

ENVIRONMENTAL NOISE EXPOSURE AND HYPOTHALAMIC–PITUITARY–ADRENAL AXIS DYSREGULATION IN PETROL PUMP ATTENDANTS: A BIOMARKER-DRIVEN CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Environmental noise most common occupational and ambient health hazard and a challengeable in a workplace hazard that can lead to serious health concerns beyond hearing loss. One major mechanism is the triggering of the hypothalamic-pituitary-adrenal (HPA) axis. Petrol pump workers are continuously affected by the trafficnoise; less research was found how body response physiology. This research was done to evaluate whether exposure to environmental noise can cause the dysregulation of the HPA axis, with the use of salivary cortisol as the indicator of stress.

Methodology: Conducted a cross-sectional survey among 140 petrol pump workers located in and around the city of Puducherry. The workers were divided into 2 categories: high exposure (>85 dB, n=70) and low exposure (<85 dB, n=70). Noise levels of the environment were assessed by a noise meter. Hearing screening tests were performed using audiometry. Salivary cortisol specimens were taken from 06:30 to 07:00 AM after oral instructions were given and then analysed through enzyme immunoassay. The Mann Whitney U test, independent t-test, and Spearman's correlation were employed for the statistical evaluation.

Results: There were no significant differences ($p>0.05$) between the high and low exposure groups in baseline characteristics such as age height weight, and BMI. But, median salivary cortisol levels of the high-exposure group [49.7 (34.272.1) μ /dL] were significantly higher than those of the low-exposure group [25.4 (18.738.3) μ /dL] ($p<0.001$). Besides, a strong positive correlation between noise levels and cortisol ($r =0.841$, $p=0.036$) indicated a dose-response relationship.

Conclusion: This study reveals a marked correlation between high-level environmental noise exposure and raised salivary cortisol levels, which implicates the activation of the HPA axis. The results point to occupational noise as a stressor that triggers physiological changes and call attention to the necessity for specific measures and long-term studies to reduce the health hazards of workers exposed to noise.

KEYWORDS: Occupational noise, Salivary cortisol, Physiological changes, Hypothalamic pituitary adrenal.

INTRODUCTION

Environmental noise has become the most common occupational and ambient health hazard and is particularly important in the context of rapid urbanization and industrialization. In addition to the already well documented auditory effects, there is an increasing body of evidence documenting significant non-auditory health outcomes of chronic noise exposure, including cardiovascular disease, sleep disruption and psychological stress. Environmental and occupational noise is established as a chronic environmental stressor capable of activating neuroendocrine-mediated physiological stress responses [1]. An explanation for many of these effects lies with the activation of the hypothalamic-pituitary-adrenal (HPA) axis, this being one of the bodies primary neuroendocrine systems responsible for stress regulation. The HPA axis becomes activated during exposure to noise stimuli as the hypothalamus in the brain releases corticotropin releasing hormone (CRH) which causes the pituitary gland to release adrenocorticotrophic hormone (ACTH), which stimulates the cortex in the adrenal gland to secrete cortisone, better known as the primary stress hormone. Cortisone maintains homeostasis, but abnormalities have been known to cause several health problems; both mental and physical. [2]A number of epidemiological and experimental studies have examined the effects of noise exposure on the HPA axis using

biomarkers such as serum or salivary cortisol. In general, the evidence provides support that noise exposure may impact on cortisol secretion and by implication physiologic stress. For instance, the results of a meta-analysis of population-based studies indicated that environmental noise pollution has the potential to disturb hormone determination whereas through the activation of the sympathetic-adrenal-medullary (SAM) system and the HPA axis with cortisol measurement as an outcome variable [3]. Results from a systematic review of occupational environments yielded similar findings that there was significant evidence between noise and cortisol [4]. The healthy subjects on the relationship between the cortisol concentration in different compartments of the body. This will help understand how the hormone level is related between the compartments, as well as how it changes according to the age and sex of the person.[5]There is inconsistency concerning noise-induced increased levels of cortisol in relation to HPA activation, which may be attributed to variations in the characteristics of noise, such as volume, time frame, exposure period, and individual susceptibility. The exposure of workers from different industrial sectors, such as mining industry, to excessive amounts of sound has the potential to cause adverse effects on their health, including noise-induced deafness as well as raised cortisol levels. Research indicates that long-term exposure to sound within industrial settings increases the amount of cortisol in the urine of affected workers [6].Petrol pump operators are constantly exposed to intense environmental noise, but very little research has been carried out with respect to the measurement of their physiological stress responses. [7]. By combining evaluation of environmental exposure with this biological marker we can more accurately elucidate the mechanisms underlying noise-related health outcomes. Thus, the present study has been planned to in order to establish an association, if any exists between environmental noise exposure and dysregulations of the HPA axis, by means of a biomarker driven in saliva, cross-sectional study among petrol pump attendants.

