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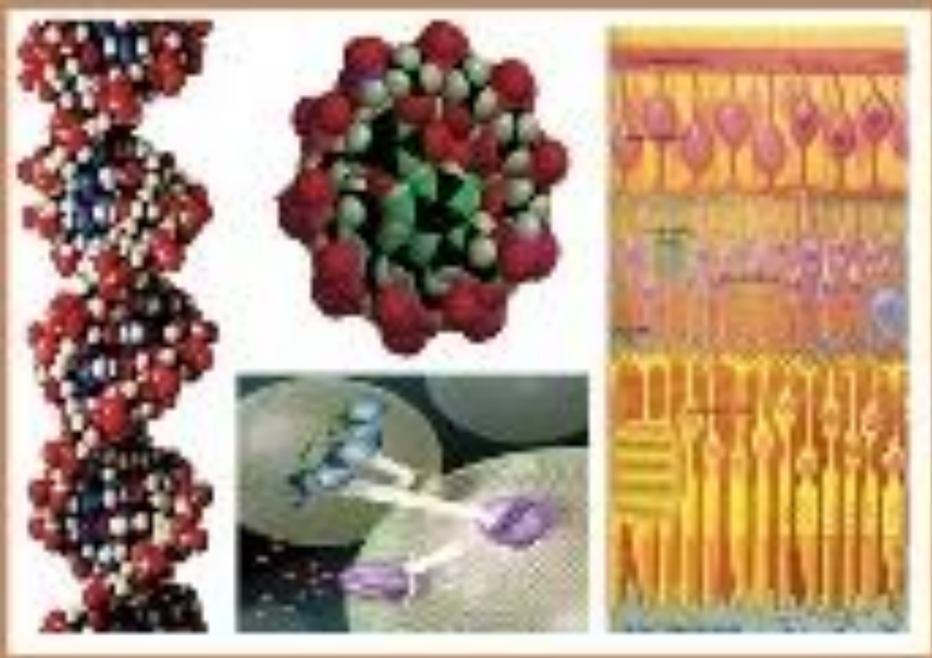

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Physiological Influence of Noise Pollution on High School Students

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ABSTRACT

This study investigated the physiological effects of noise pollution and academic stress on high school students, focusing on hormonal and cardiovascular responses. This study was conducted in Zakho, Kurdistan Region of Iraq, the study involved 60 students (15–18 years) from Haval (boys) and Payvin (girls) High Schools. Noise levels were measured in three phases: control (quiet garden), pre-exam (high stress), and post-exam (reduced stress). Results showed a significant increase in noise levels during exams, with pre-exam means of 94.3 ± 0.05 dB ($p < 0.05$) compared to the control (73.64 ± 0.03 dB). Cortisol levels rose sharply in both genders, peaking at 19.5 ± 1.03 µg/dL (males) and 21.1 ± 2.3 µg/dL (females) during exams ($p = 0.003$ and $p = 0.005$, respectively). Systolic blood pressure increased significantly in males (131.8 ± 3.6 mmHg, $p = 0.008$) and females (126.2 ± 2.21 mmHg, $p = 0.039$), while caloric expenditure surged by 51% in males (2380 ± 77.12 cal, $p = 0.004$) and 11% in females (1954 ± 38.03 cal, $p = 0.025$). Body composition changes, though less pronounced, included elevated body fat post-exam in males (15.96 ± 3.3%, $p = 0.65$) and increased muscle content in females (75.22 ± 2.31%, $p = 0.06$). The findings highlight critical environmental stressors, stress as noise pollution, impairing academic stress and triggering measurable physiological disruptions. These results advocate for noise-mitigation strategies in schools to safeguard student health and academic performance.

