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The Effects of Environmental Noise on Annoyance, Stress, and Urine Cortisol Levels Among Residents Living Near Industrial Sites in Bangkok, Thailand

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Abstract

People are exposed to environmental noise each day. It may be annoying, cause stress, induce hormonal changes, and negatively affect long-term health. This study aimed to determine the effects of environmental noise on annoyance, perceived stress, stress symptoms, and urine cortisol in people living in a selected area. This cross-sectional study was conducted from April to October 2022 on 142 participants. Urine samples were collected to determine cortisol levels, and perceived stress, stress symptoms, and environmental noise annoyance were evaluated using questionnaires. Stress symptoms correlated with traffic, industrial, and community noise, but not aircraft noise. Community noise correlated most strongly with all stress symptoms. Only community noise exposure was correlated with perceived stress. People reported that industrial and community noise affected their health and daily activities. Cortisol correlated with only traffic noise annoyance. Environmental noise was associated with stress symptoms and stress hormones. In brief, sound level is not the only indicator of stress or health impacts, but annoyance and concern over the effects of noise may negatively affect stress and health.

Keywords: annoyance, cortisol, environment, noise, stress

Introduction

The effects of environmental noise exposure have been intensifying, particularly for urban and industrial residents.[1] Environmental noise, the unwanted irritating noise, is one of the most significant environmental issues which has a negative impact on human health and wellbeing.[2] Sources of noise are transportation (traffic, aircraft), community, industrial plants (noise generated by operating machines), and other sources.[3] Traffic noise on the road is the main problem in urban areas.[4] Noise from trains or aircraft affects the surrounding area.[5,6] Some sources of community noise include the lawnmower, barking dogs, kitchen appliances, and television.[7] Mechanical processes and moving equipment are some of the biggest causes of industrial noise in the manufacturing industry.[8]

The impact of exposure to environmental noise is disruptive and depends on noise sensitivity.[9] It may cause anxiety, depression, tension, stress, and low self-esteem in some individuals.[10] Occasionally, it is identified as negative emotions associated with stress and the perception of stress. This raises inappropriate coping mechanisms (e.g., alcohol and tobacco use). According to a previous study, exposure to traffic noise could increase stress hormone levels,[11] and induce oxidative stress, which results in cell inflammation.[12] A prior study in Ahvaz City, Iran, revealed a correlation between various types of noise and human disease.[13] The effects of noise on the mind and body are irritability, nervousness,[14] emotional shifts, distraction, rapid heartbeat, changes in breathing rate, high blood pressure,[15] insomnia, and decreased work effectiveness.[16]

The mechanism of environmental noise exposure on the function of the endocrine system (hypothalamus, pituitary, and adrenal)[17] has shown changes in various hormonal levels after noise exposure, such as norepinephrine, dopamine, serotonin, and cortisol.[18] Due to the secretion of hormones, many factors are involved, such as stress and diet. A study found that cortisol could be used as a biological marker of noise exposure and is usually used to assess environmental noise exposure.[19]

The health impacts of environmental noise exposure may cause sleep disturbances and annoyance during daily ac-

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tivities. A long-term accumulation of annoyances will induce stress. Stress affects the production and secretion of stress-related hormones, such as cortisol, and the functioning of various body systems, such as blood pressure, metabolism, and mood. Long-term stress-related hormone stimulation will cause various diseases, including cardiovascular disease, diabetes, high blood pressure, obesity, and others.[20] Sources of environmental noise could be annoying, with varying exposure times, patterns, and effects on those exposed. Therefore, considering the health outcomes of several interrelated variables, holistic information should be gathered regarding both the physical and psychological factors involved.

This study investigated how environmental noise annoyance was related to stress, individual stress perception, and the body's response to stress. Additionally, the result might consider taking advantage of a stress assessment or a cortisol level measurement. The outcomes could be relied upon to be reliable and indicate the severity of annoyance, stress, or ongoing health results. This study aimed to investigate the effects of environmental noise on feelings of annoyance, perceived stress, stress symptoms, and cortisol levels after exposure to various environmental noises. The study outcomes would reveal which environmental noise exposures had the most impact on stress among people. It would be beneficial to make people aware of the long-term health impacts. Planning could be used to conduct surveillance and reduce the impact of noise exposure. Considering legal measures to increase control and punishment, the results are expected to serve to develop an assessment on the effects of noise exposure.

