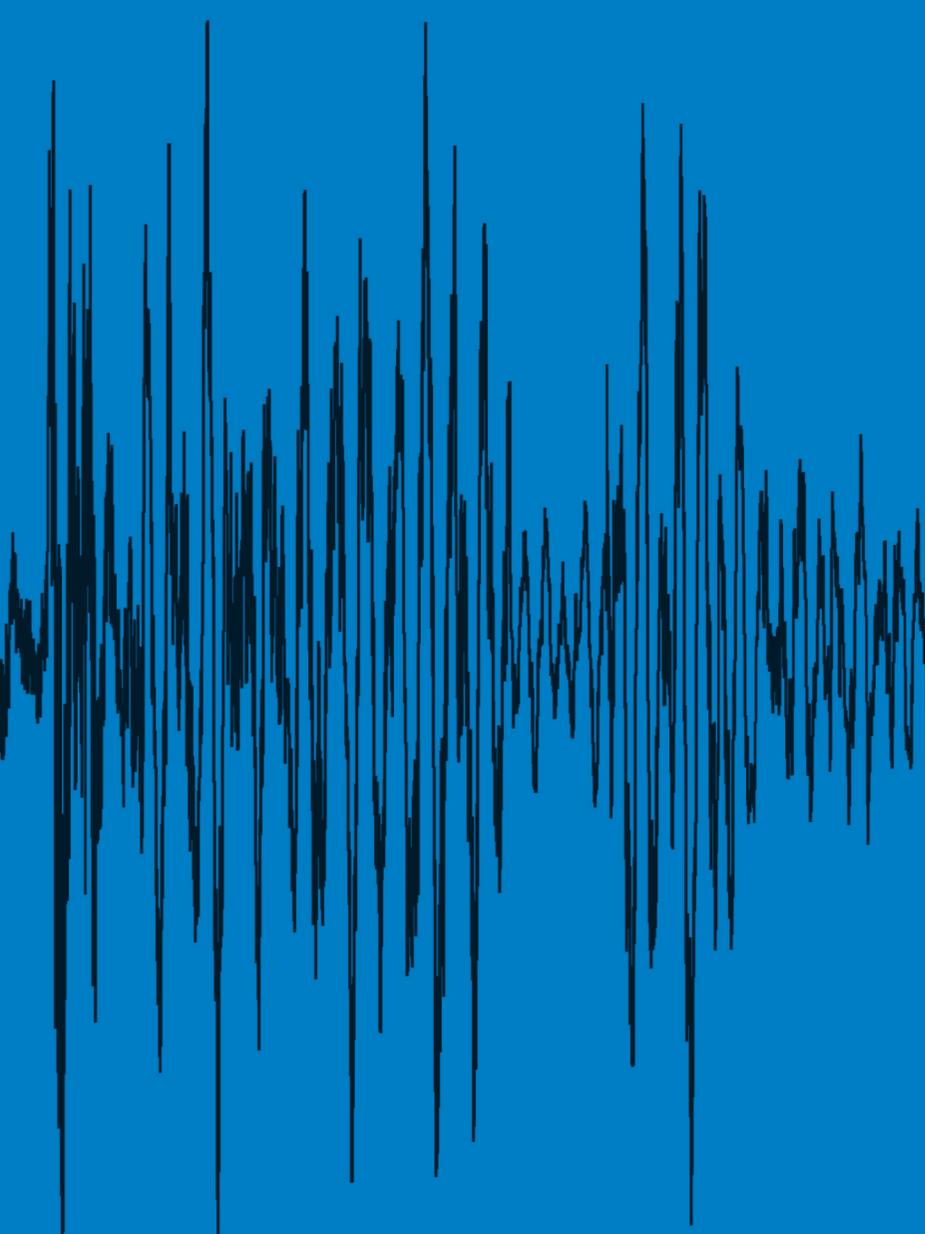


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# Industrial noise exposure and salivary cortisol in blue collar industrial workers

