

ORIGINAL ARTICLE

Non-auditory effects of industrial chronic noise exposure on workers; change in salivary cortisol pattern

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Keywords

Noise • Salivary cortisol • Worker

Summary

Background. Noise has different auditory and non-auditory effects on human. In noisy environments, noise as a non-specific stressor can activate the hypothalamic-pituitary-adrenal axis (HPA, cortisol). The aim of this study was to evaluate the effect of chronic exposure to noise on salivary cortisol on industrial workers.

Methods. This cross-sectional study had a case/control design. 136 male workers (68 workers were exposed to chronic industrial noise, and 68 other workers were exposed to background noise) voluntarily enrolled in the study. The equivalent noise level was measured at workstations and salivary cortisol for both case and control groups was measured at the beginning (6 AM) and also at the end of work shift (4 PM). The amount of change in the average of the values of the two groups were compared with each other.

Results. The measured Leq_{sh} (equivalent continuous sound level) in case and control groups were 87.43 dB-A and 67.6 dB-A, respectively. Comparison of salivary cortisol levels change in groups shows a significant differences in control groups for salivary cortisol in the morning and in the evening samples ($p < 0.05$); but not in the case group ($p = 0.052$). Also, comparison of salivary cortisol levels changes with noise exposure experience in the case subgroups revealed no significant difference ($p > 0.05$).

Conclusion. This study showed that chronic exposure to industrial noise can lead to a change in pattern of salivary cortisol secretion especially in the evening (at the end of the work shift), in a way that instead of its normal decrease, an increase happened.

Introduction

Noise is a stressor and an important contaminant in our environment that has remained largely unknown [1]. The prevalence of over-exposure to noise is increasing in industries throughout the world. Although control measures to reduce noise have been effective in many industries, but noise is still a common occupational hazard in the workplace [2, 3]. It is estimated that about 600 million workers worldwide have been exposed to noise [4]. Many studies reported that exposure to noise levels above 80 dB-A in industrial settings is quite widespread [5-7]. Earlier, most studies focused on noise in office environments and its psychological effects, such as job satisfaction, and less studies have been done on the chronic exposure to noise in industrial environments such as manufacturing sites and etc. [8]. Metal industries are part of the main industries that has been developing over the last 100 years and have many noise generating sources, including large fans for ventilation, electrical transformers, rolling processes etc. [9]. To investigate the epidemiological effects of noise, in addition to the direct method of assessing hearing loss, in an indirect way, it can be focused on stress hormones such as cortisol and risk factors including hypertension and its prominent diseases. In other words, measuring blood pressure and cortisol hormone are good indicators for studying the relationship, mechanism and interaction be-

tween exposure to noise and its health outcomes [10]. Cortisol hormone can be measured in urine, serum and saliva. Since salivary cortisol reflects free and physiologic activity cortisol in blood circulation, it is a good indicator for assessing exposure to noise in the industry [11, 12]. The aim of this study was to assess: 1) changes in salivary cortisol among industrial workers (case and control groups); 2) feasibility of saliva cortisol application in assessment of chronic exposure to noise.

Methods

This cross-sectional study had a case/control design. A total of 136 male workers from a steel factory participated voluntarily in this study (68 workers were exposed to chronic industrial noise (the job tasks included furnace operator, molding equipment, and rolling and finishing machines operators), and 68 other workers (working in a quiet office) were exposed to background noise). The Morgan's table was used to determined sample size. Participants had more than two years of job experience. The information about the goals of the study was explained to the participants. They were free to leave the study whenever they wanted to. Then the General Health Questionnaire (GHQ-28) was completed by workers.

NOISE MEASUREMENT

To measure the equivalent exposure level of noise for each participant according to ISO 9612 [13], the B & K model noise dosimeter equipment, type 4436, both a dosimeter and a sound level meter, were used. The equipment was calibrated before noise measurement and internal standard was set in ACGIH mode. Noise pattern in workstations was continuous.