INTRODUCTION

Noise pollution is a significant environmental stressor due to harmful and undesirable sound that interrupts normal life with wide-ranging impacts on human health, behaviour and cognitive functions (Basner *et al*., 2014; Mehrotra *et al*., 2024). The word "noise" arose from the Latin word nausea, highlighting its unfriendly nature and troublesome influence on psychological and physical well-being (Firdaus and Ahmad, 2010; An *et al*., 2018; Nerweyi and Al-Sulaivany, 2021). In urban settings, rising population, construction activities, road traffic and industrial operations contribute to steadily high noise levels (Fink *et al*., 2018; Dzhambov *et al*., 2021). Students are predominantly at risk due to continued exposure to environmental noise within educational institutions among vulnerable populations (Louis *et al*., 2024). In a school environment, elevated classroom noise that is measured decibels (dBA) is commonly used to quantify noise intensity and reduces learning efficiency, hinders student concentration, impairs memory retention, and usually underestimated in shaping academic outcomes (Tavşanlı *et al*., 2017; Liu *et al*., 2022).

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The examinations or study sessions during periods requiring intense focus, the background noise outside the classroom is essential for successful academic performance, such as task engagement, cognitive endurance (Szarkowska *et al*., 2024; Babazadeh *et al*., 2025). The physiological effects of chronic noise cause mental fatigue, temporary distraction, but the long-term noise pollution is strongly associated with hypertension, cardiovascular diseases, hearing impairment, ischemic heart conditions, as well as sleep disruption (Yang et al., 2024; Akosile *et al*., 2025). Furthermore, environmental noise may influence body composition, and continuous exposure to traffic noise heightens the risk of obesity with an increase in body mass index (BMI), also plays a role in altering metabolic processes (Münzel *et al*., 2018; Altug *et al*., 2024). These long-term noise exposures are also associated with metabolic syndrome that affects insulin regulation, cardiovascular function and fat distribution (Huang *et al*., 2020; Chen *et al*., 2024). Among students, the interaction between environmental noise and academic stress presents a compounded health risk due to particularly stressful examination seasons accompanied by increased sympathetic nervous system activity and sensitive psychological pressure (George, 2024; Vetrivel *et al*., 2024). And also with persistent background noise, causes an increase in the level of cortisol, which is the body's primary stress hormone, affects immune function, mental clarity and metabolism (Babisch, 2014).

Additionally, exposure to environmental noise disturbs hormonal regulation, particularly leptin and ghrelin, which contribute to regulating hunger and energy balance, further affecting cognitive performance, body weight (Stansfeld and Crombie, 2011; Kulkarni *et al*., 2024). In adolescents, noise pollution reduced academic performance and affected sleep disturbances, physiological changes and behavioral changes that cause an increase in blood pressure, irregular heart rate, and altered body composition (De Moraes et al.,2024). ` al. (2016) and Liu *et al*. (2023) emphasized that chronic stress conditions caused various physiological problems in adolescents during the exam. The noise pollution also affects many physiological responses involved in cognitive development and emotional regulation (Newbury *et al*., 2024). Psychosocial stressors are involved in anxiety, irritability that can disturb academic performance (Shalayiding *et al*., 2024).

This study examines the academic stress and noise pollution and provides a comprehensive understanding of the effect of academic stress and environmental noise on both male and female students at Haval and Payvin High Schools. This provides valuable insights for policymakers, educators, and healthcare professionals to design stress-reducing strategies and improve school environments for better academic and health outcomes.

MATERIALS AND METHODS

1-Study Area:

The study was conducted in Zakho, a city located in the Kurdistan Region of Iraq. Data was collected during March 2025, at two high schools: Haval High School (for boys) and Payvin High School (for girls). A total of 60 students of both genders with a mean body weight was 63.42, and their mean height was 166.64, were selected from the 10th, 11th, and 12th grades, ranging in age from 15 to 18 years.