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## Abstract

Measuring non-auditory effects of noise such as stress-inducing ones have become of interest recently. Salivary cortisol has become a popular measure in stress research. So, assessing noise-induced stress via saliva cortisol evaluation can present a bright future in non-invasive exposure assessment methods. This study had 3 goals: (1) Assess and compare saliva cortisol concentrations in the morning and evening in normal work day and leisure day in industrial workers, (2) assess the relationship between industrial noise exposure and salivary cortisol concentrations, and (3) assess the possibility of using salivary cortisol as a possible marker of noise-induced stress. This study included 80 male participants working in 4 different parts (painting, assembling lines, casting, and packaging) of a household manufacturing company. Morning and evening saliva samples were collected at 7.00 am and 4.00 pm, respectively. Noise exposure levels were assessed by sound level meter and noise dosimeter. All measurements occurred in two days: One in leisure day and other in working day. Descriptive statistics, paired sample t-test, and regression analysis were used as statistical tools of this study with  $P < 0.05$ . On the leisure day, morning salivary cortisol (geometric mean [GM], 15.0; 95% CI, 12.0 to 19.0 nmol/L) was significantly higher than evening cortisol (GM, 5.2; 95% CI, 4.2 to 6.3 nmol/L) ( $P < 0.05$ ). Also, on the working day, morning salivary cortisol (GM, 14.0; 95% CI, 11.25 to 18.0 nmol/L) was significantly higher than evening cortisol (GM, 8.0; 95% CI, 6.5 to 10.0 nmol/L) ( $P < 0.05$ ). No significant difference was obtained for morning cortisol levels between leisure day and working day samples ( $P = 0.117$ ). But, for evening cortisol concentrations, a strong significant difference was noted leisure day and working day ( $P < 0.001$ ). The evening cortisol in the working day correlated significantly with noise exposure  $> 80$  dBA. Our study revealed that industrial noise, with levels  $> 80$  dBA, has a significant effect on salivary cortisol elevation.

**Keywords:** Industrial noise exposure, noise-induced stress, salivary cortisol

## Introduction

A vast variety of evidence demonstrates that noise is one of the most common occupational hazards of the modern world, and this general and non-specific stressor, which affects millions of workers worldwide, can result in psychological distress symptoms and physiological reactions.<sup>[1-3]</sup> Exposure to noise is not only specific to working in industries, but also it can be present in many leisure-related activities and

ambient conditions such as transportation.<sup>[4]</sup> Many studies have shown that noise exposure has different effects other than auditory ones. These extra-auditory effects of noise can be observed on performance efficiency of intellectual, attention, and memory tasks,<sup>[2]</sup> which are all contributed to main causes of stress while working in a noise-polluted environment.<sup>[3]</sup> Noise-induced stress in some working environments has been under investigation.<sup>[5,6]</sup> Activation of the hypothalamic-pituitary-adrenal axis (HPA) and the subsequent release of cortisol are considered as major components of the physiological stress response in humans.<sup>[7]</sup> In some of the studies, saliva and/ or serum cortisol were assessed as stress hormone, which its salivary secretion in normal individuals can be monitored more easily as a non-invasive method in comparison with other forms.<sup>[5,8]</sup> Also, salivary cortisol level is a valid indicator of the plasma-free cortisol concentration.<sup>[9-13]</sup>

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Cortisol is the major glucocorticoid produced in the adrenal cortex.<sup>[14]</sup> Cortisol production has a circadian rhythm,<sup>[15,16]</sup> with levels peaking in the early morning and dropping to lowest values at night.<sup>[17,18]</sup> Levels rise independently of circadian rhythm in response to stress.<sup>[19]</sup> In recent years, salivary cortisol has become a popular measure of HPA activity in stress research for several reasons. First, plasma unbound (and physiological active) cortisol and salivary cortisol are highly correlated. Second, unlike urinary cortisol excretion, the time lag between changes in plasma cortisol and salivary cortisol is very short (1 to 2 minutes). Third, saliva flow rate has no impact on salivary cortisol levels. Finally, saliva samples can easily be obtained non-invasively, whereas plasma cortisol findings may be biased by venesection stress.<sup>[20,21]</sup>

As a result, high levels of industrial noise, known as a main stressor, can be assessed via monitoring salivary cortisol in exposed individuals.<sup>[22]</sup> Therefore, the present study is designed in order to; (1) assess and compare saliva cortisol concentrations in the morning and evening of normal work day and leisure day in blue collar industrial workers, (2) assess the relationship between industrial noise exposure and salivary cortisol concentrations in the workers, and (3) assess the possibility of using salivary cortisol as a possible marker of noise-induced stress in blue collar industrial workers.

