The Effect Of Below Exposure Noise Threshold Limit Value To Acute Stress

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Abstract

Introduction: This study aims to examine the possibility of the effect of noise with intensity below the threshold value to stress.

Method: The study is a quasi-experimental involved 108 subjects divided into 6 noise exposure groups of control, 0 dBA, 70 dBA, 75 dBA, 80 dBA and 85 dBA in 15 min exposure. Research subjects consisted of healthy males, aged 18–39 years and met the study criteria. Assessment of stress include physical stress index (PSI), the total power (TP) and low frequency/high frequency ratio (the ratio of LF/HF) measured using the test heart rate variability (HRV), adrenaline and cortisol blood levels measured before and after treatment.

Result: Research subjects who qualify as many as 102 people a year aged 23.99±4.77 years. Research subjects have equal characteristics between treatment groups according to the socio-demography.

There is no different of PSI value, the ratio of TP and LF/HF, Adrenaline between exposure groups. Cortisol levels were positively correlated with higher levels of adrenaline ($r=0.35$, $p<0.01$) while adrenaline levels and cortisol levels were strongly positively correlated ($r=0.53$, $p<0.01$). PSI values weakly positively correlated with cortisol levels ($r=0.2$, $p<0.05$) and the ratio LF/HF were positively correlated weakly with cortisol ($r=0.2$, $p<0.05$).

Discussion: Effect of noise on the stress intensity visible starting at Laeq, 65 dBA and Laeq 8 hour, 8 hour 70 dBA. Correlation parameter values autonomic balance system with adrenaline and cortisol levels demonstrate the potential use of HRV as a psychophysiological assessment instruments due to noise disturbanc

Keywords: noise, adrenalin, cortisol, autonomic balance system, stress

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Introduction

The studies showed that the noise exposure cause many health problems including hearing impairment, physiological disorders, psychological stress, communication disturbances, and other health disorders[1]. However, the study of the low intensity noise health effects is still limited. In term of the workplace, the threshold limit value of noise commonly defined as 85 dBA[2].This value need to be reviewed considering to prevent other noise health effects rather than hearing impairment.

Ising[3] mentioned that noise causes the body stress reaction that is marked by the elevating adrenaline, nor adrenaline, and blood cortisol level. Currently, the studies of noise effect to the adrenaline and cortisol use the noise intensity above 85 dBA. Suter[4] suggested to do the further noise health effects study with the low intensity noise which is less than 85 dBA.

It was expected that the noise exposure below the threshold limit value influences the incidence of psychological acute stress based on at least one of the following parameters such as either the autonomic balance system changes, the blood adrenaline hormone elevation, or blood cortisol level elevation.

This study aims to examine the possibility of the effect of noise with intensity below the threshold value to stress

Method

This experimental study involved 102 study subjects of 149 screened subjects at the beginning of the study. There were 108 subjects fulfil the eligible criteria, but only 103 participants undergone the study intervention. They were grouped into 6 different noise intensity groups by using block randomization, however some participants changed the group due to the their availabilty time. During the blood sample withdrawn one of them was syncope and discontinued to participate. Three participants were not included to the analysis since they were under medication at the day of the intervention. However, only 89 study subjects could be blood sample withdrawn within two minutes. Research subjects consisted of healthy males, aged 18-39 years who worked mainly as supporting staff at the Universitas Indonesia, and voluntarily participated.

All parameters were measured before and after intervention. The research ethics has been approved by The Health Research Ethics Committee of Universitas Indonesia/Cipto Mangunkusumo National Hospital.

Noise Exposure Intensity

All subjects except the control group subjects stayed for 15 minutes during the intervention at the sound-proofed noise room located in the Ergonomic Centres Universitas Indonesia. The control group subjects were not stayed at the noise room instead of freely stayed at the some rooms in the ergonomic centres. Based on the noise exposure level the study groups were classified into the control group, 0 dBA, 70 dBA, 75 dBA, 80 dBA and the group of 85 dBA. The noise was generated and controlled by digital voice player and the intensity of noise was measured with calibrated sound level meter. Since there were basic noise can not be controlled the noise exposure in the control group room and the 0 dBA noise room were 58 dBA and 38 dBA respectively.

