THE EFFECTS OF NOISE-SENSITIVITY ON YOUNG MOTORCYCLIST’S SALIVARY CORTISOL: A CONTROLLED EXPERIMENT

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Abstract. Noise sensitivity determines the cortisol reactivity towards high noise exposure which imparts the detrimental effects on the health. Motorcycle riders are similarly exposed to chronic noise exposure (< 90 dBA) on daily basis therefore this study aimed for an explorative controlled experimental study to monitor the difference in noise sensitivity and its relation to cortisol reactivity. A total of three hundred and one undergraduate students (aged 19-25 years) participated in determining the noise sensitivity (Weinstein Noise Sensitivity Scale, WNSS). WNSS scores categorized participants into low (L-NS) and high noise sensitive (H-NS) group. Later, 60 participants volunteered, (43 male and 17 females) from L-ns (n = 30) and H-ns (n = 30) groups to participant in laboratory experiment. Saliva was collected through passive drool technique before and after noise intervention. Saliva samples were measured in triplicate via enzyme immunoassay (EIA) method by using the high sensitivity human salivary cortisol-ELISA (enzyme-linked immunosorbent assay) kit (Salimmetrics, USA). Statistical analysis determined significant difference in salivary cortisol levels in the H-NS group before (M = 0.16 µg/dl, SD = 0.10) and after (M = 0.21 µg/dl, SD = 0.11) the high noise intervention (p < 0.05); whereas no significant difference (p > 0.05) was found in cortisol response in the L-ns group before (M = 0.22 µg/dl, SD = 0.12) and after (M = 0.20 µg/dl, SD = 0.09) controlled noise exposure. This study suggests that subjective noise sensitivity plays an important role in increasing salivary cortisol concentrations among high noise sensitive riders (H-NS). This study provides the baseline for future investigations regarding motorcyclist's physio-psychological health.

Keywords: Noise, Salivary cortisol, Noise sensitivity, Motorcycle.

Introduction. The motorcycle is one of the noisiest forms of transportation where riders are exposed of excessive noise ranging from 90 dBA at 45 mph and increases up to 110 dBA at 100 mph.1 Noise is an unwanted environmental stressor which generates the psychological and physiological reaction. The feeling of unpleasantness and nuisance tends to activate the hypothalamus-pituitary-adrenal (HPA) axis which stimulates the glucocorticoid hormone known as cortisol.2,3 Cortisol as a stress indicator plays a vital role in regulating metabolism and homeostasis process and initiating adaptive processes for beneficial energy.4 But chronic stressors leads to long-lasting activation and such prolonged secretion becomes harmful, resulting in risk factors for diseases.5 The adverse effects of cortisol involves physiological and psychological reactions including: hypertension, fatigue, sleep disturbances, aggression, annoyance, memory deficits, communication complications and with long-standing leads to advanced health issues.6

Methods of cortisol measurement includes saliva, urine or blood plasma. In daily activities, the level of cortisol concentration in saliva is found to be sensitive towards acute stressors such as noise.7 Saliva cortisol provides an assessment which is plasma-free cortisol concentration and considered as a biomarker of a stress reaction to noise exposure.8 In field studies such as noise research, the collection procedure of saliva samples are feasible, easy to handle with noninvasive and standardized method including passive drool technique,9 and oral swabs.10 Studies related to noise-induced cortisol secretion have been conducted on occupational,9 road and rail traffic noise,9 air traffic noise11 motorcycle noise exposure field study11 and some laboratory based experimental studies.12 The method of investigation ranged from the average level of cortisol at specific times of the day (diurnal rhythm),8 to the CAR (cortisol awakening response)9 and through differential effects.11

Noise sensitivity, plays a vital role as a predictor and moderator of health outcomes and well-being.10-13 According to Job (1999) described noise sensitivity as a personal trait (e.g., physiological, psychological, attitudinal) which may increases an individual’s susceptibility and vulnerability to noise reaction which acts as a confounding variable.14,15,16 The noise sensitivity determines the attitude and perception given to any noise stimulus for subsequent physiological and psychological reaction. Noise sensitivity can be measured through subjective measures such as structured questionnaires such as, a popular scale developed by Weinstein: Weinstein Noise Sensitive Scale, cited in several international publications.17,18 Noise sensitivity and poor health outcomes have been related with one and another as previous studies suggest a lower threshold for physiological stress reactivity among noise-sensitive individual under controlled and field noise exposure.7,11

Since motorcyclist’s physio-psychological health related studies are limited, while research on rider’s noise-induced cortisol arousals under controlled noise environment has not been investigated. Therefore, this study is undertaken to explore the stress reactivity among high and low noise sensitivity riders. This study aimed to determine

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the effects of artificially induced-noise and noise-sensitivity on cortisol concentration.

