

A Model to Determine the Level of Serum Aldosterone in the Workers Attributed to the Combined Effects of Sound Pressure Level, Exposure Time and Serum Potassium Level: A Field-Based Study

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Abstract

Background: Occupational exposure to excessive noise is one of the biggest work-related challenges in the world. This phenomenon causes the release of stress-related hormones, which in turn, negatively affects cardiovascular risk factors.

Objectives: The current study aimed to determine the level of workers' serum aldosterone in light of the combined effect of sound pressure level, exposure time and serum potassium level.

Methods: This cross-sectional, descriptive, analytical study was conducted on 45 workers of Gol-Gohar Mining and Industrial Company in the fall of 2014. The subjects were divided into three groups (one control and two case groups), each including 15 workers. Participants in the control group were selected from workers with administrative jobs (exposure to the background noise). On the other hand, participants in the case groups were selected from the concentrator and pelletizing factories exposed to excessive noise. Serum aldosterone and potassium levels of participants were assessed at three different time intervals: at the beginning of the shift and before exposure to noise (7:30 - 8:00 AM), during exposure to noise (10:00 - 10:30 AM), and during continuous exposure (1:30 - 2:00 PM). The obtained data were transferred into SPSS ver. 18. Repeated measures analysis of variance (ANOVA) was used to develop the statistical model of workers' aldosterone level in light of the combined effect of sound pressure level, exposure time, and serum potassium level.

Results: The results of the final statistical model to determine the level of serum aldosterone based on the combined effect of sound pressure level, exposure time and serum potassium level indicated that the sound pressure level had a significant influence on the human's serum aldosterone level ($P = 0.04$). In addition, the effects of exposure time and serum potassium on aldosterone level were statistically significant with P -values of 0.008 and 0.001, respectively.

Conclusions: The obtained model in the study revealed that the results of predictive models to determine aldosterone level were very similar to real values; therefore, the obtained values of this model were largely in line with the ones obtained from the field.

Keywords: Aldosterone, Noise, Sound Pressure Level, Exposure Time, Potassium

1. Background

There is considerable evidence indicating that noise is among the most common types of profession-related hazards in today's world (1). Research shows that, every day in Europe, about 450 million individuals are exposed to noise levels of minimum 55 dB (A), 113 million people experience a noise level of at least 64 dB (A), and 9.7 million persons are exposed to noise levels of 75 dB (A) or more (2). Exposure to high levels of occupational noise is still a big challenge in all corners of the world. Considering the USA, for instance, over 30 million workers are exposed to hazardous noise (3). Similarly, in Germany, 4 - 5 million people (which constitute 12% - 15% of the workforce) experience hazardous noise levels, as defined by world health organization (WHO) (4). When the level of noise is above the occupational limit values, it can have a debilitating influence on the performance of various human systems, leading to hearing losses, hypertension, ischemic heart disease, irri-

tation, distress and hormone-related disturbances. Noise-induced hearing loss (NIHL) is one of the most frequently reported work-related illnesses worldwide (5, 6). Around 16% of hearing-related problems in the world are caused by occupational noise (7, 8). Research revealed that, in the US 5-30 million workers experience such high noise levels at work and they run the risk of losing their hearing ability (9).

According to a postulated biological mechanism, noise exposure has stress-related hormones released, a phenomenon that negatively influences cardiovascular risk factors (10, 11). Urine and blood samples are often used to examine stress hormones in communities that are exposed to a lot of noise (12, 13).

Aldosterone hormone has a crucial function in maintaining the homeostasis of the inner ear. As a mineralocorticoid secreted by the adrenal and gland cortex, aldosterone controls the levels of serum sodium (Na^+) and

potassium (K^+). Sodium and potassium play a significant role in the inner ear and are involved in cellular functions converting the mechanical energy into nerve impulses (14). Aldosterone exercises a stimulatory impact on the expression of the sodium-potassium ATPase (Na, K-ATPase) and sodium-potassium-chloride cotransporter (NKCC) in cell membranes (15, 16).

