Obesity, **29**, 6, 650–655.
31. Efron B. (1987), *Better bootstrap confidence intervals*, Journal of the American Statistical Association, **82**, 397, 171–185.
32. Eriksson C., Rosenlund M., Pershagen G., Hilding A., Östenson C.-G., Bluhm G. (2007), *Aircraft noise and incidence of hypertension*, Epidemiology, **18**, 6, 716–721.
33. Fadaei B. *et al.* (2017), *Study of lipid profiles in the serum of cardiovascular patients suffering from diabetes*, Biomedical Research, **28**, 8, 3397–3401.
34. Farhang Dehghan S., Monazzam M., Nassiri P., Haghighi Kafash Z., Jahangiri M. (2013), *The assessment of noise exposure and noise annoyance at a petrochemical company*, Health and Safety at Work, **3**, 3, 11–24.
35. Ferrara L., Guida L., Iannuzzi R., Celentano A., Lionello F. (2002), *Serum cholesterol affects blood pressure regulation*, Journal of Human Hypertension, **16**, 5, 337–343.
36. Foraster M. *et al.* (2014), *High blood pressure and long-term exposure to indoor noise and air pollution from road traffic*, Environmental Health Perspectives, **122**, 11, 1193–1200.
37. Greenwald S. (2007), *Ageing of the conduit arteries*, The Journal of Pathology, **211**, 2, 157–172.