METHODS AND MATERIALS

Study Design: A cross-sectional analytical study was carried out in and around Puducherry, India from January 2023 to January 2024, to investigate the relationship between noise pollution from petrol pump attendants and disruption of the hypothalamic pituitary adrenal axis. The area of study included petrol pumps on high motor vehicular traffic flow roads and comparatively of those located in low traffic flow areas.

Study Population and Sampling: The study sample consisted of petrol pump attendant workers who met the selection criteria. A cross-sectional study design was used, including 140 participants, who were divided into two groups according to their level of occupational noise exposure. The present study formed part of a larger research thesis assessing the bio-psycho-physiological effects of long-term noise exposure. The sample size was calculated as 140 participants (70 in each group).

Group A (high-risk group) consisted of workers exposed to noise levels greater than the permissible limit (>85 dB over 8 hours) and engaged in duties at petrol and diesel pumps located on high-traffic roads for more than 8 hours per day.

Group B (low-risk group) included workers exposed to noise levels below 85 dB and working at petrol and diesel pumps located on low-traffic roads for more than 8 hours per day.

Participants were selected based on occupational exposure status and eligibility criteria. Written informed consent was obtained from all participants.

Inclusion and Exclusion Criteria: Inclusion criteria for the subjects were age between 25-45 years, a job service period of 5 to 10 years and daily work which lasted more than 8 hours, had been exposed to occupational noise and been healthy with no clinical abnormality. A Clinical history was elicited from each subject which included a history of any serious hearing impairment, Ear discharge or vertigo, subjects who smoked or who were regular drinkers of alcohol, those on hormonal or long-term drug therapy, in the presence of chronic diabetes, pressure emphysema, other endocrine disorders, known neurological disorders, in the midst of psychiatric therapy, subjects with hypersensitive hearing were excluded. To avoid confounding we have the sample of early morning after 12 hours of fasting.

Ethical Considerations: The study was carried out after getting approval from the Institutional Ethics Committee of Indira Gandhi Government General Hospital and Postgraduate Institute, Puducherry.

Ethics Committee details:

Name of the Institutional Ethics Committee/Independent Review Board: Indira Gandhi Government General Hospital and Postgraduate Institute, Puducherry

i. Approval Ref. No: Approval No. GHSAC/2020

ii. Date: 18.11.2020

Informed consent/assent: Written informed consent was obtained from the study participants. Status of confidentiality and anonymity to the study participants was maintained through coding of personal identifiers.

Study Tools and Data Collection

1. Environmental Noise Assessment: Environmental noise levels were quantified at each location using a calibrated noise measurement instrument (Noiseometer). Measurements were taken during working hours to assess for actual job exposure levels.Noise levels were reported as decibels (dB) and averaged over the course of a work day (8 hours) to evaluate against permissible exposure limits.

2. Pure tone audiometry testing was used to evaluate hearing, screening for severe hearing loss. Subjects identified with significant hearing impairment were excluded from further testing to prevent potential confounding factors.

3. Measurement of cortisolSalivary cortisol was measured to evaluate hypothalamic-pituitary-adrenal (HPA) axis activity, as saliva collection is a simple, non-invasive, and reliable method for assessing cortisol secretion. Salivary cortisol reflects the biologically active, free fraction of circulating cortisol and is therefore widely used as a biomarker of stress-related HPA axis function.

Sample Collection Protocol: Saliva samples were collected between 06:30 and 07:00 hours following an overnight fast of 12 hours. The samples were obtained early in the morning to capture peak cortisol secretion and to provide a

standardized measure of basal HPA axis activity. This timing was selected to facilitate the assessment of cortisol levels in relation to chronic stress while minimizing variations due to diurnal fluctuations in cortisol secretion.

