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Association of occupational noise exposure and stress in automotive parts manufacturing workers

Nutthajit Onmek[1], Narisa Kengtrong Bordeerat[2], and Supat Wangwongwatana[1]*

[1] Faculty of Public Health, Thammasat University, Rangsit Campus, Pathum Thani 12121, Thailand
[2] Faculty of Allied Health Science, Thammasat University, Pathum Thani 12121, Thailand

***Corresponding author**:
Nutthajit Onmek
onmekking@gmail.com

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ABSTRACT

The objective of this study was to study occupational noise exposure and personal factors associated with health outcomes, stress, and cortisol levels. This study included 148 automotive parts manufacturing workers. Questionnaires were used to collect general data and assess stress levels. Noise measurements and samples of cortisol in the urine were taken. It is found that the workers exposed to noise ≥80 dBA had more anxiety, concern, phobias, and depression than those exposed to lower levels. Individuals with mental illnesses had higher cortisol levels. Some stress symptoms were associated with higher cortisol levels. People exposed to noise ≥80 dBA showed a higher prevalence of comorbidities related to obesity, cardiovascular disease, and hypertension than those exposed to noise <80 dBA. In conclusion, noise at work has a lower impact on workers than factors such as sex or stress level. However, this study found an association between stress symptoms and perceived stress with loud noise levels. Our findings point to occupational noise exposure as a potential stressor, with its effects exacerbating stress. Caution should be exercised, especially for workers who have personal traits that make them susceptible to stress.

Keywords: occupational noise; stress symptoms; cortisol

1. INTRODUCTION

Noise is defined as unwanted sound (Baneshi et al., 2012), and is present in every human activity. It is classified as occupational noise and environmental noise (the community, residential, traffic, and aircraft), which can impact people's health (Li et al., 2019). Occupational noise refers to any form of noise a worker might experience at work, including sounds from operations such as stamping, punching, bending, or cutting metal. Unlike other loud noises, occupational noise exposure is controlled to not exceed regulatory limits, set at 85 dBA (Azodo and Omokaro, 2019), and if the noise level exceeds this, hearing protection must be used, or there is a time limit for working in those areas. Therefore, exposure to noise in a factory controlled to a legal noise level will not cause hearing loss throughout a worker's lifetime (Sriopas et al., 2017). However, working with machinery noise all day long can be annoying (Lee et al., 2015). The resulting annoyance can cause stress and impact health (Burns et al., 2016).

The mechanisms of noise-induced stress on the body are quite complex. Exposure to low-level noise at work can generate stress (Evans and Johnson, 2000). Noise is considered a stressor, and continuous exposure to low-level noises can be annoying. The annoyance caused by physical factors results in psychological stress. Studies have shown that stress can lead to physiological changes such as higher levels of endocrine and hormonal activity, heart rate, and blood pressure (Pedersen, 2015). As a result, low-level noise exposure not only induces annoyance but also affects the function of the endocrine system (hypothalamus - pituitary - adrenal) (Jafari et al., 2017). In previous studies, various hormonal changes, including norepinephrine, dopamine, serotonin, and cortisol, have been observed after noise exposure (Aydin and Searchfield, 2019; Baudin et al., 2019; Selander et al., 2009). Many factors, such as stress and diet, are involved in hormone secretion, making it difficult to find relationships with noise exposure. Therefore, research on the relationship between hormones and noise exposure has predominantly been conducted through laboratory and animal studies (Amanipour et al., 2018; Daiber et al., 2019; Landegger et al., 2019). Many studies have shown that cortisol can be used as a biological marker of noise exposure and is commonly used to assess exposure to transportation noise and aircraft noise (Barbaresco et al., 2019; Selander et al., 2009). However, determining work-related noise exposure through cortisol as a definitive indicator of stress level remains difficult due to the numerous factors involved. Particularly, exposure to low-level noise has relatively few correlations. As a result, the use of an in-person stress rating scale is still required for assessing noise-induced stress. Stress assessment involves various methods and considerations, as stress is influenced not only by external factors but also by internal factors such as sex, physiological condition, personal factors, and perceptions of stress (Rod et al., 2009; Wardell et al., 2020). Responses to stress may have varying effects on stress levels and the visible signs of stress (Powell and Enright, 2015).