## Methods

This study included 80 male participants working in 4 different parts (painting, assembling lines, casting, and packaging), of a household manufacturing company, with a total number of 170 male workers. All the participants received the information regarding aim and scope of the study and enrolled in the study as volunteers, also, they were free to leave the experiments whenever demanded. Mean age was  $37 \pm 6.43$  years, mean height was  $173.9 \pm 4.17$  centimeters, mean weight was  $74.5 \pm 4.25$  kilograms, and mean work experience was  $17.1 \pm 6.64$  years. Self-reporting general health status questionnaire was completed by the participants. In order to minimize interfering factors in cortisol response, the noise pattern of the worker's daily tasks was assessed to have no peak sound. In other words, the noise pattern in the 4 selected parts of the factory was continuous noise. Morning and evening saliva samples were collected at 7.00 am and 4.00 pm, respectively, and were refrigerated soon afterwards to be carried to the laboratory for further analysis.

The sampling procedure consisted of a before-after design, so that the first round of saliva samples were collected in the workers' leisure day with one important attention to the workers that they should avoid an exposure to loud noise in leisure or something else during the day of sampling in holiday, as much as possible.

The instructions in order to perform noise measurement and saliva sampling procedure were completely presented to the workers, also recording awaking time in the morning, sampling timing; its preservation and due recording were presented to them. The participants received two test tubes, practical instructions and the noise dosimeter device. The participants were instructed to collect the first saliva sample at 7:00 in the morning and the second at 4:00 in the evening. Also, they were instructed to turn the noise dosimeter on shortly after awaking in the morning and turn it off at 4:00 in the evening after collection of saliva sample. The samples were kept in refrigerator and then were delivered to the laboratory for further analysis. All participants woke up 6.00 to 6.15 in the leisure day and working day according to their daily routines.

The second round of noise measurement and saliva sampling happened during a normal working day, while they were all performing their usual tasks and with this hint that participants were asked not to use ear protection devices. Again, saliva sampling happened at 7:00 in the morning and 4:00 in the evening, and noise exposure levels were monitored and recorded accordingly.

## Saliva sampling and laboratory analysis

Saliva samples were collected at 7.00 am and 4.00 pm with a 3 ml volume in clean vials. Tooth brushing, food and drink intake were to be avoided 30 minutes before sampling. DEMEDITEC kit was used for the quantitative measurement of salivary cortisol. The intra- and inter-assay variability rates were less than 7.1% and 6.9%, respectively.

## Noise measurement

A sound level meter (Brüel and Kjær type 2236) was used to determine ambient noise levels in the workplace and at the 80 workstations where the participants worked. Only steady-state noise levels were recorded, and work stations with peak sounds were eliminated from the study. Noise levels ranged from 80 to 88 dBA. In order to assess personal noise exposure of each participant, noise dosimeter (Cel-272, UK) was used.  $L_{eq}$  that is the equivalent steady sound level of a noise energy-averaged over time can be calculated using the below formula:<sup>[23]</sup>

$$L_{eq} = 10 \log_{10} \{(Dose/100) \times (8/T)\} + 85 \text{ dBA}$$

Where: Dose = a noise exposure dose, in %, acquired in T hours,  $L_{eq}$  = A-weighted, sound level linearly energy averaged over T hours, T = the sampling time, in hours, of the measurement.

## Statistical analysis

Examining the data of salivary cortisol showed positively skewed distributions; therefore, logarithmic transformations were performed for all data for further statistical analyses

under normal data assumptions [Figure 1]. In order to investigate the difference between morning and evening cortisol concentrations, morning cortisol concentrations minus evening concentrations were calculated. The percentage of cortisol differences was calculated by dividing the difference between morning and evening concentrations by the evening cortisol concentrations. Means and confidence intervals were used to present the data; all confidence intervals and P values were two-sided. The level of statistical significance was considered to be the conventional alpha of 0.05. Paired sample t-test was used in the analysis. General linear models were used in the multivariate analysis. Also, linear regression models were used to investigate associations between noise exposure and evening saliva cortisol concentrations. Results are expressed mainly as regression coefficients and 95% CIs. The data analyses were performed with SPSS 19 for Windows.

