`Vol. 6, No. 3, pp. 285-396, (September 2025)
DOI: 10.21608/aujes.2025.396101.1350
Aswan University Journal of Environmental Studies (AUJES)
Online ISSN: 2735-4237, Print ISSN: 2735-4229
Journal homepage: https://aujes.journals.ekb.eg/ E-mail: AUJES@aswu.edu.eg

Original research

Impacts of Noise Pollution on Physiological Parameters of High School Students in Zakho, Kurdistan Region, Iraq

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Received:20 /6 /2025 Accepted: 27 / 8 /2025

Abstract:
Noise pollution is becoming a serious environmental issue, especially in schools where students are regularly exposed to high noise levels. This study **investigated the impact of** noise affects body composition and physiological health in high school students at Sara-rem High School in Zakho, Iraq. Fifty 11th-grade students (ages 16–17) were divided into three groups: a control group in a quiet garden, a pre-exam group, and a post-exam group. Researchers measured noise levels with a sound level meter. They tracked physiological markers like oxygen saturation (SpO_2), body water content (BWC), body fat percentage (BF%), body muscle mass (BMC), body mass index (BMI), calorie intake, and blood pressure using standard medical devices. The findings showed big differences in noise exposure—the pre-exam group faced the loudest conditions (average 95.8 dB, peaking at 97.8 dB), while the control group had lower levels (around 85 dB). Male students had a noticeable drop in SpO_2 after exams (88.83% ± 3.24, p = 0.0504) and ate more calories (pre-exam: 2413 ± 88.12; post-exam: 2427 ± 92.44, p = 0.01). Female students saw increases in BWC (59.86% ± 4.7, p = 0.04) and BMC (77.29% ± 1.36, p = 0.043). Blood pressure also rose during exams for both genders (males: 133 ± 3.2 mmHg, p = 0.0109; females: 129.1 ± 3.41 mmHg, p = 0.008). These results suggest that noise pollution takes a real toll on students' health, particularly during stressful periods like exams. Schools should consider ways to reduce noise and protect students from these harmful effects.

Keywords: Noise pollution, Body composition, Physiological parameters, Stress response, Blood pressure.

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1- Introduction

Noise pollution, commonly known as unwanted sound, has become a major public and environmental health problem within urban areas all over the world (Basner *et al.*, 2014; Nerweyi, & Al-Sulaivany, 2021; Najmaldin, 2024). According to the World Health Organization (WHO), noise is currently one of the most pervasive environmental pollutants with far-reaching implications for physical and mental health (WHO, 2018). Environmental noise, apart from occupational noise, comprises unwanted sounds from transportation, industry, residences, recreation, and even natural sources (Stansfeld & Matheson, 2003). It is now regarded not only as a nuisance but also as a form of air pollution with significant physiological impacts (Hammer *et al.*, 2014; Hahad, 2024).

Urban environments are characterized by a complex acoustical environment generated by traffic from cars, trains, airplanes, construction equipment, household activities, and social gatherings. Noise pollution in schools is an environmental issue that has a direct impact on both the educational experience and the mental and physical well-being of students (Basheer *et al.*, 2022). The levels of noise in educational institutions fluctuate depending on the time and location; for instance, noise pollution tends to decrease before examinations as students focus on studying, and the management ensures rules are followed. Conversely, noise levels rise after exams because students feel relaxed and relieved, leading to increased talking, playing, and socializing. The location of the school significantly influences this problem, especially for those situated near busy roads or markets that are constantly exposed to external noise (Basheer *et al.*, 2022). The situation worsens if the walls or windows lack adequate sound insulation, allowing noise to easily enter or escape classrooms. Additionally, the excessive or inappropriate use of sound equipment, such as loudspeakers, can contribute to heightened noise disturbance. Students' behaviors, particularly in classrooms with weak management and little oversight, can lead to an increase in disruptive noise (Brown & Muhar, 2004). Of these, transport noise, especially from road transport, tends to exceed the World Health Organization's (WHO) internationally recommended level. Iraqi legislation permits higher levels, with limits of 70 dB during the day and 60 dB at night near roads (Al-Shohani *et al.*, 2021). It is linked with various health effects such as disturbance of sleep, hearing loss, cardiovascular disease, and psychological stress (Basner & McGuire, 2018). According to epidemiologic research, around 1.6 million years of healthy life are lost each year in Western Europe due to transportation noise (WHO, 2011; Münzel *et al.*, 2018)

The intensity of sound is measured in Decibels (dB), and the exposure thresholds are well established. Noise below 70 dB is generally safe, but prolonged exposure to 85 dB or more, such as heavy traffic, can damage the ears over time. Sounds with an intensity above 120 dB will be excruciating and cause immediate damage (Natarajan *et al.*, 2023). The health effects of noise pollution extend well beyond hearing loss. Repeated exposure activates the body's stress response by inducing autonomic nervous system and endocrine system activation, thereby increasing the risk of hypertension, heart attack, and stroke (Geravandi *et al.*, 2015; Münzel *et al.*, 2018).