In order to be applied in the workplace, the noise equivalent levels were calculated based on *8 working hours equivalent noise exposure* ($L_{aeq,8h}$)[5]. Based on the calculation the equal exposure level of each noise groups are presented on the table 1.

Table 1. The Noise Calculation of Average Level 8 hours Equivalent

Exposure Groups	15 Minutes Noise Exposure Intensity	$L_{aeq,8h}$
0 dBA	38 dBA*	23 dBA
Kontrol	58 dBA*	43 dBA
70 dBA	70 dBA	55 dBA
75 dBA	75 dBA	60 dBA
80 dBA	80 dBA	65 dBA
85 dBA	85 dBA	70 dBA

* room basic noise

Autonomic Balance System Assessment

The Autonomic Balance System assessment were performed using Heart Rate Variability test instrument, Medicore SA-3000P type. The related parameters to the acute psycho-physiological disorders were used as markers of phsycological stress included the score of physical stress index (PSI), the total power (TP) and the low frequency/high frequency ratio (the ratio of LF/HF).

Plasma Adrenaline Measurement

The measurement of plasma adrenaline level were used *enzyme-linked immunosorbent assay* (Elisa) technique using reagen kit for research used only (LDN GmbH. Am Elchenhain 1,48531 Nordhorn, Cat: BA-E-5100, Lot: 11181, Expiry Date; February 16th 2013). The reagent kits of adrenaline have a standard range; 0.5 ng/ul to 80 ng/ul, with the detection limit was 0.01 ng/ul, and the correction factor was 0.04 ng/ul. Since the half life time of the adrenaline is less than two minutes the after intervention blood samples were drawn within two minutes immediately after the end of exposure[6].

Plasma Cortisol Measurement

The plasma cortisol level were measured with the *electrochemiluminescence immunoassay* (Eclia) technique using reagen kit of Roche Diagnostics GmbH, Sandhofer Strasse 116, D-68305 Manheim, Cat; 11875116, Lot; 16026601, and expiry date was May 31st 2012.

The venous blood samples were drawn from the *cubity* arm. The collected blood samples were 10 minutes centrifuged with 3000 rpm immediately after being drawn and the separated plasma were placed into four smaller tubes, labeled for the sample identity, and then kept in to the cool box.

The blood samples for the plasma adrenaline analyses were also used for the plasma samples of the cortisol analyses. Since the place and the time of laboratory analysis were different to the place and the

time of the sample drawn the temperature during the transportation and the storage were monitored and recorded which were acceptable. It was about 30 km distance and took 45 minutes time from the Ergonomic Centre where the blood sample were drawn to the Prodia Clinical laboratory where the samples were analyzed. During the transportation the cool box temperatures were kept in 3 to 6 degree of Celsius. Since the days of samples withdrawn were not the same days of laboratory analyses the plasma were placed into the freezer and kept in the temperature of 20 degree of Celsius.

Coefficient of variance (CV) of the sample analysis results both the adrenaline and the cortisol and also the CV between day and within run were acceptable (<0,05).

The cortisol concentration is also has circadian variation. In order to minimize the circadian variation factor the data collection were done at the same time for all exposure groups which is in range of 15.00 to 15.30. This time is also the convenience time of the study subjects.

Statistical Analysis

The means and the standard deviation of the means for all metrics numerical data were calculated for all intervention groups and also tested for the normality of data distribution. To compare the means between intervention groups the data which were normally distributed were analyzed using Analysis of Variance, followed by the Post Hoc test of Bonferroni. The variable which data was not normally distributed were analyzed using Kruskall Wallis test. Statistical analyses were performed using SPSS ver. 11.5. In all cases, p value of < 0, 05 was used to determine significance.