Method

This descriptive study determined the proportion of effects of environmental noise on noise annoyance, stress symptoms, and perceived stress, the statistical correlation of stress symptoms and perceived stress with noise annoyance, and urinary cortisol level. The participants of this study were residents of the Khlong Luang District in communities close to an industrial site on the border of Bangkok. The area is 10–15 kilometers from Don Mueang International Airport and is in the same direction as the airport takeoff and landing. People in the area experienced the aircraft noise at a level which did not pose a risk to their hearing.[21] Residential accommodations included detached houses, row houses, and dormitories or apartments.

Participants were required to meet the following criteria: at the aged of 18–60 years; not having shift work; not experiencing symptoms or receiving treatment for mental illness; not taking a dietary supplement containing omega 6, magnesium, and vitamin A; not receiving other hormones including thyroid, estrogen, and leptin; not taking medications, such as contraceptives, hydrocortisone, and spironolactone; or experiencing an illness during their participation in the study. Consequently, the overall population reached a total of 200 people. An estimate of a proportion in the population was limited.

The Kreicie and Morgan equation was applied to calculate 200 people who met the criteria. A 5% margin of error was included in the proportion estimation at 50%. The number of samples calculated was 132, and 10 people were added for missing data. The total sample size was 142 people. Morgan's table was used to determine the sample size. Urine samples were collected to determine cortisol levels, and questionnaires were used to assess stress levels, symptoms of stress, and annoyance levels from environmental noise exposure.

This study was conducted from April to October 2022. From 7 to 9 a.m., when cortisol secretion peaked, 10 cc of urine was collected from the participants. The samples were delivered to the biochemistry laboratory at the Faculty of Allied Health Science, Thammasat University, Thailand, in a cold container of 2–8˚C. The cortisol was then analyzed by enzyme-linked immunosorbent assay using the standard protocol of PerkinElmer (2012) for urine cortisol analysis (ELISA kit). This method detected the presence of cortisol antigens in urine samples. The method depended on the use of antibodies to identify a specific target antigen through specific interactions between the antibody and the antigen.[22]

The questionnaire was adapted from the standard stress evaluation questionnaire to meet the scope of this study and was evaluated by five experts consisting of researchers and specialists, with two specializing in environmental health, one in stress assessment, one in public health, and one in statistics. The validity test results were obtained as the index of item-objective congruence (IOC) = 0.86, content validity ratio (CVR) = 1, and content validity index (CVI) was greater than 0.8 (relevance 1, clarity 0.97, simplicity 0.96, and ambiguity 0.99).

The questionnaire was tried out with 30 people in a nearby factory to find the reliability (alpha coefficient) of the whole questionnaire, which was 0.935. Three sections were included in the questionnaire: 1) general information, 2) stress evaluation (stress symptoms and perceived stress), and 3) noise annoyance evaluation. The following are details of the stress evaluation and annoyance rating:

a) The stress symptoms scale was designed based on a book entitled Stress Management for Dummies by Elkin.[23] The questionnaire inquired about the frequency of stress-related symptoms, such as headaches, difficulty sleeping or staying asleep, unexplained muscular discomfort, jaw pain, out-of-control anger, and frustration for each selection

made on the rating scale: 0 = never, 1 = sometimes, 2 = often, and 3 = very often;

b) The Perceived Stress Scale was applied to examine stress. The tool was developed by Cohen.[24] The questions asked about experiences and thoughts during the previous month and inquired about each frequency. The alternate scale for each question was 0 = never, 1 = practically never, 2 = sometimes, 3 = quite often, and 4 = very often;
c) Participants completed a self-report of annoyance to assess feelings of annoyance from noise exposure and perceptions of the effects of noise on health and life. Using a 5-point Likert scale with values ranging from "very slightly" to "extremely," Self-Reported Measures asked participants to rate the extent to which they experienced each feeling in response to noise over a specific period.

Result

A total of 142 people (92 males and 50 females) participated in this study, with a mean age of 35.76 years. They had been industrial workers staying near the factory and around the industrial site. They were exposed to environmental noise, including industrial, traffic, community, and aircraft sources of noise. Most of them did not have records of hearing problems, such as otologic illness or hearing loss in the past (94.34%), taking medications for ear infections or experiencing hearing loss (97.18%), or suffering from an auditory or hearing organ injury (94.37%). About 19% of them had hearing problems.

Self-reported annoyance levels of environmental noise and the perceptions of the impacts of environmental noise exposure on health and life are shown in Table 1. Most participants reported only a low level of annoyance from the environmental noise, with an average of 1.5–2.49 of 5 scores. Industrial noise had the highest mean score of noise at 2.13±0.95, followed by traffic noise and community noise at 2.07±0.89 and 1.93±0.82, respectively. While, for the aircraft noise, 1.71±0.73 was the lowest mean score. Most participants felt that environmental noise had little impact on their health and daily life, with average scores of 1.85±1.00 and 1.85±1.01 for health and daily life, respectively.