2-Experimental Design:

The study was designed to check the physiological effects of noise and academic stress at three key stages: in nature (control) in the garden of the school. before exams, when students experienced high stress and were exposed to significant school-related noise, and after exams, when stress remained but noise levels had decreased. A sound level meter (PeakTech 8005) was used to measure both the highest and lowest noise levels in decibels (dB) equipped with an A-weighting filter to mimic human ear sensitivity and a fast-response setting to capture transient noise peaks accurately. The sound level meter was calibrated using an acoustical calibrator to ensure accuracy, as recommended by ANSI S1.4 standards (Syamala *et al*., 2024; Gavilanes *et al*., 2024). Measurements were documented in two stages: Before and after the examination, and at each stage, maximum (Lmax) and minimum (Lmin) sound levels were noted. Physiological parameters viz; body composition, oxygen saturation, blood pressure, and cortisol level were measured.

3-Measurements:

The handheld BIA device with low-level electrical current estimates body composition and body composition monitor was used to measure various components of the body, such as fat percentage, muscle mass, bone density, and water content. The following parameters were recorded:

3-1-Body Fat Percentage (BF%):

The proportion of adipose tissue relative to total body mass, measured through bioelectrical impedance (Kyle *et al*., 2004). A common estimation formula from Deurenberg *et al*. (1991):

BF% = (1.20 × BMI) + (0.23 × Age) - (10.8 × Sex) - 5.4………….. (1)

where Sex = 1 for males, 0 for females.

3-2-Body Water Percentage:

The total body water content is expressed as a percentage of body weight, determined via impedance analysis (Lukaski, 2013). Total body water percentage can be estimated using bioelectrical impedance:

TBW% = (0.73 × Fat Free Mass (FFM))..(2)

where Fat-Free Mass (FFM) is calculated through BIA

3-3-Body Mass Index (BMI):

The ratio of body weight in kilograms to the square of height in meters, automatically computed by the device (World Health Organization, 2000). The standard BMI formula:

$$BMI = \frac{\text{Weight (kg)}}{\text{Height (m)}^2} \quad \ldots\ldots\ldots\ldots (3)$$

3-4-Body Muscle Percentage:

The skeletal muscle mass relative to total body composition, calculated using BIA-derived algorithms (Janssen *et al*., 2000). Skeletal muscle mass can be estimated from bioelectrical impedance using Janssen's equation:

$$SMM = \left(\frac{H^2}{R} * 0.401\right) + (3.825 * Sex) + (0.071 * Age) + 5.102 \ldots\ldots\ldots (4)$$

where H = height (cm), R = resistance (Ω), and Sex = 1 for males, 0 for females.

The Body Muscle Percentage is then calculated as:

Muscle Percentage = (SMM/ (Body Weight)) *100…………………. (5)

3-5-Basal Metabolic Rate:

The estimated daily energy expenditure at complete rest, calculated using established predictive equations (Mifflin *et al*., 1990).

BMR is estimated using the Mifflin-St Jeor equation:

For men: BMR = (10 × Weight (kg)) + (6.25 × Height (cm)) - (5 × Age) + 5…... (6)

For women: BMR = (10 × Weight (kg)) + (6.25 × Height (cm)) - (5 × Age) – 161… (7)

3-6-Cortisol Measurement:

Blood samples were collected from the students, and the serum was analyzed in the laboratory using RIA (Radioimmunoassay), ELISA (Enzyme-Linked Immunosorbent Assay), or chemiluminescent immunoassays to determine cortisol concentrations, which were reported in µg/dL.

3-7-Blood Pressure Measurement:

Pulse oximeter is used to measure the oxygen saturation level of heart rate, and blood. It works by passing light through a fingertip or earlobe to determine the amount of oxygen in the blood using red and infrared light absorption (Moshkovitz *et al*., 2021). An electronic device used to measure the arterial blood systolic and diastolic pressure and heart rate using oscillometric methods. (O'Brien *et al*., 2019; Messerli *et al*., 2020). MAP is a critical physiological parameter that reflects the average blood pressure, and MAP is commonly calculated using the formula:

$$MAP = DBP + \frac{1}{3}(SBP - DBP) \ldots\ldots\ldots (8)$$

where DBP is diastolic blood pressure and SBP is systolic blood pressure (Guyton and Hall, 2021).