Stress could be assessed by exploring how individuals perceive uncontrollable and unpredictable everyday occurrences, as well as how they navigate and exhibit self-assurance in managing problems and obstacles. Perceived stress characteristics gauge an individual's perceptions and attitudes towards stress management. People respond differently to stress, and their ability to manage stress is influenced by personal traits such as personality, coping resources, and support. Perceived stress reflects an individual's interaction with a stressful environment (Taylor, 2015). When the body experiences stress, whether by psychological or physical factors, it manifests as physiological reactions, such as excessive sweating, increased heart rate and breathing rate, high blood pressure, and changes in brain activity, digestion, and excretion (Chu et al., 2023; Nicolaides et al., 2015; Zefferino et al., 2021). Prolonged exposure to these physiological reactions can lead to stress-related symptoms such as anxiety, sleeplessness, eating disorders, headaches, exhaustion, diarrhea, and more (Graham et al., 2020; Satsangi and Brugnoli, 2018). Consequently, assessing symptoms indicative of stressful conditions, in conjunction with evaluating perceived stress characteristics, may provide insights into an individual’s stress tendency and its effects on their well-being.

Working in a factory can be stressful due to factors such as workload, personal factors, economic concerns, and social aspects. This is particularly true in the automotive parts manufacturing industry, where machinery continuously produces loud noises through processes like grinding, polishing, or stamping. Workers in this environment are at risk of work-related noise, which may cause stress and have long-term health consequences. Consequently, the aims of this study were to investigate the characteristics of occupational noise exposure and the personal factors associated with stress and noise exposure, establishing the connection between stress—indicated by stress symptoms and perceived stress characteristics—with noise exposure at work, and using cortisol levels as an indicator of body stress levels.

2. MATERIALS AND METHODS

2.1 Population

This was a cross-sectional study. The sample size was calculated using the Kreicie and Morgan equation to estimate a proportion within a finite population. The estimated proportion was set at 50%, with an estimation error of 5%. Considering an estimated population size of 200, the calculated sample size was 132 people. To account for potential missing data, the number of collections was increased by 10%. A total of 148 workers from automobile part factory participated voluntarily in this study: 79 in the manufacturing process with various job tasks, including furnace operators, molding equipment operators, and rolling and finishing machines operators, while 69 other workers (working in an office) were exposed to background noise. The subjects were selected using stratified sampling methods from workers, who met the selection criteria.

2.2 Data collection

Data collection was organized into five sections: general information, health examination, stress evaluation, noise measurement, and urine sample collection. The first step involved selecting individuals who met the inclusion criteria. Alongside weight, height, and waist circumference measurements, participants were required to complete questionnaires and stress level assessments. Subsequently, a sound measurement was conducted. Within 9:00 a.m. of the following day after the sound measurement, a urine sample was collected. The operation details are outlined below:

2.2.1 General information

Variables considered in this section include demographic factors such as age and sex, along with health-related factors, including congenital diseases, alcohol consumption, smoking habits, caffeine intake, sleep disorders, psychological conditions, and noise-related factors such as medical history of hearing problems and annoyance experienced due to workplace noise.

2.2.2 Health examination

The health examination included anthropometric measurements of the participants, focusing on weight, height, and waist circumference. Body mass index (BMI) was calculated from the person's weight and height. BMI interpretation for adults (20 years of age and older) followed the standard weight status associated with BMI ranges. The CDC guidelines were applied for determining weight status based on BMI measurements. Waist circumference served as an indicator of visceral fat. A higher risk for developing obesity-related conditions was considered when the waist circumference exceeded 40 inches in men and 35 inches in women (Centers for Disease Control and Prevention, 2022).

2.2.3 Stress evaluation

We examined two dimensions of stress—stress symptoms and perceived stress—using a developed questionnaire.

1) The stress symptoms scale was developed based on the model described by Elkin (2013). The survey included questions about the frequency of stress-related symptoms. Participants were asked to indicate the frequency of each symptom on a rating scale, with response options as follows: 0 = never, 1 = sometimes, 2 = often, and 3 = very often.