Result and Discussion

Research subjects who were included to the study were 102 people aged 23.99 ± 4.77 years. The characteristics of research subjects were equal between exposure groups at the beginning of the study according to the variables age, length of service at the current job, length of total work, the General Health Questionnaire (GHQ), the BMI rate, pulse rate, respiratory rate, systolic and diastolic blood pressures.

The study showed that the after exposure PSI score at some exposure groups were decrease, but some its score at another groups were higher compare to its before exposure levels (see table 3). The means of PSI score difference were increased at the exposure groups of control, 80 dBA, and 85 dBA which were 3,1±13,6, 4,4±14,5 and 2,1±15,4 respectively. However the PSI score at the group of 0 dBA, 70 dBA, dan 75 dBA were decreased. The differences of the means of PSI score differences were not statistically significant (p>0.05). The differences of the means of PSI score both before and after exposure between exposure groups were also not statistically different.

The after exposure Total Power score at the 70 dBA group and 80 dBA group were lower than its score before exposure (see table 3). However the differences of the means of Total Power score between before and after exposures were not statistically significant for all exposure groups.

Tabel 2. The Comparison of The Initial Subject Characteristics between the Exposure Groups

Variable	0 dBA n= 16	Control N=17	70 dBA N=16	75 dBA N=17	80dBA N=16	85 dBA N=17	p value
Age (years)							
Mean ± SD	23,4 ± 4,1	25,2 ± 5,9	24,4 ± 6,5	24,8 ± 5,6	22,6 ± 2,9	24,0 ± 2,1	0,651*
Length of current service (months) Median (min-max)	3 (3-240)	3 (3-240)	3 (3-240)	3 (3-192)	3 (3-108)	3 (3-180)	0,920*
Length of total service (months) Median (min-maks)	3 (0-60)	6 (0-36)	0 (0-29)	12 (0-50)	18 (0-60)	0 (0-38)	0,071*
GHQ							
Mean ± SD	10,4 ± 2,3	10,3 ± 2,9	12,1 ± 1,9	10,6 ± 3,0	12,4 ± 2,8	12,5 ± 3,4	0,058*
BMI (kg/m2)							
Mean ± SD	22,2 ± 3,2	21,3 ± 2,6	21,6 ± 2,7	21,2 ± 3,0	20,1 ± 1,9	21,4 ± 2,8	0,308*
Pulse(bpm)							
Mean ± SD	69,4 ± 9,6	68,2 ± 9,1	66,5 ± 8,0	73,7±13,8	75,1±10,4	71,9±10,2	0,143*
Respiration Rate (f/minute)							
Mean ± SD	18,0 ± 2,1	18,9 ± 2,2	18,2 ± 1,5	19,7 ± 2,3	18,3 ± 2,3	19,7 ± 1,9	0,051*
Systolic (mmHg)							
Mean ± SD	117,4 ± 13,2	113,6 ± 9,5	112,8 ± 10,5	118,8 ± 9,7	115,7 ± 9,5	114,9 ± 8,2	0,540#
Diastolic (mmHg)							
Mean ± SD	80,3 ± 11,5	76,1 ± 6,9	76,3 ± 9,4	78,4 ± 7,0	76,8 ± 7,7	75,8 ± 6,9	0,837*

*Kruskal Wallis *Tes; t*# 1-way Anova *Test; GHQ=General Health Questionnaire; BMI=Body Mass Index; bpm=beat per minute;*

The score increase of TP were occurred at the group of 0 dBA, control, 75 dBA, and the group of 85 dBA. The highest increase of TP score were at the group of control. There was no statistically different of the means of TP difference score between the exposure groups ($p > 0.05$). The comparison of the means of both TP score before and after exposure between the exposure groups were not statistically significant difference ($p>0.05$).

The highest means of the LF/HF score ratio before the exposure were at the group of 70 dBA, and the lowest score at the group of control. The means of the LF/HF score ratio after the exposure were highest at the group of 75 dBA, and the lowest score at the group of 70 dBA. However, there was no statistically significance different of the means of between LF/HF ratio before and after exposure at all exposure

groups. The analysis result showed that the after exposure LF/HF ratio score of group of control, 70 dBA, 75 dBA, and 80 dBA were higher than its before exposure score. The highest means of LF/HF ratio score difference were group of 75dBA, whereas the lowest score difference were 85 dBA exposure group. Statistically the difference of LF/HF ratio score difference between the exposure groups were not significant (p>0,05). See table 3.