4-Statistical Analysis:

The statistical analysis was performed to evaluate the differences among the three different stages. GraphPad Prism 10 was used, and one-way ANOVA was performed, followed by Duncan's Multiple Range Test

RESULTS

Noise levels were measured at different stages. First stage: at Haval and Payvin High Schools, a calm control setting (quiet garden or non-exam period), 2nd Stage: classroom environment before exams began, 3rd Stage: same classroom environment after exams. The lowest noise level was found in at First stage, representing a relatively quiet setting with minimal disturbances, with a maximum; 82±0.05, a mean of 73.64±0.03, and minimum; 53±0.06. At the 2nd stage, noise levels increased sharply with a maximum; 98.4±0.002, a mean of 94.3±0.05, and minimum; 87.4±0.04. These values reflect a significantly noisier environment due to pre-exam discussions, stress, and anxiety. While at stage 3rd, recorded noise levels remained elevated with a maximum, 96.1±0.03, a mean of 91.32±0.06, and a minimum, 89.1±0.004 (Table 1). These values showed a slight decrease compared to the 2nd stage due to a slight reduction, due to partial return to calm after the assessments concluded.

Table 1: 1illustrates the noise level at three different stages.

	Control 1st stage	Befor-Exam 2nd stage	After- Exam 3rd stage
Maximum	82±0.05a	98.4±0.002b	96.1±0.03ab
Mean	73.64±0.03a	94.3±0.05b	91.32±0.06ab
Minimum	53±0.06a	87.4±0.04b	89.1±0.004ab

Table (2) present the physiological responses of male students under control, pre-exam, and post-exam conditions. Oxygen saturation (SpO_2) showed slight variation across stages but remained statistically non-significant ($p = 0.72$). Body water content (BWC) gradually declined from 63.97% to 59.3%, yet the change was not significant ($p = 0.54$). Body fat content (BFC) increased slightly after exams, while body muscle content (BMC) stayed consistent throughout ($p = 0.65$ and $p = 0.82$, respectively). BMI values fluctuated mildly with no significant differences ($p = 0.74$). A significant rise in caloric expenditure was observed, increasing from 1571 ± 154 cal (control) to 2380 ± 77.12 cal (pre-exam) and 2390 ± 87.43 cal (post-exam), with a p-value of 0.004. Cortisol levels also rose markedly before exams (19.5 ± 1.03 µg/dL) and remained elevated post-exam (17.3 ± 1.3 µg/dL) compared to the control phase (12.4 ± 1.9 µg/dL), with a statistically significant difference ($p = 0.003$), indicating a strong hormonal response to academic stress.

Table 2: Presents the physiological parameter values recorded in male students under control conditions, before the exam, and after the exam.

Parameters	Control 1st stage	Befor-EXAM 2nd stage	After-EXAM 3rd stage	P-Value
SpO2	94.66±0.83	96.4±1.31	95.66±1.52	0.72
BWC (%)	63.97±1.6	62.53±1.01	59.3±0.81	0.54
BFC (%)	14.2±1.74	14.03±3.21	15.96±3.3	0.65
BMC (%)	78.44±3.5	78.46±2.1	78.22±1.17	0.82
BMI (%)	22.37±3.5	22.74±6.5	22.71±2.41	0.74
Calories (cal)	1571a±154	2380b±77.12	2390b±87.43	0.004
Cortisol (µg/dL)	12.4 ± 1.9	19.5± 1.03	17.3±1.3	0.003

Note: SpO_2 refers to Oxygen Saturation Level, BWC denotes Body Water Content, BFC stands for Body Fat Content, BMC represents Body Muscle Content, and BMI refers to the Body Mass Index.