2) We utilized the perceived stress scale (PSS) to assess stress levels, a technique developed by Cohen (1994). The survey inquired about participants' experiences over the preceding month, seeking information regarding the frequency of occurrence for each. Participants were instructed to choose the alternate scale for each question: 0 = never, 1 = practically never, 2 = sometimes, 3 = quite often, and 4 = very often.

The validity of the questionnaire was examined (Pezeshki et al., 2017). Face and content validity were evaluated by three experts with experience in the fields of epidemiology, industrial hygiene, and stress evaluation. Reliability testing involved thirty workers from the same factory who met the inclusion and exclusion criteria but were not study subjects. Using the Cronbach's alpha coefficient formula, the correlation coefficient was calculated at a significance level of $p<0.05$. The results from the validity test yielded $\alpha = 0.88$, and the reliability test resulted in $\alpha = 0.82$.

2.2.4 Noise measurement

The noise measurement was designed to assess noise levels during working hours (8 a.m. – 5 p.m.). Class 1 sound level meters, following IEC 61672-1:2002 (International Electrotechnical Commission, 2002) were installed in selected areas to measure Leq8h. Measurement points were strategically placed to cover the area representing the noise exposure of each study group. The noise measurement was scheduled 24 h before urine collection. A 10-min average was used to conduct a noise survey at 148 points within the hearing zone of all participants exposed to continuous noise throughout the day.

2.2.5 Cortisol measurements

A total volume of 10 mL of urine was collected from participants during the morning period, specifically between 7:00 a.m. and 9:00 a.m. Following collection, it was imperative to ship the samples to the laboratory within a cooled container, maintaining a temperature range of 2 to 8 °C. Cortisol levels in urine were analyzed using an enzyme-linked immunosorbent assay (ELISA) kit “LENCE Ultra Cortisol Detection Kit” (2012), which is the standard method for cortisol measurement (Karachaliou et al., 2023).

2.3 Statistical analysis

The data were analyzed using descriptive statistics, an independent t-test, and a chi-square test using IBM SPSS Statistics Version 20.0 for Windows.

2.4 Ethical considerations

This study was based on a research project approved by the Human Research Ethics Committee of Thammasat University (Science), (HREC-TUSc), COA No. 045/2564. The process began by explaining the objectives to the volunteers and obtaining their decision to participate. Participants were provided with an information sheet and a consent form. After signing consent to participate, participants completed questionnaires, and physical examinations, and provided urine samples on the designated days and times. The period for requesting approval to proceed with the data collection was one year, from May 19, 2021 through May 19, 2022.

3. RESULTS AND DISCUSSION

3.1 Noise measurement

The eight-hour average noise measurements were conducted in 16 work areas, encompassing a comprehensive survey for all workers. Results from the eight-hour average noise measurements were consistent. Subsequently, participants were categorized into two groups based on their noise exposure level: the group exposed to noise below 80 dBA and the group exposed to noise at 80 dBA and higher. The recorded noise levels ranged from a minimum of 47.90 dBA to a maximum of 89.50 dBA. In the group exposed to noise levels below 80 dBA, the average noise level was 66.99±9.42 dBA, while the group exposed to noise levels at 80 dBA and above had an average noise level of 83.14±2.53 dBA (Table 1).

Table 1. The t-test compared mean noise measurements between two groups

Variables	Groups	Mean	SD	t-test	*p*-value
Sound level	<80 dBA	66.99	9.42	-9.860*	<0.05
	≥80 dBA	83.14	2.53		

Note: Independent t-test, *$p<0.05$

3.2 General data and level of noise exposure

A total of 91 people were exposed to noise levels below 80 dBA, while 43 participants experienced noise levels of 80 dBA or more, and data from 14 participants were missing. The association between noise exposure levels and personal health data was studied (Table 2). We found that there was an association between noise exposure and certain demographic factors, including sex, waistline, smoking behaviors, and work duration. ($p<0.05$). However, no significant associations were found with alcohol consumption, caffeine intake, sleeping problems, or psychological issues. The level of noise exposure demonstrated a correlation with waist circumference, but no correlation was observed with BMI.