**Results**

For all the 80 participants on the leisure day, morning salivary cortisol (geometric mean [GM], 15.0; 95% CI, 12.0 to 19.0 nmol/L) was significantly higher than evening cortisol (GM, 5.2; 95% CI, 4.2 to 6.3 nmol/L) ( $P < 0.05$ ). Also, for the concentrations assessed on the working day, morning salivary cortisol (GM, 14.0; 95% CI, 11.25 to 17.6 nmol/L) was significantly higher than evening cortisol (GM, 8.0; 95% CI, 6.5 to 10.2 nmol/L) ( $P < 0.05$ ). No significant difference was obtained for morning cortisol levels between leisure day and working day samples of the participants ( $P = 0.117$ ) [Table 1]. But, for evening cortisol concentrations, a strong significant difference was observed between leisure day and working day concentrations ( $P < 0.001$ ) [Table 1]. The morning and evening cortisol concentrations difference of leisure day samples (GM, 9.0; 95% CI, 7.0 to 12.0 nmol/L) was significantly higher than

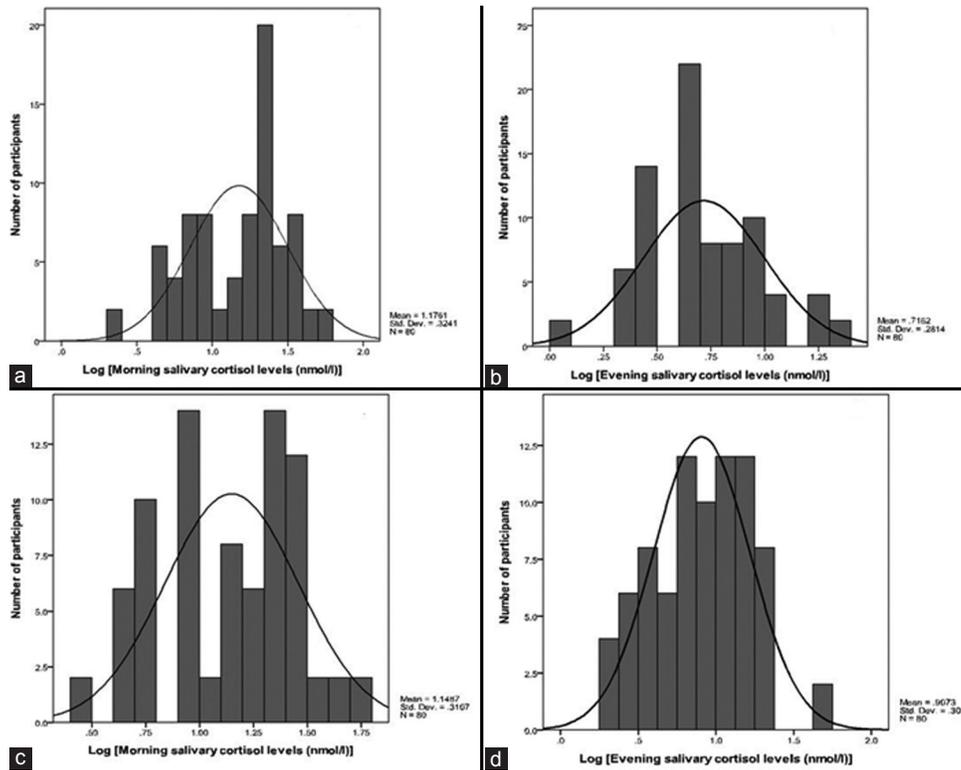


Figure 1: (a) Log transformed frequency distribution of morning saliva cortisol levels in leisure day (b) Log transformed frequency distribution of evening saliva cortisol levels in leisure day (c) Log transformed frequency distribution of morning saliva cortisol levels in working day (d) Log transformed frequency distribution of evening saliva cortisol levels in working day

**Table 1: Comparison of cortisol concentrations in morning and evening of leisure day and working day of study population (N = 80)**