38. Hall J., Brands M., Hildebrandt D., Kuo J., Fitzgerald S. (2000), *Role of sympathetic nervous system and neuropeptides in obesity hypertension*, Brazilian Journal of Medical and Biological Research, **33**, 6, 605–618.
39. Hart E.C., Joyner M.J., Wallin B.G., Charkoudian N. (2012), *Sex, ageing and resting blood pressure: gaining insights from the integrated balance of neural and haemodynamic factors*, The Journal of Physiology, **590**, 9, 2069–2079.
40. He F.J., Pombo-Rodrigues S., MacGregor G.A. (2014), *Salt reduction in England from 2003 to 2011: its relationship to blood pressure, stroke and ischaemic heart disease mortality*, BMJ Open, **4**, 4, e004549, 7 pages.
41. Héritier H. *et al.* (2014), *The association between road traffic noise exposure, annoyance and health-related quality of life (HRQOL)*, International Journal of Environmental Research and Public Health, **11**, 12, 12652–12667.
42. ISO (2003), ISO/TS 15666: *Acoustics – Assessment of noise annoyance by means of social and socio-acoustic surveys*, Geneva, International Organization for Standardization.
43. ISO (2009), ISO 9612: *Acoustics – Determination of occupational noise exposure – Engineering method, Geneva*, International Organization for Standardization.
44. Ising H., Braun C. (2000), *Acute and chronic endocrine effects of noise: review of the research conducted at the Institute for Water, Soil and Air Hygiene*, Noise and Health, **2**, 7, 7–24.
45. Ismaila S.O., Odusote A. (2014), *Noise exposure as a factor in the increase of blood pressure of workers in a sack manufacturing industry*, Beni-Suef University Journal of Basic and Applied Sciences, **3**, 2, 116–121.
46. Jain A., Nagarsheth M., Desai H. (2016), *Effect of smoking on body mass index, blood pressure and pulse pressure in chronic smokers*, National Journal of Integrated Research in Medicine, **7**, 2, 41–43.
47. Jarup L. *et al.* (2008), *Hypertension and exposure to noise near airports: the HYENA study*, Environmental Health Perspectives, **116**, 3, 329–333.
48. Jones D.W., Kim J.S., Andrew M.E., Kim S.J., Hong Y.P. (1994), *Body mass index and blood pressure in Korean men and women: the Korean National Blood Pressure Survey*, Journal of Hypertension, **12**, 12, 1433–1437.
49. Kelsey R.M., Blascovich J., Tomaka J., Leitten C.L., Schneider T.R., Wiens S. (1999), *Cardiovascular reactivity and adaptation to recurrent psychological stress: Effects of prior task exposure*, Psychophysiology, **36**, 6, 818–831.
50. Kline R.B. (2015), *Principles and practice of structural equation modeling*, Guilford Publications, New York, Lindon.
51. Kovacic J.C., Moreno P., Nabel E.G., Hachinski V., Fuster V. (2011), *Cellular senescence, vascular disease, and aging*, Circulation, **123**, 17, 1900–1910.
52. Krogh C.M. *et al.* (2018), *Health Canada's wind turbine noise and health study – A review exploring research challenges, methods, limitations and uncertainties of some of the findings*, Open Access Library Journal, **5**, 12, ID:89289, 25 pages.
53. Krogh C.M., Jeffery R.D., Aramini J., Horner B. (2012), *Annoyance can represent a serious degradation of health: Wind turbine noise: A case study*, [in:] INTER-NOISE and NOISE-CON Congress and Conference Proceedings, Institute of Noise Control Engineering, 1, 12, pp. 3898–3909, 19–22 August, New York, USA.
54. Lakatta E.G. (1999), *Cardiovascular aging research: the next horizons*, Journal of the American Geriatrics Society, **47**, 5, 613–625.
55. Laurenzi M. *et al.* (1990), *Multiple risk factors in hypertension: results from the Gubbio Study*, Journal of Hypertension, **8**, S7–S12.
56. Lawes C.M., Vander Hoorn S., Rodgers A. (2008), *Global burden of blood-pressure-related disease, 2001*, The Lancet, **371**, 9623, 1513–1518.
57. Lercher P., Hörtnagl J., Kofler W.W. (1993), *Work noise annoyance and blood pressure: combined effects with stressful working conditions*, International Archives of Occupational and Environmental Health, **65**, 1, 23–28.
58. MacGregor G., He F. (2005), *Importance of controlling blood pressure*, Climacteric, **8**, sup3, 13–18.
59. MacMahon S.W., Blacket R.B., Macdonald G.J., Hall W. (1984), *Obesity, alcohol consumption and blood pressure in Australian men and women. The National Heart Foundation of Australia Risk Factor Prevalence Study*, Journal of Hypertension, **2**, 1, 85–91.
60. Mardia K.V. (1970), *Measures of multivariate skewness and kurtosis with applications*, Biometrika, **57**, 3, 519–530.
61. Marotta T. *et al.* (1995), *Factors affecting lipoprotein lipase in hypertensive patients*, Metabolism, **44**, 6, 712–718.
62. Masuo K., Mikami H., Ogihara T., Tuck M.L. (2000), *Weight gain-induced blood pressure elevation*, Hypertension, **35**, 5, 1135–1140.
63. McCubbin J.A., Pilcher J.J., Moore D.D. (2010), *Blood pressure increases during a simulated night shift in persons at risk for hypertension*, International Journal of Behavioral Medicine, **17**, 4, 314–320.
64. Melamed S., Froom P., Kristal-Boneh E., Gofer D., Ribak J. (1997), *Industrial noise exposure, noise annoyance, and serum lipid levels in blue-collar workers – the CORDIS Study*, Archives of Environmental Health: An International Journal, **52**, 4, 292–298.
65. Mohammadi H., Alimohammadi I., Roshani S., Pakzad R., Abdollahi M.B., Dehghan S.F. (2016), *The effect of occupational noise exposure on blood and biochemical parameters: a case study of an insulator manufacturer in Iran*, Electronic Physician, **8**, 1, 1740–1746.

66. Monazzam M.R. *et al.* (2018), *Investigation of occupational noise annoyance in a wind turbine power plant*, Journal of Low Frequency Noise, Vibration and Active Control, 1461348418769162, 1–10.

67. Motamedzade M., Ghazaiee S. (2003), *Combined effects of noise and shift work on workers' physiological parameters in a chemical industry*, Avicenna Journal of Clinical Medicine, **10**, 1, 39–46.

68. Ndrepepa A., Twardella D. (2011), *Relationship between noise annoyance from road traffic noise and cardiovascular diseases: a meta-analysis*, Noise and Health, **13**, 52, 251–259.