There were no statistically significant differences of PSI score and the score ratio of TP and LF / HF between exposure groups. However, the PSI score has clinically significant changed at groups of 80 dBA ($L_{aeq,\ 8h}$ 65 dBA). Based on the TP score the clinically change occured in the groups of 70 dBA ($L_{aeq,\ 8h}$ 55 dBA) and groups of 80 dBA ($L_{aeq,\ 8h}$ 65 dBA). The clinically change also occurred for the score ratio of LF/HF at the intensity of 75 dBA ($L_{aeq,\ 8h}$ 60 dBA).

Table 3. HRV Parameter Score for PSI, TP, and LF/HF Ratio based on Exposure Group

		HRV Parameter Score mean ± SD						
		0 dBA n=15	**Control** n=16	**70 dBA** n=16	**75 dBA** n=17	**80dBA** n=16	**85 dBA** n=17	**p value**
Before	**PSI**	21,2±10,6	21,4±12,7	21,9±13,6	29,3±16,8	26,9±16,0	26,0±16,7	0,637*
	TP	2653,8 ± 1680,1	3268,4 ± 3028,2	3197,7 ± 3552,7	2224,1 ± 1863,7	2646,5 ± 2118,8	2592,7± 1763,9	0,930*
	LF/HF Ratio	1,2±0,8	0,9±0,5	2,3±3,2	2,05±2,5	1,7±1,9	1,9±1,9	0,633*
After	**PSI**	19,4±9,7	24,6±16,8	21,3±11,7	25,7±14,1	31,3±20,0	27,7±19,1	0,574*
	TP	3008,5 ± 2540,7	4741,7± 7192,4	2056,9 ± 1394,5	2731,1 ± 2619,4	1976,7 ± 1199,8	3666,9 ± 4051,7	0,810*
	LF/HF Ratio	1,2±0,7	1,3±1,2	1,2±1,3	2,1±1,7	1,9±1,2	1,5±1,0	0,087*
Difference	**PSI**	-1,9±7,5	3,1±13,6	-0,65±9,8	-3,6±13,2	4,4±14,5	2,1±15,4	0,196*
	TP	354,7 ± 1860,2	1473,2± 7106,2	-1140,7 ± 3238,5	506,7 ± 2197,8	-669,8 ± 1395,7	1048,1± 3099,6	0,267*
	LF/HF Ratio	0,36±1,2	-0,23±0,9	0,30±1,8	0,84±12,9	0,1±2,3	-1,03±3,1	0,359*

*Kruskal-Wallis test; PSI=Physical Stress Index; TP=Total Power; LF=Low Frequency; HF=High Frequency

Not all study participants were included into the adrenaline analyses because The means of after exposure plasma adrenaline concentrations were highest at the group of 85 dBA which was 85.94±98.45pg/dl, and the lowest means of after exposure adrenaline concentration were the group of 70 dBA which was 53.08±20.52pg/dl. The differences of the means of adrenaline concentration between the exposure groups were statistically not significant.

The analysis result showed that the means of after exposure adrenaline concentration were lower than its initial concentration. However there was statistically significant different between the after exposure adrenaline concentration and its initial concentrations only at the 80 dBA exposure group. The means of

before and after exposure adrenaline concentration at this exposure group were 71,60±39,90 pg/dL and 57,73 + 28,16 pg/dL respectively (p=0,048).