This is consistent with a previous study, which revealed that prolonged noise exposure affected the metabolism and led to obesity (Khosravipour et al., 2020). It was found that waist circumference is influenced by metabolism, whereas BMI reflects blood sugar and metabolism disorders (Li et al., 2021). The research found that people exposed to noise levels above 80 dBA showed a higher prevalence of comorbidities related to obesity, cardiovascular disease, and hypertension than those exposed to noise levels below 80 dBA (Li et al., 2019).

Health outcomes, such as smoking and waist circumference, were associated with noise exposure levels, with a stronger correlation observed among males due to smoking preferences. Furthermore, since men typically have a larger waist circumference than women, as indicated by BMI, their body shape was unrelated to noise exposure. Therefore, it can be concluded that noise exposure in the two groups had no impact on health factors or healthcare outcomes.

Table 2. General information about participants

Parameter		<80 dBA	≥80 dBA	χ^2	*p*-value
Sex	Male	22	70	10.572*	0.001
	Female	25	24		
Congenital disease	Underlying disease	2	15	5.656	0.05
	No underlying disease	42	72		
Drinking behaviour	No drinking	23	42	0.007	0.935
	Drinking	25	47		
Smoking behaviour	No smoking or ex-smoker	39	57	5.805*	0.016
	Smoke	9	36		
Waistline	Normal	43	68	5.536*	0.019
	Obese	5	26		
BMI	Normal or healthy weight	44	85	0.003	0.957
	Overweight/obese	4	8		
Caffeine intake	Have caffeine intake	42	82	0.013	0.908
	No caffeine intake	6	11		
Sleep problem	No sleep problem	37	70	0.117	0.732
	Have sleep problem	11	24		
Psychology problem	No psychology problem	43	84	0.002	0.968
	Have psychology problem	5	10		
Work duration	3 years and over	29	54	8.281*	0.004
	Less than 3 years	35	24		

Note: Chi-square test, *$p<0.05$.

The results of the medical history of hearing indicated an association between hearing problems and the level of noise exposure ($p<0.05$), but no significant association was found with other hearing-related illnesses and injury factors (Table 3). Production workers demonstrated a higher susceptibility to noise exposure, compared to office workers, with reported instances of sore ears and hearing problems. Long-term exposure to loud noise can result in tinnitus and hearing loss (Themann and Masterson, 2019). It was found that groups exposed to noises louder than 80 dBA had more hearing problems. These individuals exhibited the behavior of wearing protective equipment and expressed greater annoyance with noise exposure compared to those exposed to low-level noises.

Table 3. The medical history of hearing

Parameter		<80 dBA	≥80 dBA	χ^2	*p*-value
Otologic illness or hearing loss in the past	Yes	2	6	1.288	0.256
	No	61	73		
Used medications for ear infections or suffered hearing loss	Yes	1	3	0.625	0.429
	No	62	76		
Suffered an auditory or hearing organ injury	Yes	2	6	1.288	0.256
	No	61	73		
Had hearing problems	Yes	3	24	15.522*	< 0.05
	No	60	53		

Note: Chi-square test, *$p<0.05$

3.3 Occupational noise exposure

The feeling of annoyance from workplace noise was statistically associated with occupational noise exposure ($p<0.05$). Individuals working in areas with noise levels greater than 80 dBA reported higher levels of annoyance than those in areas with lower noise levels (Table 4). This difference can be attributed to the fact that workers exposed to noise levels exceeding 80 dBA worked in production areas where noise was consistently generated, making noise more annoying. In such areas, it was necessary for workers exposed to loud noise to wear personal protection equipment, unlike office workers who were not in direct proximity to noise sources.