Pre-Collection Instructions

Instruction to the Study participants:

- Study participants were instructed to avoid intake of sugar, acidic foods, caffeine, alcoholic beverages or medication at least 12 hours before sampling.
- Study participants are advised not to perform any strenuous activity for 12 hours prior to the sample collection
- Study participants were asked not to brush teeth or eat a complete meal or drink liquids 60 minutes prior to sampling.
- Study participants are advised to rinse the mouth with water and then wait for 10 minutes prior to sample collection.
- Study participants are instructed to maintain a record of food consumption and physical activity before sampling and maintains a record of oral conditions before sampling.

Post-Collection Handling: Following collection, the saliva samples were refrigerated and subsequently stored at freezing temperatures until laboratory analysis was performed.

Laboratory Analysis: Salivary cortisol concentrations were measured quantitatively using a regular enzyme immunoassay (EIA) procedure. All assays were conducted using procedures provided by the manufacturers.

Data Management and Quality Control: All data were collected using a structured pro forma. Instruments were calibrated before use, and standard operating procedures were followed during laboratory measurement and data collection. Data quality was assured through validation, checking, and monitoring.

RESULTS

A total of 140 occupationally noise-exposed workers, specifically petrol pump attendants, were included in the study. The study population consisted of an equal number of male and female participants (50% each). The study groups were comparable with respect to baseline demographic and anthropometric characteristics, including age, height, weight, and body mass index (BMI), with no statistically significant differences observed. All participants were healthy young adults with normal hearing, as confirmed by audiometric examination, and had a mean range of 20.5 ± 2.7 dB Salivary cortisol levels were measured as a biomarker of hypothalamic–pituitary–adrenal (HPA) axis activity. A statistically significant difference in salivary cortisol levels was observed between the groups, suggesting a potential association between occupational noise exposure and physiological stress response.

Table 1: Comparison of baseline characteristics and salivary cortisol levels between high and low noise exposure groups

Variable	Group	Median (Q1-Q3)	MW test	p-value
Age (years)	High risk (n=70)	36.5 (35-38)	2795.5	0.145
	Low risk (n=70)	35.5 (34-37)		
Height (cm)	High risk (n=70)	156 (152-159)	2160	0.226
	Low risk (n=70)	157 (153-162)		
BMI (kg/m ³)	High risk (n=70)	27.99 (24.34-31.63)	2889	0.068
	Low risk (n=70)	26.71 (24.01-29.12)		
Weight (kg) Mean	High risk (n=70)	58	t=1.137	0.258
	Low risk (n=70)	60		
Salivary Cortisol (µg/dL)	High risk (Group A)	49.7 (34.2-72.1)	3941	<0.001
	Low risk (Group B)	25.4 (18.7-38.3)		

As Table 1 shows the Comparison of the baseline characteristics between high-noise exposure group (Group A) and low-noise exposure group (Group B) showed that the differences in age ($p=0.145$), height ($p=0.226$), body mass index ($p=0.068$), and weight ($p=0.258$) were all statistically insignificant. This suggests that the two groups were well-matched for demographic and anthropometric variables such that the confounding effects are likely to be minimal.

On the other hand, salivary cortisol levels were significantly different between the two groups as per statistics ($p < 0.001$). The median cortisol level in the high-risk group was significantly higher than that of the low-risk group. This is a remarkable indication that the higher levels of environmental noise result in an increased physiological stress response, thus showing a possible HPA axis dysfunction due to chronic noise exposure.