Changes in the serum potassium level in pathological conditions can have more harmful effects on the outer hair cells rather than the inner hair cells and auditory nerve fibers (17).

Some researchers claim that the decrease in the serum aldosterone level may cause hearing loss. Its increase, on the contrary, can result in hearing protection and protect the ear against possible harms (18). Tadros et al. demonstrated that the hearing thresholds of old males and females at lower levels of aldosterone (but still within the clinically normal range) were worse than those of participants whose aldosterone levels were in the upper middle of the normal range. As a result, aldosterone may function protectively in the cochlea (15). However, little research is conducted on the combined effect of sound pressure level (SPL), exposure time, and the serum potassium level on the aldosterone serum level among industrial workers, the current study aimed to investigate the relationship between serum aldosterone levels and age-related hearing loss (i.e. presbycusis) among humans.

2. Objectives

The current study aimed to determine the statistical model of aldosterone serum level in light of the combined effect of SPL, exposure time and potassium serum level.

3. Methods

3.1. Study Population and Industry Selection

The population of the study included male workers of Gol-Gohar Mining and Industrial Company in Sirjan, South-East of Iran. The study was conducted in the fall of 2014. Prior to conducting the research, participants' health status (including the hearing status as well as heart, vascular and mental condition) was examined by their medical records. The review of these records helped the researchers to select healthy individuals to participate in the study.

Since Gol-Gohar Mining and Industrial Company was appropriate; it was selected as the study setting. The company has four active factories (involving magnetite, pelletizing, hematite and polycom factories). Since the wet ball mill of the magnetite factory and the dry ball mill

of the pelletizing factory met the prerequisites, they were selected as the target context exposing workers to industrial noise. Workers did not experience any thermal stress. There was no main source of vibration, either. Since measurement domains differed in terms of the SPL, ± 5 dBA was considered as the proper standard deviation for this variable.

3.2. Sampling Method

The study followed a case-control pattern, with a single control group and two case groups. The workers were equally divided into three groups. Following the available literature, with a power of 80% and type one error of 0.05 ($\alpha = 0.05$), 45 subjects were needed for the sample (19-21). The differences between the two groups constituted the basis of the formula used to calculate the sample size; thus, 15 participants were assigned to each group.

3.3. Study Design

Prior to conducting the experiment, the subjects were fully informed about the study objective, and finally signed a consent forms to participate in the research project. On the day of the experiment, subjects' demographic data were collected by a specifically-designed form, followed by calculating their body mass index (BMI). The sample included 30 individuals working in manufacturing departments and 15 office employees of the mining company. On the other hand, participants in the control group were selected from workers with administrative jobs. Subjects of the exposed groups did not use ear muffs. Moreover, according to the international organization for standardization (ISO) 8996, their working practices were defined as light work (22). As an environmental variable, noise intensity values were measured in the target locations. Serum aldosterone and potassium levels of participants in the control and exposed groups were assessed at three different time intervals: at the beginning of the shift and before exposure to noise (7:30 - 8:00 AM), during exposure to noise (10:00 - 10:30 AM), and during continuous exposure (1:30 - 2:00 PM). The studied participants had a shift work of 3-3-3 (three morning shifts, three afternoon shifts, three night shifts, and three days off). In light of the findings related to the aldosterone circadian rhythm in a previous study (23), the samples were collected on the first day after the rest days.

3.4. Measurements

3.4.1. Noise

Following ISO 9612 (24), a sound level meter (CEL-440, CASELLA, USA) was utilized to assess the noise at each workstation. To accurately calibrate the sound level meter be-

fore the measurements, CEL-282 calibrator (CASELLA, USA) was exploited.

3.4.2. Aldosterone and Potassium

To measure the levels of serum aldosterone and potassium, 5 mL of the blood sample was collected from each worker at the three above mentioned time intervals during the shift work hours. Samples were taken from participants as they were in the sitting position. Blood samples were transferred into a series of numbered tubes which contained anticoagulant ethylenediaminetetraacetic acid (EDTA) and were immediately taken to an authentic medical diagnostic laboratory under controlled conditions (i.e. inside ice box). The Enzyme-linked immunosorbent assay (ELISA) was used to measure the aldosterone level. In addition, a kit (DBC-Diagnostic Biochem Canada Inc., Ontario, Canada) and a flame photometer (Jenway PFP7, Essex, UK) were utilized to assess the level of serum potassium.