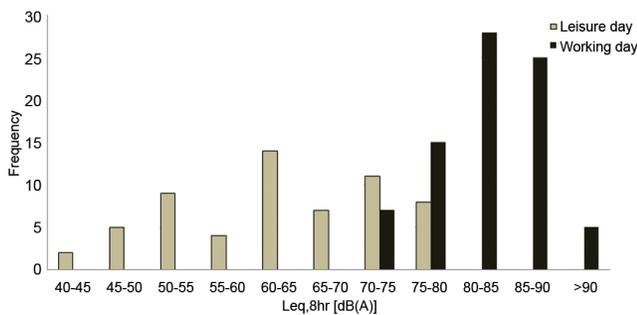
	Leisure day (n = 80)		Working day (n = 80)		P
	Geometric Mean	95% CI	Geometric Mean	95% CI	
Morning cortisol concentration	15.0	12.0-19.0	14.0	11.25 - 17.6	0.117
Evening cortisol concentration	5.2	4.2-6.3	8.0	6.5 - 10.2	0.001
Morning and evening difference*	9.0	7.0-12.0	5.4	4.0 - 7.0	0.001
% of morning evening difference	172.3	138.0-216.0	66.3	54.4 - 81.0	0.05

\*The morning and evening difference was calculated by morning minus evening cortisol concentration (nmol/l). The percentage of morning evening difference was calculated by dividing morning and evening difference by evening concentration; CI: confidence interval, P value was calculated using paired sample t-test

that of working day saliva samples (GM, 5.4; 95% CI, 4.0 to 7.0 nmol/L) ( $P < 0.001$ ) [Table 1]. The percentage of morning and evening differences in salivary cortisol concentrations of working day samples (GM, 66.3; 95% CI, 54.4 to 81.0 nmol/L) was significantly lower than that of leisure day samples (GM, 172.3; 95% CI, 138.0 to 216.0 nmol/L) ( $P < 0.001$ ) [Table 1]. Table 2 shows linear regression coefficients and 95% CIs for cortisol levels in saliva from evening samples in relation to noise levels ( $L_{eq, 8h}$ ). As the table shows, there is a strong significant association between noise exposure levels higher than 80 dBA and evening salivary cortisol concentration assessed in the working day. Figure 2 shows the distribution of  $L_{eq, 8 hr}$ , the equivalent continuous sound level (A-weighted), in working day and leisure day. This Figure shows that the majority of participants had exposure levels higher than 80 dB (A) in working day. Two examples of noise exposure curves are given in Figure 3.

**Discussion**

Morning saliva cortisol concentrations for both leisure day and work day were obtained to be similar with no significant difference. In leisure day samples, the morning salivary cortisol concentrations were roughly three times higher than the evening levels as shown by previous studies.<sup>[24-26]</sup> The evening salivary cortisol levels are significantly higher in work day samples (exposure with noise higher than 80 dBA in 45 participants) ( $P < 0.05$ ). Very similar to our findings, Hebertt *et al.* (2009) assessed the effects of noise exposure on cortisol levels and subjective stress in tinnitus participants and controls without tinnitus. Their results showed higher cortisol levels for both groups immediately before, immediately after, and 10 min after the end of noise exposure than at other time

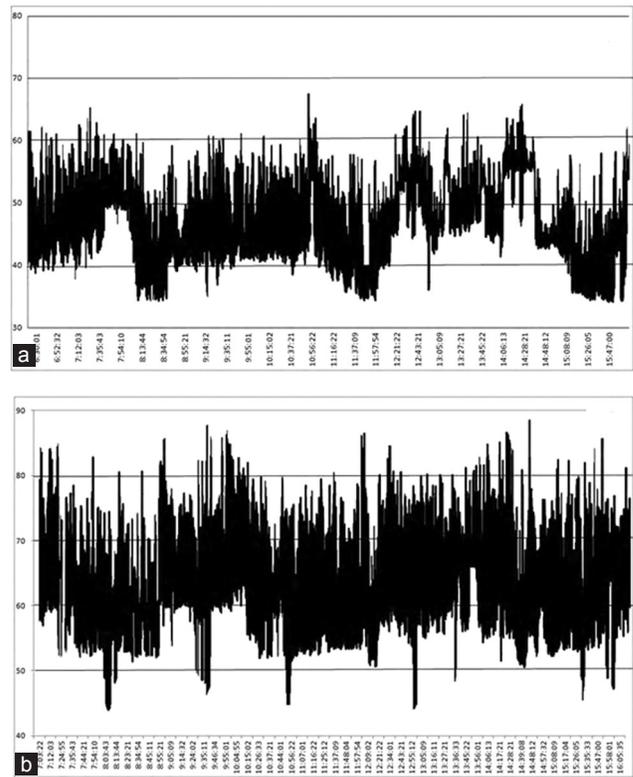


**Figure 2:** The distribution of  $L_{eq, 8 hr}$  for the working day and the leisure day

points. Their overall results showed that noise exposure influences cortisol response and subjective stress.<sup>[27]</sup>