Almost all the exposure groups showed that their after exposure adrenaline concentration were decreased within range of -19.29±37.9 pg/dl to -0.13±105.42 pg/dl, except at the group of 70 dBA which was increased of 7±19,71 pg/dl. No statistically significance different of the means of the adrenaline concentration difference between the exposure groups (p>0,05). (See table 4)

The means of the initial cortisol concentration was highest at the group of 75 dBA which was 11,5 ± 5,1 g/dland the lowest initial cortisol concentration was the group of 70 dBA which was 5,5 ± 2,6 g/dl. However the initial cortisol concentrations were no statistically different between the exposure groups. The means of after exposure cortisol concentration was highest at the group of 75 dBA (12,1 ± 5,4 g/dl), and the lowest means of after exposure cortisol concentration was 70 dBA (6,9 ± 3,7 g/dl). The difference of the means of after exposure cortisol concentration between the exposure groups was statistically significant (p=0,050). Considering the means of initial cortisol concentrations was statistically significance different between the exposure groups, therefore to evaluate the noise exposure effect to the cortisol concentration we used the means comparison of the means of cortisol concentration difference. (See table 4).

Tabel 4. The Comparisons of Adrenaline level and Cortisol Levels between the Exposure Groups

		0 dBA n=14/16	Control n = 14/17	70 dBA n=13/16	75 dBA n=17/17	80 dBA n=15/16	85 dBA n=16/17	p value
Before	**Adrenalin (pg/dL)**	93,29±57,07	79,93±39,22	46,08±17,03	99±43,65	71,60±39,90	73±50,19	0,068#
	Cortisol (ug/dL)	6,1 ± 2,5	7,1 ± 3,1	5,5 ± 2,6	11,5 ± 5,1	8,5 ± 3,8	6,8 ± 3,5	0,000*
After	**Adrenalin (pg/dL)**	74±35.96	73.00±50.19	53.08±20.52	85.65±44.19	57.73±28.16	85.94±98.45	0,112*
	Cortisol (ug/dL)	11,0 ± 4,6	9,4 ± 5,7	6,9 ± 3,7	12,1 ± 5,4	9,8 ± 4,1	9,8 ± 6,6	0,050*
Difference	**Adrenalin (pg/dL)**	-19.29±37.9	-5.9±48.6	7±19.71	-13.35±39.31	-13.87±23.74	-4.13±105.42	0,215*
	Cortisol (ug/dL)	4,8 ± 4,3	2,3 ± 4,5	1,4 ± 3,8	0,5 ± 3,6	1,3 ± 1,9	2,9 ± 4,9	0,039*

* *1-way Anova*; # Kruskal-Wallis test; n = #/# (n for adrenaline/n for cortisol);

The mean difference of cortisol concentration in each exposure group was highest in the group 0 dBA (4.8 $\pm$ 4.3 ug/dL), followed by a group of 85 dBA (2.9 $\pm$ 4.9 ug/dL). The lowest cortisol average difference concentration was at 75dBA group (0.5 $\pm$ 3.6 ug/dL). The mean difference of the cortisol concentration between exposure groups were statistically significant ($p<0.05$). The statistically significant difference is found between the average levels of cortisol 0 dBA group and 70 dBA group ($L_{aeq,8h}$ 55 dBA), 75 dBA ($L_{aeq,8h}$ 60 dBA) and 80 dBA ($L_{aeq,8h}$ 65 dBA).

Discussion

The study subjects' age were ranged of 18 – 39 years old who represented the productive age workers and included both administrative and technical/field job. Initial characteristics of subjects were equal based on the sociodemograpic and physical variable therefore the potential confounding come from sociodemographics and physical factors can be minimized.

The relationship between the noise exposure and psychophysiological disorder parameters

Kristiansen[7] suggested that Heart Rate Variability test can be used to detect the acute stress by measuring the activities of sympathetic and para sympathetic nerves. Some parameters are used including Physical Stress Index, Total Power score, and LF/HF ratio. Total Power is activities total score of *very low frequency (VLF), low frequency (LF) and high frequency (HF).* VLF and LF score represent the energy of para-sympathetic nerve activities, and HF score represents the energy of sympathetic nerve activities. At the situation of psycho-physiological disorders the PSI score, and LF/HF ratio are increased, and the TP score is decreased.