3.5. Statistical Analysis

The obtained data were transferred into SPSS ver. 18 (SPSS, Inc. Chicago, Illinois, USA). These data were first summarized by descriptive data analysis techniques (e.g., frequency, mean and standard deviation). Shapiro-Wilk test was then applied to evaluate the normal distribution of the data. Since the data were collected several times in the course of the study, repeated measurements analysis of variance was used to analyze the data and provide the model. The $P < 0.05$ was considered as the significance level.

3.6. Ethical Considerations

The study was conducted in accordance with the ethical principles of the ethics committee of Tehran University of Medical Sciences (ID: 1394.51). A written consent form was obtained demonstrating subjects' free will to participate in the study. Furthermore, participants were completely assured that the data would remain strictly confidential and would be used only for research purposes. The participating workers could also withdraw from the study at any stage they wished without any consequences.

4. Results

4.1. Analysis of Demographic Features

Table 1 shows the mean age and body mass index of the three studied groups.

4.2. Measurement of Sound Pressure Levels in the Industry

Table 2 demonstrates the results of SPL for the control group (administrative offices) and the two cases (ball mill of the magnetite and pelletizing factories).

4.3. The Results of the Statistical Models to Determine the Levels of Serum Aldosterone and Potassium

4.3.1. The Statistical Model to Determine the Level of Serum Aldosterone Based on the Combined Effects of SPL and Exposure Time

The combined effects of the SPL and exposure time on the level of serum aldosterone were calculated by a mixed model. The results are presented in Table 3.

Based on Table 3, the following formula shows the final model of serum aldosterone in humans:

$$\text{Aldosterone level (pg/mL)} = 132.15 + 0.22 \text{ SPL} - 5.66T$$

Where,

SPL = sound pressure level

T = duration of being exposed to noise (measured in hours)

In the above statistical model, the exposure time was considered to range from 7:30 AM to 2:00 PM (i.e. the exposure time ranges from zero to 6.5 hours).

4.3.2. The Statistical Model to Determine the Level of Serum Potassium Based on the Combined Effects of SPL and Exposure Time

The mixed model was used to calculate the combined effects of the SPL and exposure time on the level of serum potassium. The results are presented in Table 4.

As indicated in Table 4, the following formula shows the final model of serum potassium in humans:

$$\text{Potassium level (mM/L)} = 3.92 + 0.002 \text{ SPL} - 0.014T$$

Where,

SPL = sound pressure level

T = duration of being exposed to noise (measured in hours)

In the above statistical model, the exposure time was considered to range from 7:30 AM to 2:00 PM (i.e. the exposure time ranges from zero to 6.5 hours).

4.3.3. The Statistical Model to Determine the Level of Serum Aldosterone Based on the Combined Effects of SPL, Exposure Time and Serum Potassium Level

The combined effect of SPL, exposure time and serum potassium level with the level of serum aldosterone was calculated by mixed model. Table 5 illustrates the results of this model.

According to Table 5, the following formula shows the final model of serum aldosterone in humans:

$$\text{Aldosterone level (pg/mL)} = 91.95 + 0.19 \text{ SPL} - 5.49T + 10.21K$$

Where,

SPL = sound pressure level

T = duration of being exposed to noise (measured in hours)

Table 1. Demographic Characteristics of the Studied Subjects^a

Variables	Control Group Exposed to Noise Level 72 dBA (n = 15)	Case Group Exposed to Noise Level 88 dBA (n = 15)	Case Group Exposed to Noise Level 103 dBA (n = 15)
Age, y	28.8 ± 2.05	30.1 ± 2.37	29.4 ± 2.63
Work experience, mo	26 ± 7	31 ± 9	28 ± 5
BMI, kg/m ²	25.11 ± 2.28	25.50 ± 3.25	25.5 ± 2.97

^aValues are presented as mean ± SD.