**Methodology**

1.1. Study participants

The study procedure consisted of two phases: survey and laboratory experiment. Participants were undergraduate University students at Universiti Teknologi Mara, Kampus Puncak Alam Malaysia who rode motorcycle has a primary means of transportation. Simple random technique was adopted for sampling across the different faculties, representing from all over Malaysia. Inclusion criteria set for samples was (i) age between 19 to 25 years old, (ii) nonsmoker; (iii) absence of chronic diseases. The survey phase collected 356 motorcyclists which after screening process included 301 respondents in the noise sensitivity assessment. Study Information sheet and consent of participation was also endorsed from the participants. The second phase of the study consisted of 60 respondents, recruited upon noise sensitivity evaluation. Study process and strategy was approved by Faculty’s (Health Sciences) Internal Ethical Committee, Universiti Teknologi Mara.

1.2. Study Instruments

1.2.1. Demographic Information

A self-reported questionnaire was constructed to obtain the participant’s demographic data which includes information related to age, gender, motorcycle experience (years), faculty and semester, helmet-riding behavior, usage of ear protectors, tobacco- smoking habit and incidence of chronic diseases.

1.2.2. Weinstein Noise Sensitivity Scale

The Weinstein Noise Sensitivity Scale (WNSS) was adapted for this study. The self-reported standardized test consists of 21-items based on six-point Likert-type scale. The scale ranges from “disagree strongly” to “agree strongly” while the scores are ranged between 21 (minimum) to 126 (maximum). Previous studies from field and experimental studies have reported satisfactory psychometric properties, predictive validity and internal consistency of the WNSS, i.e., 0.84 to 0.87 (Kuder-Richardson reliability).

1.2.3. Saliva collection instruction

Participants were directed with pre-saliva collection guidelines which they had to follow strictly before the actual saliva sample to be collected. The guidelines were constructed to avoid possible contamination in the oral cavity of the samples and to control pH level in their saliva. There were four components of the guidelines: First, participants had to avoid night before saliva collection the anti-acids, bismuth medications, mouth wash, lotions or cream on the face. Second, participants had to avoid the day of saliva collection the chocolates, onions, garlic, or cruciferous such as cauliflower, broccoli, and cabbage intake. Third, one hour before saliva collection teeth should not have brushed one hour before the saliva sample to be collected. Fourth, respondents mouth had to be rinsed thoroughly for 30 seconds with cold water to remove food residues before 10 minutes of sample collection.

1.2.4. Saliva collection procedure

Passive drool method was adopted for saliva collecting sample in which participants had to tilt the head a little forward for increased saliva collection into the oral cavity and directly transferring into a 2 ml polypropylene vial. Contaminated samples (blood) were discarded and repeated sample collection after rinsing the mouth with cold water. Collected saliva samples were coded with the time and date on the vial and stored within 30 minutes at freezer (−80°C). Saliva samples were stored in aliquots to avoid repeated freeze thaw while the ELISA analysis were conducted within seven months of its storage. The cortisol concentrations were expressed in µg/dL. The optical density of 450nm measured the cortisol concentration. The coefficients of variation (CV) were calculated from the means of triplicated saliva cortisol assay where the intra and inter assay CV’s were less than 5% and 15% respectively.

1.3. Experimental Procedure

**Figure 1** illustrates rider’s selection from noise-sensitivity to laboratory experiment and ELISA analysis. WNSS scores categorized into three groups: High-Noise Sensitive (H-ns) group, Moderate-Noise Sensitive group, and Low-Noise Sensitive (L-ns) group. To investigate the salivary cortisol reaction with and without artificially induced noise, participants from H-ns and L-ns were recruited into experimental and control group respectively.