Table 1. Noise Annoyance Self-Report

	Very Slightly (1)	A little (2)	Moderately (3)	Quite a bit (4)	Extremely (5)	Total	Mean±SD
Aircraft noise	63	58	20	-	1	142	1.71±0.73
Traffic noise	37	70	24	9	2	142	2.07±0.89
Industry noise	39	57	39	2	5	142	2.13±0.95
Communities noise	43	73	21	2	3	142	1.93±0.82
Effect on life	66	41	28	2	5	142	1.87±1.01
Effect on health	63	52	17	5	5	142	1.85±1.00

Note: SD = Standard Deviation

Table 2. Correlation of Stress Symptoms and Perceived Stress with the Annoyance Level of Environmental Noise

	Symptom Stress	Perceived Stress	Annoyance			
			AN	TN	IN	CN
Symptom stress	1.00					
Perceived stress						
r	0.201*	1.00				
p-value	0.02					
AN annoyance						
r	0.16	0.04	1.00			
p-value	0.07	0.61				
TN annoyance						
r	0.236**	0.11	0.534**	1.00		
p-value	0.01	0.22	<0.01		a	
IN annoyance						
r	0.182*	0.11	0.342**	0.467**	1.00	
p-value	0.03	0.19	<0.01	<0.01		
CN annoyance						
r	0.349**	0.199*	0.345**	0.432**	0.465**	1.00
p-value	<0.01	0.02	<0.01	<0.01	<0.01	

Notes: Pearson Correlation (r), * = Correlation is significant at the 0.05 level (2-tailed), ** = Correlation is significant at the 0.01 level (2-tailed), AN = Aircraft Noise, TN = Traffic Noise, IN = Industry Noise, CN = Communities Noise.

The correlation between stress symptoms and perceived stress with noise annoyance scores of each environmental noise source is explained in Table 2. It shows that stress symptoms are correlated with annoyance of traffic noise (r = 0.236, p-value = 0.01), industrial noise (r = 0.182, p-value = 0.03), and community noise (r = 0.349, p-value = 0.05), but not aircraft noise. Only community noise annoyance correlates with perceived stress (r = 0.199, p-value = 0.02). The T-test was applied to compare the level of noise annoyance level between those experiencing normal and high stress. The results showed that participants with normal and high stress experienced different levels of annoyance. Those bothered by the traffic, industry, and community noise showed statistically significant differences (p-value < 0.05) in symptom stress levels. However, there was no difference in stress levels when exposed to aircraft noise.

Regarding stress symptoms and environmental noise annoyance, this study found that they were significantly correlated. In Table 3, community noise annoyance is the most significantly correlated with all symptoms of stress. In addition, industrial and traffic noise has been correlated with some stress symptoms, such as fatigue, headaches, anxiety, eating disorders, and muscle pain. Fatigue and eating disorders were the only two symptoms correlated with aircraft noise annoyance. However, when considering the correlation level, the most significant correlation between noise annoyance and stress symptoms was found to be generally weak. The correlations between community noise with eating disorders (r = 0.481, p-value < 0.05) and difficulty falling asleep (r = 0.403, p-value < 0.05) were moderate.

The correlation between environmental noise annoyance and perceived effects on health and life is shown in Table 4. Participants reported that environmental noise affected their daily lives, with industrial and community noise causing negative health impacts. The results showed that environmental noise annoyance was correlated with the sensation of affecting life: traffic noise (r = 0.234, p-value = 0.11), industrial noise (r = 0.420, p-value < 0.05), and community noise (r = 0.357, p-value < 0.05). The perceived negative health impacted from the environmental noise were correlated with industrial noise (r = 0.386, p-value < 0.05) and community noise (r = 0.276, p-value < 0.05). Industrial noise had the strongest correlation with its effect on life and health.

Table 3. The Correlation Between Each Stress Symptom and the Annoyance Level of Environmental Noise