69. Neaton J.D., Wentworth D. (1992), *Serum cholesterol, blood pressure, cigarette smoking, and death from coronary heart disease overall findings and differences by age for 316099 white men*, Archives of Internal Medicine, **152**, 1, 56–64.

70. Neghab M., Maddahi M., Abdolreza R. (2009), *Hearing impairment and hypertension associated with long term occupational exposure to noise*, Iranian Red Crescent Medical Journal, **2009**, 2, 160–165.

71. Ni C.-H. *et al.* (2007), *Associations of blood pressure and arterial compliance with occupational noise exposure in female workers of textile mill*, Chinese Medical Journal, **120**, 15, 1309–1313.

72. Nikolic S., Abhayaratna W., Leano R., Stowasser M., Sharman J.E. (2014), *Waiting a few extra minutes before measuring blood pressure has potentially important clinical and research ramifications*, Journal of Human Hypertension, **28**, 1, 56–61.

73. Öhrström E., Skĺnberg A., Svensson H., Gidlöf-Gunnarsson A. (2006), *Effects of road traffic noise and the benefit of access to quietness*, Journal of Sound and Vibration, **295**, 1, 40–59.

74. Osadad Y., Yamamotoa T. (2004), *The Okinawa study: effects of chronic aircraft noise on blood pressure and some other physiological indices*, Journal of Sound and Vibration, **277**, 469–470.

75. Ouis D. (2002), *Annoyance caused by exposure to road traffic noise: An update*, Noise and Health, **4**, 15, 69–79.

76. Passchier-Vermeer W., Passchier W.F. (2000), *Noise exposure and public health*, Environmental Health Perspectives, **108**, Suppl 1, 123–131.

77. Pinto E. (2007), *Blood pressure and ageing*, Postgraduate Medical Journal, **83**, 976, 109–114.

78. Resink T., Buhler F., Hahn A., Bochkov V. (1994), *Interaction between plasma lipoproteins and vascular smooth muscle cells: how relevant is it to arterial hypertension?*, Nutrition Metabolism and Cardiovascular Diseases, **4**, 3, 163–163.

79. Rhee M.-Y., Kim H.-Y., Roh S.-C., Kim H.-J., Kwon H.-J. (2008), *The effects of chronic exposure to aircraft noise on the prevalence of hypertension*, Hypertension Research, **31**, 4, 641–647.

80. Rosenlund M., Berglind N., Pershagen G., Järup L., Bluhm G. (2001), *Increased prevalence of hypertension in a population exposed to aircraft noise*, Occupational and Environmental Medicine, **58**, 12: 769–773.

81. Rylander R. (2004), *Physiological aspects of noise-induced stress and annoyance*, Journal of Sound and Vibration, **277**, 3, 471–478.

82. Soares F. *et al.* (2017), *Traffic noise: Annoyance assessment of real and virtual sounds based on close proximity measurements*, Transportation Research Part D: Transport and Environment, **52**, 399–407.

83. Sung Y.J. *et al.* (2016), *An empirical comparison of joint and stratified frameworks for studying $G \times E$ interactions: Systolic blood pressure and smoking in the CHARGE Gene-Lifestyle Interactions Working Group*, Genetic Epidemiology, **40**, 5, 404–415.

84. Suwazono Y. *et al.* (2008), *Shift work is a risk factor for increased blood pressure in Japanese men*, Hypertension, **52**, 3, 581–586.

85. Vallance P., Collier J., Moncada S. (1989), *Effects of endothelium-derived nitric oxide on peripheral arteriolar tone in man*, The Lancet, **334**, 8670, 997–1000.

86. van Kempen E.E., Kruize H., Boshuizen H.C., Ameling C.B., Staatsen B.A., de Hollander A.E. (2002), *The association between noise exposure and blood pressure and ischemic heart disease: a meta-analysis*, Environmental Health Perspectives, **110**, 3, 307–317.

87. Zamanian Z., Monazzam M.R., Satyarvand M., Dehghan S.F. (2012), *Presentation of a model to identify dominant noise source in agricultural sector of sugarcane industry*, Advances in Environmental Biology, **6**, 11, 3002–3007.