Table 4. Occupational noise exposure

Parameter		<80 dBA	≥80 dBA	χ^2	*p*-value
Feel annoyed by the noise from work	Yes	16	52	6.790*	0.009
	No	32	40		

Note: Chi-square test, *$p<0.05$

The comparison of the stress within the sample group revealed no statistically significant difference in stress symptoms or perceived stress between participants who were exposed to workplace noise levels above 80 dBA and those who were exposed to noise levels below 80 dBA (Table 5). This observation can be attributed to two crucial factors: the noise level of both groups was not excessively loud to the extent of being detrimental to hearing or influenced stress. A study suggested that noise levels above 90 dB(A) had a considerable effect on tension and stress hormones (Khosravipour et al., 2020). In addition, numerous studies have found that, beyond noise, other significant factors affecting stress include personal factors (Juster et al., 2016) and work-related factors (Lundberg and Frankenhaeuser, 1999). Therefore, in this study, due consideration was given once more to each stress characteristic associated with noise exposure.

Table 5. Correlations between occupational noise exposure level and stress

Stress level	Groups	Mean	SD	t-test	*p-value*
Symptom stress	<80 dBA	21.91	8.09	1.284	0.20
	≥80 dBA	20.09	7.97		
Perceive stress	<80 dBA	14.50	5.65	0.397	0.69
	≥80 dBA	14.11	5.13		

Note: t-test, *$p<0.05$

3.4 Noise exposure level and stress symptoms

People exposed to noise levels of 80 dBA or greater exhibited a statistically significant ($p<0.05$) increase in boredom or depression compared to those exposed to noise levels of less than 80 dBA (Table 6). Consistent with previous research, exposure to low levels of noise has been linked to psychological effects such as depression, anxiety, annoyance, and alteration in the levels of stress hormones in the body (Hahad et al., 2019). Moreover, it has been associated with stress-related symptoms, including headache, dizziness, irritation, stress, fatigue, high blood pressure (Yadav et al., 2021), sleep disruptions (Bevan et al., 2019), cognitive impairment (Münzel et al., 2018), and dementia in adults (Hegewald et al., 2020). This mental and physical condition has also been associated with a rise in poor coping behaviors, such as alcohol and tobacco use, which negatively impact health (Hahad et al., 2019).

Therefore, stress can stimulate the autonomic nervous system, endocrine signaling, and inflammation. The stress mechanism induces inflammation and oxidation by stimulating nicotinamide adenine dinucleotide phosphate oxidase, leading to the dissociation of nitrate synthesis on endothelial and nerve cells. It induces dysfunction in the endothelium and nerve cells, resulting in cardiac diseases (Hahad et al., 2019). In addition, nighttime exposure to loud noise was found to elevate stress hormone levels and oxidative stress in the blood vessels (Münzel et al., 2018). Consequently, this disruption interrupts sleep at night, causing daytime drowsiness that affects mood and interpersonal relationships (Basner et al., 2014).

Stress induced by even low levels of noise, such as that from speaking, can affect office workers, even if they are not directly exposed to the noise generated by production machinery. Stress hormones, including cortisol and noradrenaline, were found to change plasma concentrations in response to noisy speech during concentration-demanding work. This alteration influences the heart rate variability (HRV), leading to an increase in blood pressure and causing disruption due to noises and fatigue. Notably, working while engaged in speech was more stressful and resulted in greater physiological stress than working in other noisy environments (Radun et al., 2021).

3.5 Expression of cortisol on personal factors, work factors and stress

Cortisol levels exhibited a statistically significant correlation among people with mental health issues or those taking psychotic symptom-treating drugs, as demonstrated by the chi-square correlation test (χ^2 = 4.842, $p<0.05$). However, other personal factors did not show an association with cortisol levels. In comparison to a group of people with normal and high cortisol levels, using factors related to stress symptoms and perceived stress, the results showed statistically significant difference in cortisol levels among those with "anxiety, worry, phobias, and problems that accumulate more and more until you cannot handle them all" ($p<0.05$). Those with normal cortisol levels had a negative correlation with the positive question, feeling capable of dealing with whatever comes can be distracting (χ^2 = -0.217, $p<0.05$). The lower the score on the positive question, the greater the level of cortisol.