	Annoyance			
	AN	**TN**	**IN**	**CN**
Headache				
r	0.05	0.12	0.189*	0.319**
p-value	0.56	0.17	0.03	<0.05
Tense muscle, sore neck, and back pain				
r	0.16	0.220**	0.12	0.269**
p-value	0.06	0.01	0.16	<0.05
Fatigue				
r	0.209*	0.238**	0.227**	0.255**
p-value	0.02	0.01	0.01	<0.05
Anxiety, worry, and phobia				
r	0.08	0.245**	0.235**	0.377**
p-value	0.38	<0.05	0.01	<0.05
Difficulty falling asleep				
r	0.10	0.17	0.14	0.403**
p-value	0.25	0.05	0.10	<0.05
Bouts of anger/hostility				
r	-0.01	0.15	0.09	0.291**
p-value	0.96	0.07	0.31	<0.05
Boredom, depression				
r	0.00	0.13	0.208*	0.239**
p-value	0.99	0.14	0.02	0.01
Eating too much or too little				
r	0.216*	0.305**	0.299**	0.481**
p-value	0.01	0.00	0.00	<0.05
Diarrhea, cramps, gas, and constipation				
r	0.12	0.14	0.16	0.270**
p-value	0.18	0.12	0.07	<0.05
Restlessness, itching, and tics				
r	0.04	0.06	0.11	0.314**
p-value	0.61	0.52	0.23	<0.05

Notes: Pearson Correlation (r), * = Correlation is significant at the 0.05 level (2-tailed), ** = Correlation is significant at the 0.01 level (2-tailed), AN = Aircraft Noise, TN = Traffic Noise, IN = Industry Noise, CN = Communities Noise.

Table 4. The Correlation of Environmental Noise Annoyance with Perceived Effects on Life and Health

	Perceived Effect on Life	Perceived Effect on Health	Annoyance			
			AN	TN	IN	CN
Perceived effect on life	1.00					
Perceived effect on helath						
r	0.888**	1.00				
p-value	<0.05					
AN annoyance						
r	0.14	0.11	1.00			
p-value	0.11	0.21				
TN annoyance						
r	0.234**	0.13	0.534**	1.00		
p-value	0.01	0.13	<0.05			
IN annoyance						
r	0.420**	0.386**	0.342**	0.467**	1.00	
p-value	<0.05	<0.05	<0.05	<0.05		
CN annoyance						
r	0.357**	0.276**	0.345**	0.432**	0.465**	1.00
p-value	<0.05	<0.05	<0.05	<0.05	<0.05	

Notes: Pearson Correlation (r), * = Correlation is significant at the 0.05 level (2-tailed), ** = Correlation is significant at the 0.01 level (2-tailed), AN = Aircraft Noise, TN = Traffic Noise, IN = Industry Noise, CN = Communities Noise.

Table 5. Correlations Between Environmental Noise Exposures and Cortisol Level

	Cortisol	Annoyance			
		AN	TN	IN	CN
Cortisol	1				
AN annoyance					
r	0.104	1			
p-value	0.245				
TN annoyance					
r	0.185*	0.534**	1		
p-value	0.037	<0.05			
IN annoyance					
r	0.139	0.342**	0.467**	1	
p-value	0.120	<0.05	<0.05		
CN annoyance					
r	0.165	0.345**	0.432**	0.465**	1
p-value	0.064	<0.05	<0.05	<0.05	

Notes: Pearson Correlation (r), * = Correlation is significant at the 0.05 level (2-tailed), ** = Correlation is significant at the 0.01 level (2-tailed), AN = Aircraft Noise, TN = Traffic Noise, IN = Industry Noise, CN = Communities Noise.

This study observed the physiological response to the annoyance effects resulted by environmental noise by determining a correlation between annoyance and cortisol levels. The results are shown in Table 5. This study found a correlation between environmental noise annoyance levels and urinary cortisol levels. Cortisol was correlated with annoyance caused by exposure to traffic noise only (r = 0.185, p-value = 0.037). While, Table 6 shows the correlation between the perceived effect of environmental noise exposure and cortisol level. Cortisol was significantly correlated with the perceived effects of environmental noise on life (r = 0.255, p-value = 0.003) and health (r = 0.266, p-value = 0.002).

Discussion

Exposure to environmental noise causes feelings of annoyance expressed at the level of annoyance and gives rise to symptoms of stress.[25] Table 1 shows the results of the self-reported annoyance. The results might not accurately represent the level of noise to which a person was exposed but rather their attitude to the noise. Additionally, stress could be attributed to an individual's attitude to or perception of negative effects associated with noise exposure.[7]

Table 6. Correlations Between Cortisol Level and the Concerned Effect of Noise

	Cortisol	Perception of Effect on Life	Perception of Effect on Health
Cortisol	1		
Perception of effect on life			
r	0.255**	1	
p-value	0.003		
Perception of effect on health			
r	0.266**	0.888**	1
p-value	0.002	<0.05	

Notes: Pearson Correlation (r), * = Correlation is significant at the 0.05 level (2-tailed), ** = Correlation is significant at the 0.01 level (2-tailed).