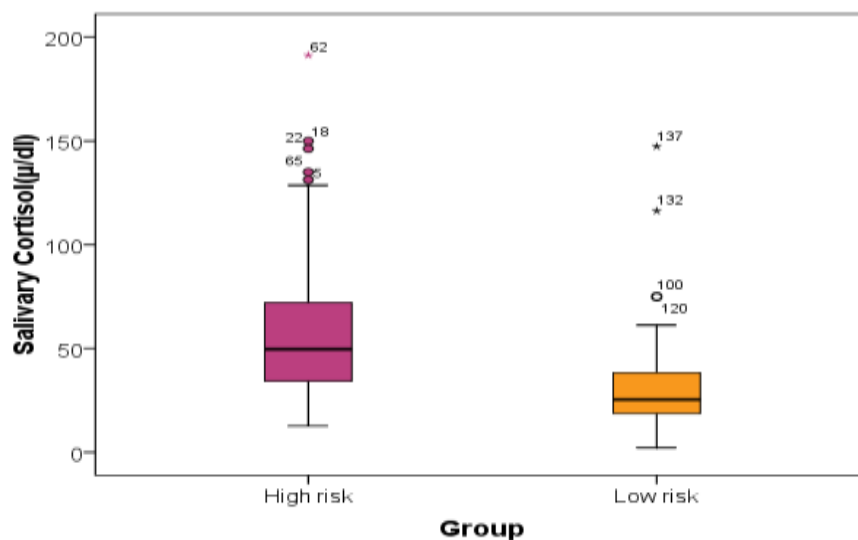


Figure 1: Comparison of salivary cortisol levels between high- and low-noise exposure groups

Participants who were exposed to road noise of high-risk group having a median with interquartile range of salivary cortisol level that is 49.7 (34.2 - 72.1) $\mu\text{g/ml}$, which is higher than the 25.4 (18.7 - 38.3) $\mu\text{g/ml}$ found in the low-risk group (Figure 1). The high-risk group also has a wider interquartile range, meaning that there were bigger differences in cortisol levels among those individuals who were exposed to higher noise levels. Both groups have a few outliers, but more extreme values are found in the high-risk group, which points to stronger physiological stress responses in some individuals. Besides, Spearman's rank correlation analysis revealed a significant association between environmental noise levels [LeqdB(A)] and the concentration of cortisol in saliva ($r=0.841$, $p=0.036$). This significant relationship statistically proves that as noise exposure increases, cortisol levels also rise, which is consistent with the role of chronic environmental noise as a stressor at the physiological level. These results not only visually but also statistically back up the assumption that the noise to which petrol pump workers are exposed at work may lead to alteration of the HPA axis.

DISCUSSION

The present study investigated the association between environmental noise exposure and changes in hypothalamic–pituitary–adrenal (HPA) axis activity in petrol pump attendants by assessing salivary cortisol levels. The results showed a highly significant increase in the cortisol levels of the workers exposed to very high noise levels (>85 dB) compared to those exposed to lower noise levels (<85 dB). Furthermore, a substantial positive correlation was found between the average continuous noise levels [LeqdB(A)] and cortisol levels ($r=0.841$, $p=0.036$) which may imply a dose response relationship between environmental noise and physiological stress. Environmental noise is considered to be a chronic stressor which can lead to the stimulation of neuroendocrine systems, specifically the HPA axis. This paper's finding of increased cortisol levels in the high exposure group aligns with the biological stress model, where noise acts as a non-specific environmental stressor leading to the release of corticotropin-releasing hormone from the hypothalamus and the opening of the HPA axis. Moreover, research up to now has shown that one of the ways in which environmental noise may be responsible for non-auditory health effects is through stress-mediated pathways. The marked difference in salivary cortisol between the high- and low-risk groups in this study is supported by previous occupational and environmental research. For example, Eriksson et al. (2019) showed that people living around airports with higher aircraft noise revealed changes in cortisol secretion patterns, a hallmark of chronic stress activation [3]. Likewise, a systematic review by Skogstad et al. (2016) found that occupational exposure to noise is often linked to an increase in cortisol levels; however, there is still some heterogeneity among studies that depends on exposure characteristics and individual factors. [4] Besides, the very strong positive correlation found in this study is a solid piece of evidence supporting the idea that with increase in noise level there is a greater activation of the HPA axis. This is supported by other studies that found a dose response relationship between environmental noise and stress-related biological markers. Ising and Kruppa (2004) pointed out that constant exposure to loud sounds might result in the long-term activation of stress mechanisms and therefore may cause health problems such as hypertension, metabolic disorders, and psychological problems. Importantly, not finding statistically significant differences in baseline characteristics such as age height weight, and body mass index between the two groups enhances the study's internal validity [7]. Community noise research has focused on measuring stress hormone responses using urine and blood analyses (Babisch 2003; Babisch et al. 2001; Dallman 1993; Evans et al. 2001; Maschke 2003; Miki et al. 1998; Pruessner et al. 1999; Schulz et al. 1998) [8,9,10,11,12,13,14,15]. The assessment of cortisol in saliva is relatively simple, accurately measures free cortisol concentration in the bloodstream (Hofman 2001) [16], and has been employed recently in a number of studies assessing exposure to road and aviation noise (Poll et al. 2001; Stansfeld et al. 2001; Waye et al. 2003) [17,18,19]. Salivary cortisol as a biomarker is a major strength of this work. Besides, the fixed timing of sample collection (early morning) helped in reducing the cortisol levels' natural variation over the day, hence increasing the reliability of the cortisol measurement. These procedures follow the standard protocols used in environmental health research (Hwang & Chan, 2017) [20]. Nonetheless, there are some limitations that need to be considered. A cross-sectional study design is not very helpful in determining the relationship between noise exposure and