Melamed *et al.* (1996) assessed the effects of chronic industrial noise exposure on urinary cortisol, fatigue, and irritability in 32 healthy industrial workers. These workers were chronically exposed to high ambient noise levels ( $> 85$  dB A) without using ear protectors. The results of this study showed that the urinary cortisol level at the end of the workday was significantly higher ( $P < 0.05$ ) under the chronic noise condition in comparison with attenuated noise condition.<sup>[3]</sup>

Persson Wayne *et al.* (2002) assessed salivary-free cortisol concentrations, rated stress, and annoyance in 32 subjects before, during, and after carrying out a battery of performance



**Figure 3:** (a) Exposure to noise,  $L_{eq}$  during leisure day, the exposure corresponds to 62 dB (a) during an 8-hour leisure day (b) Exposure to noise,  $L_{eq}$  during working, an example regarding one of participants working in the factory, the exposure corresponds to 85 dB (a) during an 8-hour working day

**Table 2: Linear regression coefficients for the relation between noise exposure and evening salivary cortisol concentrations among 80 participants**

$L_{eq,8h}$ (dB)	Evening salivary cortisol in leisure day			Evening salivary cortisol in working day		
	N	Coefficient (95% CI)	$P^*$	N	Coefficient (95% CI)	$P^*$
$<70$	41	0.12 (-0.27 to 0.6)	0.605	-	-	-
$\geq 70$ to $\leq 80$	19	0.69 (-1.2 to 2.5)	0.418	35	-0.65 (-1.66 to 0.35)	0.132
$>80$	-	-	-	45	3.67 (1.43 to 5.91)	0.002

\* $P$  value  $< 0.05$

tasks for 2 hours during an exposure to ventilation noise with dominant low frequencies. The study showed physiological evidence (saliva cortisol) of increased stress related to noise sensitivity and noise exposure during work.<sup>[6]</sup>

Persson Waye *et al.*, in an another study in 2003, assessed the effects of night-time exposure to traffic noise or low frequency noise on the cortisol awakening response and subjective sleep quality. This study thus showed that night time exposure to low frequency noise may affect the cortisol response upon wake-up and also lower cortisol levels after awakening were associated with subjective reports of lower sleep quality and mood.<sup>[28]</sup>

Butmanabane *et al.* (2003) performed a study to find out whether acute exposure of healthy individuals to loud occupational noise during the day time would cause changes in their nocturnal sleep, architecture, heart rate during sleep, and serum cortisol levels. Their results showed that after exposure to noise, serum cortisol levels increased significantly.<sup>[29]</sup>

Miki *et al.* (1998) assessed Urinary and salivary stress hormone levels while performing arithmetic calculations in a noisy environment. Their results showed higher cortisol levels during performing the task in noisy environment in comparison with pre-task levels of cortisol and the cortisol in quiet conditions.<sup>[30]</sup>

These results all support the findings presented in this paper as noise exposure in industrial settings increases saliva cortisol concentrations significantly. Although there are some other studies, which found no significant relationship between noise exposure and salivary cortisol increase,<sup>[5,31-33]</sup> it should be noted that the noise levels mentioned in these studies were not of industrial kind, it was in general road traffic noise or air craft noise with levels under 60 dBA and not with an industrial nature above 80 dBA.

In the present study, grouping the participants according to their noise exposure levels and the corresponding evening salivary cortisol concentrations revealed that exposure to high levels of industrial noise (>80 dBA) strongly and significantly has increased evening saliva cortisol levels ( $P < 0.002$ ). Also, our study revealed that industrial noise with levels below 80 dBA has no significant effect on salivary cortisol elevation. It can be suggested that assessment of saliva cortisol levels seems to be a valuable method for objective measurement of stress response in relation to industrial noise exposure and non-auditory noise impacts on the human body. It should be stated that more extensive studies should be carried out on industrial noise exposure effects on stress-induced responses in the affected subjects. Salivary cortisol investigation as a simple and non-invasive method has demonstrated its feasibility in this study and is suggested to be used in future studies in this field.

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