This study found that the means of PSI score, TP score, dan LF/HF ratio after exposure have no statistically significant change for all of the exposure groups. The means difference of all those parameters between before and after exposure were also no statistically significant difference among the exposure groups. Although there was no statistically significant change, the increase of PSI score clinically significant (>10% change). Based on this criteria the PSI scores were clinically change at the exposure group of $L_{aeq,8h}$ 65 dBA (80 dBA exposure) which was 4,4 ± 14,5 (16,3% increase), and at $L_{aeq,8h}$ 43 dBA (control group) which was 3,1 ± 13,6 (14,4% increase).

The difference of the PSI score means between the after exposure means and its initial score at the $L_{aeq,8h}$ 43 dBA (control group) may because of other stressor during the intervention in relation with the situation of the place they stayed in. In contrast with the other exposure groups who have privacy at the room provided during the study, the control group stayed in open space but they could not go anywhere because they have to go back on time at the minute 15th. In addition the ergonomic centre is a place they have not been familiar yet.

Clinically changes were also applied for the means of TP at the group of $L_{aeq,8h}$ 55 dBA (70 dBA exposure) which was – 1140,7 ± 3238,5 (35,6% decrease) and at $L_{aeq,8h}$ 65 dBA (80 dBA) which was -669,8±1199,8 (25,3% decrease). The means of LF/HF ratio was also changed at the level of $L_{aeq,8h}$ 60 dBA (75dBA exposure) which was 0,84 ± 12,9 (40,9% increase).

The relationship of the noise exposure and adrenocortical hormone concentrations

It has been widely accepted that the stressors affect the adrenocortical hormone concentration through the Hypophyse – Pituitary – Adrenal (HPA) Axis[8]. Noise exposure as a stressor stimulates the adrenocortical hormones including adrenaline, nor-adrenaline, and cortisol hormones.

Adrenaline levels generally decreased but there was no statistically significant differences between exposure groups. Since the half-life of adrenaline is less than two minutes, and the research subjects were able to adapt to the noise exposure made the results of adrenaline level measurement after 15 minutes exposure were lower than its initial level. The Adrenaline half life time (t1/2) is less than 2 minutes. This study used 15 minutes time exposures to the low intensity noise that might enable the study subject to make adaptation. Therefore the adrenaline concentrations might be increased at the first minutes of exposure, but after the subjects overcome the situation the adrenaline concentration went back to basic.

At the exposure group of 80 dBA ($L_{aeq,8h}$ 65 dBA) and the exposure group of 85 dBA ($L_{aeq,8h}$ 70 dBA) the means of the cortisol concentrations statistically significant increased which were 1,3 ± 1,9 ug/dL and 2,9 ± 4,9 ug/dL respectively. The means of the cortisol concentrations were also increased statistically significant at the group of 0 dBA ($L_{aeq,8h}$ 23 dBA) which was 4,8 ± 4,3 ug/dL.

The increase of the cortisol concentrations at the exposure group of 0 dBA can be explained follow. At this study, all subjects have been explained to get one of various levels of noise exposures. The subjects of 0 dBA group might be anxious to wait the noise they anticipated in fact they did not find any noise exposure. Even they found the very silent situation that make them in an uncertainty situation. The uncertainty might stimulates the balance mechanism of autonomic system. Hirsh [9] mentioned that uncertainty could be a very strong stressor. Furthermore the group of 0 dBA faced the situation that there were approximately more than 20 dBA noise intensity difference whenever they came out from the noise room to go to the examination room. Ising [3] found that the cortisol concentrations were increased due to additional noise exposure of 9 to 19 dBA.

Conclusion and Suggestion

Based on the change of blood cortisol concentration, the effect of noise exposure as the psychological stress were showed at the intensity level $L_{aeq,8h}$ 65 dBA and $L_{aeq,8h}$ 70 dBA.

This finding also contributed to the data of the low intensity noise health effect especially the acute psychological stress. To prevent the mental health disorders the noise exposure should be controlled and limited although the exposure levels are below the threshold limit value of 85 dBA.

Further study is needed to find other low intensity noise health effects.

Conflict of Interest

There is no potential conflict of interest relevant to this article.

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