K = potassium level (mM/L)

In the above statistical model, the exposure time was considered to range from 7:30 AM to 2:00 PM (i.e. the exposure time ranges from zero to 6.5 hours).

5. Discussion

In the current study, the levels of aldosterone and potassium were calculated for the participants in the control group and the subjects exposed to noise. Sampling was conducted in three different occasions during the shift: 7:30 - 8:00 AM, 10:00 - 10:30AM, and 1:30 - 2:00 PM. The results showed that the levels of aldosterone and potassium among the participants were within the normal range. The normal levels of aldosterone and potassium in the blood are around 6 - 22 ng/100 mL and 5 - 5.3 mM/L, respectively. The results obtained from the current study were in line with these values (25). One of the main factors to regulate the secretion of aldosterone is the increase of potassium level in the extracellular fluid (26). Thus, to examine the effect of potassium level of aldosterone, the researchers also concentrated on assessing the level of serum potassium.

The study further aimed to examine the influence of working experience, body mass index and age on the levels of aldosterone and potassium, with the results indicating no interactive effect of these three variables on aldosterone and potassium level. Therefore, after adjusting these three factors in aldosterone and potassium levels, the effect of SPL and exposure time were investigated on the levels of aldosterone and potassium in the obtained statistical models. The results of the statistical model used

to determine the aldosterone level based on the combined effects of SPL and exposure time showed that the SPL had a significant influence on the human's serum aldosterone level ($P = 0.04$). Similarly, exposure time had a significant effect on aldosterone level ($P = 0.004$). In contrast, the results of the statistical model used to determine the potassium level based on the combined effect of SPL and exposure time indicated that SPL had no significant impact on human's serum potassium level ($P = 0.37$). The effect of exposure time on serum potassium level was not significant either ($P = 0.34$).

The results of the final model to determine the level of serum aldosterone based on the combined effect of SPL, exposure time and serum potassium level demonstrated that all three factors had significant effects on aldosterone level, with P-values of 0.04, 0.008, and 0.001 for SPL, exposure time and serum potassium, respectively. Some studies showed that a small increase in the potassium level can significantly enhance the secretion of aldosterone (27). As a result, the predicted model was completely in line with this scientific logic.

Ising et al. found that, as a source of stress, noise increases the secretion of aldosterone (28). In another study, Charloux et al. observed a significant decline in aldosterone level from the beginning to the end of the shift (23). These two findings are in line with those of the current study.

Melamed et al. examined the relationship between chronic exposure to industrial noise and the level of urinary cortisol among 35 healthy individuals who worked in the industrial sector and were exposed to an SPL of 85 dB while used no device to protect their ears. During an eight-hour shift, the urinary cortisol level was measured in three occasions, i.e. 6:30 AM, 10:30 AM and 1:30 PM. The results revealed an increasing trend in the level of urinary cortisol from the beginning to the end of the shift. The current study also assessed serum aldosterone level in three different occasions during a shift (the beginning of the shift, three hours after exposure and eight hours after exposure) among subjects of the control and experimental groups. The results showed that, compared to the beginning of the

Table 2. The Results of the SPL in Measurable Areas

Study Group	SPL ± SD (dB)
Control group	72 ± 1.32
Case group (wet ball mill of the magnetite factory)	88 ± 2.29
Case group (ball mill of the pelletizing factory)	103 ± 2.21

Abbreviation: SPL, sound pressure level.

Table 3. The Parameters of the Model Designed to Determine the Level of Aldosterone in Light of the Combined Effects of SPL and Exposure Time

Model Parameter	Estimate	Standard Deviation	Degrees of Freedom	P-Value	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	132.15	11.48	44.18	0.001	109	155.30
Sound pressure level	0.022	0.0128	43	0.04	-0.037	0.048
Exposure time	-5.66	0.036	89	0.004	-6.39	-4.93

Abbreviation: SPL, sound pressure level.