SALIVA SAMPLING AND ANALYSIS

Electrochemiluminescence (ECL) method was used to measure salivary cortisol concentration. Since this method is fast, reliable and convenient, it has been suggested as a technique for measuring salivary cortisol [14]. The 5 ml Maxwell sampling vial was used to get salivary cortisol samples. The participants were asked to take 2 ml of saliva sample in the morning before brushing and eating or drinking (between 6:00 and 7:00 AM), as well as at the end of the work shift (4:00 PM). These saliva samples were frozen in a freezer at -18°C and finally transferred to the laboratory for testing. Analysis of saliva samples was done in the Cobas radioimmunoassay kit (IBL International GmbH, Hamburg, Germany) using the ECL method and the Elecsys 2010 analyzer device. The mean (CV%) intra- and inter-assay precision were 1.1 (6.2%) and 1.95 (8.7%), respectively. Finally, the amount of salivary cortisol concentration at the beginning of the shift in the two groups, as well as the amount of changes in cortisol concentration. (Salivary cortisol concentration at the end of the work shift minus salivary cortisol concentration at the beginning of the shift) was compared in the two groups. The statistical analyzes were performed by SPSS software Version 19. In this study, the Kolmogorov-Smirnov test was used to examine the variables' normality. Also, t-test and linear regression were used to the data analysis. The significance level was considered at $p < 0.05$.

ETHICAL CONSIDERATIONS

This study is based on a research project approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (Research Ethics Code: IR.AJUMS.REC.1394.242).

Results

There were 136 participants in this study, 68 workers were exposed to chronic industrial noise and 68 employees worked in administrative departments (without industrial noise exposure). Table I shows the demographic data of study participants. According to the results, the groups did

not have a significant statistical difference in terms of job experience ($p = 0.83$). The mean of general health score in the exposed group, was 21.5 ± 9.28 and in the control group 20.91 ± 8.49 , which had no significant statistical difference ($p = 0.84$). The mean of the equivalent exposure level in the case group and in the control group were 87.43 ± 3.9 , 67.16 ± 4.93 dBA, respectively; which had a significant statistical difference ($p = 0.001$). Table II presents comparison of salivary cortisol levels change in groups. There were significant differences in control groups for salivary cortisol in the morning and in the evening samples and similarly between two groups ($p < 0.05$). But in the case group, near significant differences for salivary cortisol in the morning and in the evening, samples was observed ($p = 0.052$). Linear regression coefficients for exposed to noise and salivary cortisol levels are shown in Table III. The results show that the noise exposure ($\text{Leq}_{8h} > 80$ dBA) and saliva cortisol levels in the end of work shift are statistically significant ($p < 0.001$). Table IV shows comparison between salivary cortisol in case group which is classified about noise exposure experience. Results shows a significant change in normal salivary cortisol secretion pattern in the case group. Although the amount of noise exposure experience is different between subgroups, the percentage of difference was very close for subgroups and comparison between these subgroups revealed no significant difference ($p > 0.05$) as the decrease of cortisol levels in the end of shift work with respect to the start of shift work is not significant in all classifications.

Discussion and conclusion

In this study, the mean cortisol concentration in workers exposed to noise was higher at the start of the work shift compared to the control group, which was statistically significant. Also, similarly results were observed for the end of work shift between two groups. These findings indicate that chronic exposure to industrial noise leads to an increase in salivary cortisol levels in exposed individuals. In other words, the differential amount of morning and evening salivary cortisol concentration was lower in case group when compared to control group. The incremental changes in the concentration of salivary cortisol at the end of the work shift compared to the beginning of the shift was statistically significant. Overall, the findings of this study showed that due to the higher salivary cortisol Concentration at the beginning of the shift work in the exposed group, as well as significant increase in salivary cortisol concentration after exposure to noise than the control group, exposure to industrial noise (as a stressor) of

Tab. I. Demographic data of study participants.

Groups	Age (year)	Height (cm)	Weight (kg)	Job experience (year)	Leq_{8h} (dBA)
	Mean \pm SD	Mean \pm SD	Mean \pm SD	Mean \pm SD	Mean \pm SD
Case (n = 68)	37.3 ± 5.8	174.1 ± 5.2	76.2 ± 8.2	8.53 ± 5.14	87.43 ± 3.9
Control (n = 68)	36.6 ± 5.2	174.2 ± 4.9	77.3 ± 9.4	8.10 ± 4.74	67.16 ± 4.93
P value	0.701	0.890	0.238	0.843	0.000

Tab. II. Comparison of salivary cortisol levels change between groups.