Table 3 presents the physiological responses of female students across the control, pre-exam, and post-exam phases. Oxygen saturation (SpO_2) remained stable throughout with no significant difference (p = 0.85). BWC increased noticeably before exams and slightly declined afterwards, showing a near-significant change (p = 0.071). Body fat content (BFC) remained consistent across conditions (p = 0.69), while muscle content (BMC) showed a marked increase before exams and remained elevated post-exam, though the overall difference was not statistically significant (p = 0.06). Body Mass Index (BMI) fluctuated but showed no significant change (p = 0.73). Caloric expenditure rose significantly from 1761 ± 45.24 cal (control) to 1954 ± 38.03 cal (pre-exam) and 1951 ± 45.74 cal (post-exam), with a p-value of 0.025. Notably, cortisol levels rose sharply before exams (21.1 ± 2.3 µg/dL) compared to control (12.7 ± 2.4 µg/dL) and dropped post-exam (16.4 ± 2.3 µg/dL), showing a statistically significant stress response (p = 0.005).

Table 3: Female students' physiological parameters (mean ± SD) during control, pre-exam (B-Exam), and post-exam (A-Exam) periods with p-values.

parameters	Control 1st stage	Befor-EXAM 2nd stage	After-EXAM 3rd stage	P Value
SpO2	93±1.23	93.0.23±2.21	93±1.3	0.85
BWC (%)	51.62a±1.14	61.03±4.6	59.76b±1.13	0.071
BFC (%)	17.1±0.2	17.23±1.4	17.02±2.21	0.69
BMC (%)	67.64a±4.61	75.22b±2.31	75.03b±1.12	0.06
BMI (%)	23.53±2.4	18.22±0.61	21.23±0.63	0.73
Calories (cal)	1761a±45.24	1954b±38.03	1951b±45.74	0.025
Cortisol (µg/dL)	12.7 ± 2.4a	21.1 ± 2.3b	16.4 ± 2.3c	0.005

Table (4) summarizes the blood pressure changes among male and female students during the control, pre-exam, and post-exam periods. In male students, systolic pressure rose significantly from 112.4 ± 3.5 mmHg (control) to 131.8 ± 3.6 mmHg before exams and further to 135.8 ± 4.4 mmHg after exams (p = 0.0082), reflecting an acute cardiovascular response to academic stress. Diastolic pressure increased slightly but was not statistically significant (p = 0.34). Mean Arterial Pressure (MAP) showed an upward trend (control: 82.21 ± 3.62; post-exam: 93.24 ± 1.41 mmHg) with a p-value of 0.14, indicating a moderate but non-significant rise. In female students, systolic pressure also increased significantly from 106.4 ± 6.4 mmHg (control) to 126.2 ± 2.21 mmHg before exams and slightly decreased to 124.3 ± 4.04 mmHg after exams (p = 0.039). Diastolic pressure rose modestly but without statistical significance (p = 0.19). However, MAP showed a significant elevation across conditions (p = 0.043), suggesting heightened cardiovascular activation in response to examination stress, particularly in females.

Table 4: Comparison of blood pressure values between control and examination phases in male and female students.

parameters	Control 1st stage	Befor-EXAM 2nd stage	After-EXAM 3rd stage	P Value
Systole Male	112.4a±3.5	131.8b±3.6	135.8b±4.4	0.0082
Diastole Male	67.65±3.3	66.64±2.3	75.4±2.4	0.34
MAP (mmHg) Male	82.21a±3.62	87.34ab±3.41	93.24b±1.41	0.14
Systole Female	106.4a±6.4	126.2b±2.21	124.3b±4.04	0.039
Diastole Female	61.41±3.6	72.86±8.064	70.73±3.4	0.19
MAP (mmHg) female	77.41±4.04	93.51±4.4	88.414±2.2	0.043

DISCUSSION

The present study investigated the effect of environmental noise on hormonal and physiological responses of high school students at different phases: control, pre-examination, and post-examination. The study described multiple physiological indicators such as blood pressure, caloric expenditure, cortisol levels and body composition, aligning with existing research on stress-induced physiological responses.

The current study found the significant elevation in cortisol levels in both male and female students before and after examinations. These increased cortisol levels in the pre-exam and post-exam phases are consistent with findings by Christensen *et al.* (2016) and Chen *et al.*, (2019), who described that cognitive task anticipation increases cortisol secretion. Cortisol is the glucocorticoid hormone widely secreted by the adrenal cortex in response to stress and recognized as a biomarker for psychological and physiological strain (Battaglia *et al.*, 2024; Brunyé *et al.*, 2025). James *et al.* (2023) and Sarmiento *et al.* (2024) also found elevating cortisol concentrations due to exam stress causes acute activation of the hypothalamic-pituitary-adrenal axis.