Table 4. The Parameters of the Model Designed to Determine the Level of Serum Potassium in Light of the Combined Effects of SPL and Exposure Time

Model Parameter	Estimate	Standard Deviation	Degrees of Freedom	P-Value	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	3.92	0.28	44.29	0.001	3.34	4.49
Sound pressure level	0.002	0.003	43	0.37	-0.0038	0.009
Exposure time	-0.014	0.009	89	0.34	-0.032	0.004

Abbreviation: SPL, sound pressure level.

Table 5. The Parameters of the Final Model to Determine Serum Aldosterone Level

Model Parameter	Estimate	Standard Deviation	Degrees of Freedom	P-Value	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	91.95	4.47	4.4	0.001	79.99	103.90
Sound pressure level	0.19	0.006	4.08	0.04	0.181	0.216
Exposure time	-5.49	0.149	13.55	0.008	-5.82	-5.17
Serum potassium concentration	10.21	1.11	4.31	0.001	7.21	13.22

shift, aldosterone level was lower at the end of the shift (21).

Nawaz et al. demonstrated that various levels of sound pressure influenced the level of serum aldosterone. They examined the effect of three different SPLs (i.e. lower than 80 dB, between 80 and 94 dB, and higher than 94 dB) among healthy individuals and observed a significant negative relationship between SPL and aldosterone level, i.e. as SPL increased, aldosterone level declines (29). Similarly, the results obtained in the present study showed that as SPL went up, aldosterone level increased significantly ($P < 0.05$). While Nawaz et al. (29) collected their data from people living in urban areas, the current study focused on industrial workers; hence, the results of the current study contributed to occupational health.

Mahdizadeh measured aldosterone level among 45 nurses in Mashhad (a city in North-East of Iran) during various work shifts. The results indicated that the aldosterone levels ranged from 65 to 156 pg/L, depending on the shift. It was also demonstrated that working experience had a positive relationship with aldosterone level, that is as

the years of experience increased, so did the level of aldosterone (30). In the current study, however, working experience had no significant effect on aldosterone level among the participants in the three groups. The value of the aldosterone level measured in the control group was fairly similar to Mahdizadeh's study. (30).

Tadros et al. compared the level of serum aldosterone of normal people with a mean age of 64 years and that of individuals with presbycusis smooth pattern and their mean age was 71.4. The results showed significant differences ($P = 0.0003$), in the sense that the aldosterone level among people with presbycusis was significantly lower than that of normal participants. They concluded that aldosterone might have a protective effect on the hearing ability of old people, with its effect being more profound on inner hair cells than outer hair cells (15). Given that other studies showed that aldosterone and serum potassium can affect people's hearing ability, the present study also took the influence of SPL of these hormones into account.

Farahani et al. examined the relationship between the

level of aldosterone and serum potassium in the blood and hearing ability of 54 elderly patients in Hamadan, West of Iran. The results indicated that, in both control and case groups, the level of serum aldosterone was within the normal range among 92.5% of the participants, with only 7.5% of them experiencing an abnormal aldosterone level. The average level of serum aldosterone in the control group was 129.7 pg/mL, while it was 157 pg/mL in the case group, and the results of paired-samples T-test showed no significant difference between them. Furthermore, there was no significant relationship between participants' aldosterone level and hearing ability. The levels of potassium in the control and case groups were 4.4 mM/L and 4.49 mM/L, respectively, with no significant relationship between potassium level and hearing ability. The ranges of aldosterone and serum potassium in the current study were similar to those of Farahani et al.'s research (31).

Taken together, the results of the current study investigating the effect of the SPL and exposure time on serum aldosterone showed that SPL independently affected aldosterone level, that is as SPL increased, the mean level of aldosterone increased too. In addition, exposure time had a significant effect on serum aldosterone level, which meant that increasing the duration of exposure time resulted in the decline of aldosterone level. Finally, serum potassium level had a significant influence on aldosterone level, while SPL and exposure time had no significant impact on serum potassium level. Considering the models obtained in the study, it was concluded that the results of predictive models to determine aldosterone level were very similar to real values; therefore, the reliability of the results obtained from this model was largely in line with the values obtained from the field.

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Footnotes

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