Groups	Salivary cortisol levels ($\mu\text{g/dL}$)			P value*
	Before work shift (morning)	End of work shift (evening)	Before and end differences	
	Mean \pm SD	Mean \pm SD	Mean \pm SD	
Case (n = 68)	5.21 \pm 4.58	3.92 \pm 2.98	1.29 \pm 1.7	0.052
Control (n = 68)	3.37 \pm 2.13	1.77 \pm 1.06	1.61 \pm 1.07	0.001
P value**	0.041	0.001	0.121	

*Comparison between morning and evening in each group; **comparison between two groups.

Tab. III. Linear regression coefficients for exposed to noise and salivary cortisol levels.

Leq _{8h} (dB)	Salivary cortisol					
	Before work shift (morning)			End of work shift (evening)		
	N	Coefficient (95% CI)	P*	N	Coefficient (95% CI)	P*
< 65	148	0.32 (0.27 to 0.58)	0.415	12	-0.11 (-0.21 to 0.42)	0.324
\geq 65 to \leq 80	20	0.77 (-1.3 to 1.9)	0.420	56	0.85 (0.66 to 1.04)	0.062
> 80	-	-	-	86	4.16 (1.29 to 6.11)	0.001

*P value < 0.05.

Tab. IV. Comparison of salivary cortisol levels change with noise exposure experience.

Noise exposure experience	N	Salivary cortisol levels ($\mu\text{g/dL}$)		% difference*	P value**
		At begging of work shift (mean \pm SD)	At end of work shift (mean \pm SD)		
2-4	7	3.99 \pm 2.38	3.01 \pm 1.78	32.5	0.112
4-6	20	5.24 \pm 3.11	4.07 \pm 2.33	28.7	0.193
6-8	16	6.87 \pm 4.68	5.21 \pm 2.28	31.8	0.091
8-10	13	6.91 \pm 2.89	5.48 \pm 2.03	26.1	0.327
> 10	12	7.12 \pm 2.08	6.02 \pm 3.19	18.3	0.471

*The percentage of difference was calculated by dividing begging and end difference by end concentration; **p value (paired sample t-test) < 0.05.

more than 80 dB can lead to stimulation of the hypothalamic-pituitary-adrenal axis and eventually trigger cortisol hormone secretion. Also, the results demonstrated that increased noise exposure experience in workers causes decrease in the differential amount of cortisol secretion in morning and evening samples. In other word, normal pattern of cortisol secretion in workers with chronic noise exposure, changes accordingly and faces fluctuations. Our findings on the effect of noise on salivary cortisol concentrations are confirmed by some other studies. In a study by Green at al. salivary cortisol levels were reported to increase in daytime regarding chronic exposed to noise [15]. Also, the results of the study by Dehaghi et al. showed that there is a significant relationship between exposure to industrial noise higher than 85 dBA and salivary cortisol increase [16]. In another study by Hebert et al. In 2009, the effect of short exposure to noise on salivary cortisol, mental stress, and tinnitus intensity in a laboratory environment was investigated. The results showed that exposure to noise even within the standard range (80 dB) and for 20 minutes, affects the HPA axis (hypothalamic-pituitary-adrenal), which is responsible for secretion of cortisol and mental stress [17]. In a study by Gitanjali et al. serum cortisol level increased significantly on the morning of the day after acute exposure to noise [18]. Some studies that investigated cortisol concentration in blood serum and urine, reported increase in cortisol levels after noise exposure [19-21]. There exist some controversial studies

that reported no fluctuation in cortisol secretion due noise exposure [22, 23]. These different findings can arise from: study design, study population (gender, age, job, etc.), noise emission pattern, noise exposure duration and noise levels differences. The aim of this study was to survey the non-auditory effects of noise exposure. In other words, the relationship between exposure to occupational noise and physiological variables such as increasing stress hormone secretion was studied. It should be noted that noise levels above 80 dB increased salivary cortisol. One of the limitations of this study can be stated as; while selecting the sampling site, only one industrial setting was achievable from a wide variety of industries with high level of exposure to chronic noise. A larger population size could make it more feasible for statistical extrapolation. This study revealed that chronic exposure to industrial noise can lead to a change in pattern of salivary cortisol secretion especially in the evening (at the end of the work shift), in a way that instead of its normal decrease, an increase happened. Also testing salivary cortisol is a feasible tool in assessing the effects of chronic noise exposure.

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Conflict of interest statement

The authors declare no conflicts of interest.

Authors' contributions

BFD conceived the study and drafted the manuscript. FK collected the data and drafted the manuscript. KAA carried out the statistical analysis.

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