The cardiovascular function, such as systolic blood pressure, increased significantly during exam phases in both male and female students, and particularly in males. This is similar to the findings of Münzel *et al.* (2020, 2023) and Majeed *et al.* (2024), who described that exam pressure leads to activation of the sympathetic nervous system activation which increases the systolic pressure, while the changes in diastolic pressure were not statistically significant. These cardiovascular responses are also similar to the findings by Recio *et al.* (2016) and Sivakumaran *et al.* (2022) and Ali *et al.* (2023), which described that the academic anxiety and noise-induced stress potentially compound cardiovascular strain during periods of high stress and independently raise systolic pressure. Furthermore, greater cumulative stress, mean arterial pressure (MAP) in female students also increase during the pre- and post-exam phases. The previous studies also exhibited the cardiovascular reactivity in female students due to academic stress, and due to the differences in coping mechanisms and hormonal cycles (Maculewicz *et al.*, 2023; Förster *et al.*, 2025). Interestingly, changes in SpO_2 were found same across all phases in both genders, which indicates the exam-induced psychological stress was less sensitive to the respiratory parameters. However, delicate fluctuations exhibit the physiological alterations under stress, as noted by Lian *et al.* (2021), who recorded peripheral decreases in oxygen saturation during cognitive workload.

Body composition parameters, viz, BWC, BFC, BMC, and BMI, showed uncertain changes across study phases. In males, fat content rose slightly, and body water content declined after exams, which represents that under stress, mild physiological shifts possibly due to changed Metabolism and hydration. Similar designs have been reported by Christaki *et al*. (2022) and Ogren *et al*. (2023), who studied chronic stress influences lipid metabolism and body fluid balance in students.

Before exams, BWC increased in female students due to anticipatory physiological changes and slightly deteriorated post-exam. These changes are also reported by Madaro *et al*. (2023) and Crintea *et al*. (2025), who explained that acute stress may trigger electrolyte regulation and transient changes in fluid. During the pre- and post-exam stages, BMC persisted comparatively stable in males but showed a notable increase in females, although this did not remain significant. Muscle tension can shift temporarily during periods of heightened stress. This is also reported by Alexander *et al*. (2022) and Landen *et al*. (2023), who described hormonal changes due to stress affecting muscle metabolism, particularly in females. A significant increase in caloric expenditure in both genders during examination phases may be attributed to increased sympathetic activity and metabolic rate. These findings are supported by studies from Chakraborty *et al*. (2023) and Theodorakis *et al*. (2024), who described that stress elevates energy expenditure by modifying energy metabolism pathways and stimulating the autonomic nervous system. In addition, numerous studies have investigated noise pollution in the Kurdistan Region, addressing contexts such as student environments. Similarly, Basheer et al. (2022) found that the most common direct effect of noise on students was annoyance and headaches.

CONCLUSION

The present study confirms that noise pollution, even within school environments, acts as an active environmental stressor capable of inducing notable physiological changes in students. The findings highlight the importance of recognizing environmental noise not only as an academic distraction but also as a significant factor affecting students' physical health. Future strategies to improve educational environments should include active noise management to minimize the physiological burden on students during critical academic periods

Declarations:

Ethical Approval: This study was conducted through survey-based data collection from the two high schools (Boys and Girls). Participation was voluntary, and confidentiality and privacy of respondents were ensured. No animals or medical interventions were involved.

Competing interests: The author declares no conflict of interest of any kind

Authors' Contributions: Suzan M. Haji designed the research, acquired the data, recorded the measurements, analyzed the data, wrote the manuscript, and discussed the results.

Data Availability Statement: Data supporting the findings of this study are available from the corresponding author upon reasonable request

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