The experiment procedure started with rider’s endorsement of saliva guideline checklist, followed by 10 minutes break to saliva sample collection as “before noise exposure”. Laboratory experiment carried out in a controlled set-up, where H-ns (experimental group) riders were exposed to artificially induced motorcycle noise (>90 d BA) for 40 minutes as “intervention”. Sound was being monitored through Sound Level Meter (soundPro SE and DL, SLM of class/type 1 (serial no BEI040002) from Quest Technologies Oconomowoc, WI, USA.) while motorcycle noise was induced through speakers. Riders were seated 5 feet away from the speakers as each pair was on each side of the respondents in the experimental room. After 40 minutes saliva sample was immediately re-collected as “after noise exposure”. The same study protocol was adopted for L-ns (Control group) riders besides there was no artificial noise (intervention) and laboratory noise was up to 65 d BA. Respondents in control part of experiment provided saliva before and after spending time quietly in the experimental room. Later the High-sensitivity human salivary cortisol-ELISA (enzyme-linked immunosorbent assay) kit (Salimetrics, State College, PA, USA) were used to measure the saliva cortisol concentration by enzyme immunoassay (EIA) technique as followed the manufacturer’s instructions. Prior to testing, the ELISA Kits were stored at −4 to 8°C.
Statistical analysis. Participants information data and cortisol concentration values were tabulated and logged on excel worksheet for database and computed for statistical analysis through Statistical Package for Social Sciences, IBM SPSS (Version 22 Inc., Chicago, IL). Descriptive data of variables, i.e., age, gender and cortisol concentrations were obtained through frequency table. Data distribution was found normally distributed through Shapiro-Wilk test. To evaluate the differences between before and after the intervention the cortisol concentration in experimental and control was analyzed through paired sample t-test with an alpha level set of 0.05 for all subsequent analysis.

Results

Noise sensitivity

The coefficient of reliability of WNSS items was $\alpha = 0.776$ though Cronbach’s alpha of total population ($n = 301$). Noise sensitivity (NS) scores constituted into three groups: Low-Noise Sensitive (L-ns) ($M = 6.72 \pm SD, 4.36; n = 48$), Moderate-Noise Sensitive (M-NS) ($M = 82.49 \pm SD, 6.7; n = 202$) and High-Noise Sensitive (H-ns) ($M = 101.8 \pm SD, 5.31; n = 54$). A total of 60 participants were recruited for laboratory experiment, constituting of H-ns-Experimental group ($n = 30$) and L-ns-Control group ($n = 30$).

1.4. Descriptive profile of participants

The demographic profile of the participated riders ($n = 60$) in the laboratory experiment was dominated by male riders ($n = 43$, 71.7%) then females ($n = 17$, 28.3%). Participants age ranged from 19 to 25 years ($M = 22.02; SD = 1.172$). The L-NS (Control) group was mainly dominated by male participants i.e., $25$ (83.3%) males with minor percentage of females 16.7%. Whereas the participants from H-ns (Experimental) group constituted of 60% males ($n = 18$) and 40% females ($n = 12$).

1.5. Cortisol concentration analysis

The average cortisol concentration of participants from L-ns-Control group before and after the experiment under controlled setup was $0.22 \pm 0.11 \mu g/dL$ (ranged: $0.05 – 0.66$) and $0.20 \pm 0.09 \mu g/dL$ (ranged: $0.07 – 0.43$) respectively. L-NS rider’s salivary cortisol concentration was not found significant between their before and after the experimental exposure, $t (0.895) 29, p = 0.378$ as shown in figure 2(A). Results revealed that participants under controlled noise environment had no effect on their cortisol concentrations. The participants from H-ns group mean salivary cortisol concentration before and after the intervention of noise was $0.16 \pm 0.10 \mu g/dL$ (ranged: $0.06 – 0.54$) and $0.21 \pm 0.11$
μg/dL (ranged: 0.07 – 0.44), respectively. The significant increase in H-nss group cortisol levels was determined after the intervention, \( t (-2.48) \), \( p = 0.019 \) as shown in figure 2(B). Results indicated that participants with high-noise sensitivity had increased cortisol concentration after noise-induced exposure.