There was no association found between office workers and production workers exposed to low noise levels. Cortisol was not found to correlate with age and BMI (Jafari et al., 2021), which aligns with the findings of this study. Exposure to excessive noise levels has direct effects on both physical and mental stress. However, the results of this study indicated that the effect on the cortisol level correlated with certain symptoms of stress and perceived stress characteristics, including anxiety, worry, phobias, and the feeling of accumulating problems until they become overwhelming. This correlation was statistically significant. These results suggested that cortisol levels are more influenced by psychological stress than physical stress resulting from exposure to occupational noises. It may be concluded that exposure to low levels of occupational noise primarily has psychological effects. The work environment, organizational culture, co-workers, or workload may have a greater psychological effect. Consequently, there was no detectable change in cortisol levels among workers exposed to varying levels of noise when stress hormone levels were evaluated. This differs from the impact observed when exposed to environmental noise.

Table 6. Comparison of stress symptoms at different noise exposure levels

Stress symptom	Groups	Mean	SD	t-test	*p*-value
Headaches	<80 dBA	2.35	1.15	0.03	0.98
	≥80 dBA	2.35	1.33		
Tense muscles, sore neck and back	<80 dBA	3.04	1.36	0.63	0.53
	≥80 dBA	2.88	1.40		
Fatigue	<80 dBA	2.92	1.34	0.15	0.88
	≥80 dBA	2.88	1.48		
Anxiety, worry, phobias	<80 dBA	1.92	1.21	1.90	0.05
	≥80 dBA	1.52	0.94		
Difficulty falling asleep	<80 dBA	2.03	1.26	- 0.06	0.95
	≥80 dBA	2.05	1.33		
Bouts of anger/hostility	<80 dBA	2.22	1.24	1.53	0.13
	≥80 dBA	1.88	1.05		
Boredom, depression	<80 dBA	1.82	1.17	2.24*	0.03
	≥80 dBA	1.37	0.85		
Eating too much or too little	<80 dBA	1.99	1.24	1.00	0.32
	≥80 dBA	1.76	1.24		
Diarrhea, cramps, gas, constipation	<80 dBA	1.61	0.81	- 0.86	0.39
	≥80 dBA	1.76	1.11		
Restlessness, itching, tics	<80 dBA	1.43	0.88	- 0.48	0.63
	≥80 dBA	1.51	1.01		

Note: t-test, *$p<0.05$

4. CONCLUSION

The noise exposure in the two groups had no impact on health factors or care outcomes. However, noise levels exceeding 80 dBA were associated with increased hearing problems. Individuals in this group wore hearing protection and reported higher levels of annoyance, compared to those exposed to low-level noise. Interestingly, noise exposure did not correlate with stress symptoms or perception. Nevertheless, workers exposed to noises above 80 dBA exhibited significantly distinct symptoms of stress.

There was no statistically significant correlation found between cortisol levels and occupational noise exposure levels. This study showed that, while occupational noise levels had some effect on stress, the majority of stress could be due to psychological effects. When evaluating stress hormone levels, there was no detectable change in cortisol levels among subjects exposed to varying levels of noise. However, the research results revealed a significant correlation between cortisol levels and symptoms of stress and perceived stress, including anxiety, worry, phobias, and the feeling of problems accumulating to an unmanageable extent.

This study did not uncover significant biological or physiological changes, resulting from occupational noise exposure. The similarity between the two study groups may pose a minimal risk, potentially explained by the adherence to noise exposure regulations in workplaces with an average 8-h noise exposure below 85 dBA. Workers exposed to excessive noise must wear protective equipment, engage in hearing prevention practices, and participate in hearing conservation programs. Consequently, workplace noise appears to have a lesser impact on workers, compared to personal factors such as sex or stress. As a result, it is difficult to determine the health effects, resulting from fluctuations in cortisol levels in the body due to low-level noise at work. However, this study found a statistically significant association between stress symptoms and noise exposure, boredom, and depression. By suggesting the possibility of establishing indicators to identify people who are more sensitive to workplace noise and more susceptible to stress, the study's findings can serve as a valuable framework for assessing workers' stress levels. It is essential for workplaces to implement suitable measures aimed at reducing both physical and mental risk factors within the work environment to prevent and monitor stress and long-term health effects among workers.

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