hormonal (HPA axis) imbalance. In our study, cortisol was measured at early morning after 12 hours fasting to assess chronic stress patterns. Besides, confounding factors such as psychosocial issues, sleeping disturbance patients, during menstruation in female were excluded in our study. Nevertheless, the findings highlight the importance of occupational health in this context. Petrol pump attendants represent an exposed and often neglected occupational group who are continuously subjected to environmental noise generated by vehicular traffic. The observed association between noise exposure and elevated salivary cortisol levels suggests that this group may be more susceptible to physiological stress. These results emphasize the need for preventive measures, including effective noise control strategies, regular health monitoring, and improved workplace safety practices. In conclusion, this study indicates that chronic exposure to environmental noise is associated with increased salivary cortisol levels, reflecting a possible disruption of hypothalamic–pituitary–adrenal (HPA) axis function among petrol pump workers. The positive association between noise exposure and cortisol further supports the concept of environmental noise as a physiological stressor. Long-term studies incorporating additional biomarkers and psychosocial factors are needed to better establish causal relationships and to inform occupational health interventions.

CONCLUSION

In this study, we show, for the first time, that environmental noise exposure can be related to the activation of the hypothalamic pituitary adrenal (HPA) axis in petrol pump attendants. Those who were exposed to greater noise levels (>85 dB) had significantly higher concentrations of salivary cortisol than those who were exposed to lower noise levels, thus resulting in increased physiological stress. Additionally, the high positive correlation between noise levels [LeqdB(A)] and cortisol demonstrates a dose-response relationship, further confirming the role of environmental noise as a chronic stressor. This study points out that it is essential to take into account the non-auditory effects of noise on health, especially the neuroendocrine changes, in occupational environments where noise exposure is continuous. With regard to public health, petrol pump attendants are an occupational group that is vulnerable to stress-related health issues due to their habitual exposure to traffic noise. Long-term studies on causal relationships and health effects of chronic noise exposure would greatly benefit from repeated biomarker measurements and including more psychosocial and environmental variables. This should be the focus of future research.

LIMITATIONS

- The study's cross-sectional design prevents us from definitively saying that noise exposure causes changes in the HPA axis.
- Only morning salivary cortisol sample was taken, so we circadian variation of cortisol was missed to check or typical stress levels.
- Besides, we didn't really take into account other factors that could have influenced the results like the level of psychosocial stress, sleep quality, dietary habits, and work-related stress.
- We can't say for sure that changes in cortisol levels and the stress response are due to individual differences since we didn't have a full control over them.
- Noise exposure was estimated using area-level rather than personal dosimetry measurements, which probably do not provide a very accurate picture of individual exposure.
- Moreover, the study only looked at a certain occupational group (petrol pump attendants) from a single geographic region, so the findings might not apply to other groups.
- Besides, the sample size, although sufficient, may still be unable to represent the population at large in general.

RECOMMENDATIONS

- Noise control methods can work well at petrol pumps, particularly in areas of heavy footfall (e.g. barriers engineering controls, traffic management).
- Start regular occupational health screening programmes, which should involve monitoring of stress biomarkers such as salivary cortisol.
- Leverage health education and awareness programmes to emphasize the non-auditory health effects of noise exposure.
- Promote the adoption of personal protective methods in situations where this is possible.
- Later research ought to make use of longitudinal designs to prove causal relationships.
- Integrate multiple cortisol samples to analyze the daily changes and long-term stress patterns.
- Apply personal noise dosimetry for better precision in exposure measurement.
- Future studies should consider measuring psychosocial, behavioural, and lifestyle factors.
- Conduct studies on larger and more heterogeneous samples to enhance generalizability.

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