This study showed that industrial noise and traffic noise had the highest average level of annoyance. However, the figure turned out to be lower when considering the average perceived impact on life or health. Therefore, annoyance might result from exposure to noise and negative attitudes to noise. The findings of this study were consistent with the findings of other studies that noise annoyance was classified as a psychological state.[25,26] There were many non-acoustic factors associated with annoyance in different ways.[25] Age, education level, and community size were all the factors that could make noise annoying.[26]

The correlation between noise annoyance and stress symptoms, which are correlated with all noise sources, excluding aircraft noise, is shown in Table 2. This might be due to the fact that participants included in this study did not live in an area directly affected by aircraft noise, thereby excluding the detection of such a correlation. This differed from the findings of other studies showing a significant relationship between stress and aircraft noise.[5,27] Nevertheless, this study revealed that people's stress levels were actually affected by environmental noise, with community noise having the strongest correlation with stress symptoms correlated with perceived stress.

After examining the correlation between stress symptoms and the level of annoyance caused by each source of noise in Table 3, apparently, the strongest association is found between stress symptoms and community noise annoyance. A prior study explained factors contributing to the significant impact of community noise on people's stress.[28] The interactions between neighbors and community members also affected both stress and sleep.[28] This occurred as the community noise did not only disturb sleep or daily life at an intense level but was also accompanied by negative emotions, sentiments, or attitudes.[29]

For example, vulgarity, insults, and cursing make those hearing them more stressed.[30] In addition, symptoms of stress, including fatigue, anxiety, concern, and excessive or insufficient appetite, were associated with environmental noise exposure in this study. Several previous studies also found associations relevant to these symptoms in both physiological and psychological stress responses,[30] including cardiovascular disease,[31] metabolic disorder,[32] cognitive impairment, and sleep disturbance.[7]

For experiencing noise from different sources, several studies found variables affecting noise sensitivity, including residential characteristics, duration, period, or frequency of noise exposure, sex, age,[33] and even the spatial restrictions enforced by industrial zones in residential areas.[34] This study showed that the participants performed a range of annoyance levels that varied from low to moderate. As a result, it was possible that additional factors, for which those variables were not gathered, contributed to its occurrence. However, the study was intended to confirm stress levels through cortisol measures. It was an indicator which could be used to quantify the stress level within the body.[35]

Cortisol has been used to measure stress levels and the effects of noise exposure in the environment. The results presented in Table 5 figure out such a correlation with only traffic noise annoyance. This result differed from other studies that found a correlation between noise from airports,[36] and noise from the community.[37] This might depend on many factors involved, especially the characteristics of different samples and the limited sample size. However, several previous studies revealed that noise exposure affected cortisol levels.[27,29,38-40]

A study in Denmark reported the adverse effects of traffic noise, as the exposure to traffic noise resulted in poor mental health and increased levels of perceived stress.[29] A meta-analysis showed that residential street traffic noise was associated with anxiety and depression, with a 4% higher incidence of depression and anxiety increasing by 12%,[27] which could lead to mental illness.[29] The noise annoyance might mediate the relationship between traffic noise and psychological illness.[38] It had also been correlated with psychotropic drug use,[39] in which noise in a socially susceptible context might lead to substance abuse and be associated with suicide.[40] This study showed that those perceiving that the environmental noise negatively affected their lives and health had a higher cortisol level.

Conclusion

This study has shown that environmental noise annoyance is associated with stress, symptoms of stress, and biological (hormonal) changes in the body. The environmental noise annoyances, such as traffic noise, industrial noise, and community noise, have a significant correlation with stress symptoms. The noise annoyance is the most strongly correlated with the following stress-related symptoms: fatigue, anxiety, concern, and excessive or inadequate appetite. In contrast, perceived stress is the only correlated with community noise annoyance. The correlation between levels of stress and annoyance indicates that people experiencing higher stress levels also have a higher level of annoyance.

Abbreviations

IOC: Item-objective Congruence; CVR: Content Validity Ratio; CVI: Content Validity Index.

Ethics Approval and Consent to Participate

This study is based on a research project approved by the Human Research Ethics Committee of Thammasat University (Science), (HREC-TUSc), COA No. 045/2564.

Competing Interest

The author declared that no significant competing financial, professional, or personal interest might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

All study data are available upon reasonable request to the corresponding author. The identities of the participants remain classified.

Authors' Contribution

NO reviewed literature, conceptual frameworks, and research methodologies, coordinated with the sample group, collected samples, analyzed results, and developed the first draft of the study report. NB and SW participated in the research concept and methodology, including recommendations for noise measures, cortisol collection and analysis, data analysis, and solutions. All authors read and approved the final manuscript.

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