![Figure 2 Salivary cortisol concentration differences between “before” and “after” the experiment: (A) Low-Noise sensitive group as control group without noise exposure (B) High-Noise Sensitive Group as experimental group with noise exposure Note: (*) p-value < 0.05.](image)

**Discussion.** The young motorcyclists (\( n = 301 \)) noise sensitivity constituted majority of population (66.7%) under moderate noise sensitive level whereas 15.3 % and 18 % respondents exhibit low and high noise sensitivity respectively. Studies on noise sensitivity on different population reveals the similar trend where minor respondents encompasses high noise-sensitivity tendency and tends to be more vulnerable towards health risk associated with noise. The noise levels ranging between 85 to 90 d BA is sufficient for activation of HPA axis which release the stress hormone cortisol to either fight or flight from the acute stressor. Therefore, the experimental group (H-nss) was exposed of artificially induced high motorcycle noise (> 90 d BA) and the results revealed significant (\( p > 0.05 \)) increase in salivary cortisol concentration after the intervention. Cortisol level in the body tends to decline naturally during the time, particularly in the morning, consequently, to evaluate the cortisol level after intervention could be determined through investigating the differential effects between before and after cortisol concentration. The changes in concentration either increased or declined cortisol level indicates the influence of external stressor on HPA axis. The individual differences towards noise exists mainly because of different noise sensitivity tolerance level. The phenomenon of noise sensitivity is still rare to be included as an important personality factor in investigation of noise-related studies. The studies on noise sensitivity reported that it increases the risk of detrimental health. In current study noise sensitivity was investigated between low to high noise-sensitive participants in a controlled experiment to determine the precise cortisol reactivity associated with high-noise exposure. The significant (\( p > 0.05 \)) increase in cortisol concentration among H-nss participants after the intervention of artificially induced- noise evident the influence of noise sensitivity on increasing the stress reactivity in individuals. The similar results were found in a recent reported study in which the motorcycle rider’s salivary cortisol concentration was investigated in the field study. Participants rode motorcycle (\( n = 57 \)) for average of 45 minutes and saliva concentration difference between before and after the ride was compared among high-noise sensitive (H-NS) riders and low-noise sensitive (L-NS) riders.

The results reported showed the significant (\( p > 0.05 \)) difference in cortisol increase after motorcycling among H-NS riders.

Previously two laboratory studies undertook to investigate the influence of noise sensitivity on salivary cortisol in a controlled setup. First study was conducted by Wayne (2002) in which noise sensitivity of the participants and cortisol reactivity along with performance was investigated under low-frequency noise exposure. The significant association was reported among high noise sensitive participants increased cortisol level and affected performance in the psychological battery test. The results also showed that an acute stress impaired the cognitive performance of the high noise-sensitive participants. The motorcyclists exhibiting high-noise sensitivity may also experience impaired cognitive functioning during a commute and may beholds risk factor to road accidents, which requires further investigation. Second study by Ljungberg and Neely (2007), also reported impaired cognitive performance among noise-sensitive participants but no significant relation was determined between salivary cortisol arousal with noise exposure among noise sensitivity participants.

The other laboratory studies investigated only the relation of salivary cortisol to naturalistic noise exposure. Such as study by Wagner (2010) in which respondents (\( n = 20 \)) were exposed to experimental noise level up to 75 dB for 20 minutes, and saliva samples were collected before and after the noise exposure. Results showed the significant increase in cortisol levels after the noise exposure and decreased test performance (\( p = 0.01 \)). Similarly, Hebert and Lupien (2007), also reported differential effects in increased cortisol level in dose-response noise exposure in the controlled study. The significant association was also reported between cortisol elevation among tinnitus suffering respondents. It was also identified that cortisol concentration reached at the peak after 30 minutes and starts dropping gradually with the termination of noise, for this reason in current study, respondents were exposed to high noise greater than 30 minutes to elevate the cortisol level to its peak.

An organism acts to threats naturally by increasing cortisol secretion above baseline while frequent exposure
and stimulation of adrenal-pituitary axis gets affected which may alter the functionality of the axis which later leads to dysregulation in HPA activity at rest with poor health outcomes. Motorcyclists noise exposure is categorized as chronic condition with constant high noise exposure (< 90 dBA), which can impair the health of the rider. This study provides confirms the susceptibility of higher cortisol secretion associated with high-noise sensitive young riders as investigated under control laboratory setup where the increases in cortisol can be related to noise specifically.

Conclusion. The study reveals the significant association between noise sensitivity with cortisol reactivity. It also signifies the risk factors associated with motorcycling among young motorcyclists whose physiological and psychological health factors have not been investigated.

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