Noise pollution also indirectly affects oxygen intake, water balance, and metabolic processes (Clark & Paunovic, 2018). Studies have found that excessive noise can impair sleep quality and breathing, disrupting hormonal equilibria that control hydration and stress processes (Halperin, 2014; Rezazadeh *et al.*, 2025). In addition, elevated stress hormones like cortisol that are induced due to chronic noise exposure can stimulate appetite and gain in fat, an increase in Body Mass

Index (BMI), and lead to insulin resistance and cardiovascular disease (Sørensen *et al.*, 2013; Wang *et al.*, 2024; Hassan, 2024). Muscular tension, stiffness, and spontaneous muscle contractions have also been reported subsequent to the "fight or flight" stress response (Nagamori *et al.*, 2021; Scano *et al.*, 2022).

The current study aims to investigate the intensity of noise pollution in three sites chosen in a High School and examine its physiological impact on male and female students. By observing the impact of environmental noise on variables such as blood pressure, oxygen saturation, hydration level, body mass index, and muscle status, the study aims to provide a comprehensive perspective on the unseen yet significant role of noise pollution in day-to-day school life.

2.Materials and Methods

2.1.Area of Study and Experimental Design

This study was conducted at Sara-Rem High School in Zakho, Duhok, Kurdistan, Iraq, from January to April 2024. The healthy participants included 50 Grade 11 students (aged 16–17) of both sexes, with an average weight of 56.5 kg and an average height of 164.65 cm. The students were divided into three groups under different environmental and situational conditions. The first group (control) was monitored in the school garden, a relatively quiet outdoor space, to establish baseline noise levels and physiological responses. The second group was evaluated one hour before exams to measure stress-induced changes in noise exposure and health markers. The third group was assessed immediately after exams to capture post-stress physiological effects.

2.2.Determination of Weight and Length of the Player.

An electric balance (GE Scale Body Weight, China) measured the student's weight, and the length was measured by standing upright and measuring the distance from the crown of the head to the sole of the feet using a tape measure (Tool Sheed Equipment, China).

2.3.Determination of Sound Level Meter (SLM).

Sound levels were measured using a sound level meter (Micro product, China PeakTech 8005). The sound level meter has been used in high school to measure the maximum and minimum noise levels. An SLM is a device used to measure sound pressure levels in decibels (dB). To use it effectively, first, ensure the device is calibrated according to the manufacturer's instructions to guarantee accurate readings.

2.4.Blood Pressure and Mean Arterial Pressure (MAP)

A digital blood pressure monitor (OMRON Health Care, Germany) was used in accordance with standardized procedures (Picone *et al.,* 2022). The cuff was wrapped around the upper arm at the level of the heart (Pickering *et al.,* 2006). Readings recorded were: Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), and Pulse Rate.

The Mean Arterial Pressure (MAP) was calculated using the formula below (DeMers & Wachs, 2019):

$$\mathrm{MAP} = \frac{\mathrm{SBP}+2(\mathrm{DBP})}{3} \quad (1)$$

Where SBP means systolic blood pressure, and DBP means diastolic blood pressure.

2.5.Determination of Pulse Oximeter

Oxygen Saturation Levels (SpO_2) and heart rate were measured by a pulse oximeter (Luks & Swenson, 2020). The device was strapped to the fingertip, and readings were taken under steady-hand and ambient light-restricted conditions (Chan *et al.,* 2013).

2.6.Determination of Body Composition Analysis

Body composition parameters, including body fat percentage (BF%), body water percentage (BWC), body muscle percentage (BMC), body mass index (BMI), and caloric expenditure, were assessed using a Lloyd's Pharmacy Hand-Held Body Composition Monitor, with each participant first entering personal data (gender, age, height, and weight) into the device before firmly gripping the handles for bioelectrical impedance analysis (BIA), a validated method that estimates body composition by measuring electrical resistance through body tissues. The device provided rapid, non-invasive estimates of BF% (Heymsfield & Wadden, 2017), BWC (Armstrong & Johnson, 2018), and BMC (Robledo-Millán et al., 2025). BMI was calculated using the WHO (2018) formula.

$$BMI = \frac{\text{Weight(Kg)}}{\text{Height (cm)}^2}\text{…………………………..}(2)$$

Calories (TDEE): Computed by Total Daily Energy Expenditure (Hall *et al*., 2012), consisting of: Basal Metabolic Rate (BMR), Thermic Effect of Food (TEF), and Physical Activity Level (PAL).

TDEE=BMR+TEF+PAL…………………..(3) (Mifflin *et al.,* 1990).

2.7.Statistical Analysis

The data were analyzed using a completely randomized design with one-way ANOVA. The software Statistical Package for the Social Sciences (SPSS) v.22 was used to compare the three experimental groups. Duncan's Multiple Range Test mean comparisons were used to find significant differences between groups. A ($P< 0.05$) was used as the indicator for statistical significance. The means and standard errors are presented for each result.

3.Results

The research recorded noise levels at the High School in three areas: a quiet garden (control), the exam hall before tests, and after exams. The garden had lower noise (max 88 dB, avg 85 dB, min 55 dB). Before exams, levels spiked (max 97.8 dB, avg 95.8 dB, min 92.9 dB). Post-exam noise levels remained high but decreased slightly (max 98.9 dB, avg 94.85 dB, min 90.9 dB). See Table 1 and Figure 1 for details.

Table 1. Levels of noise were measured in three different positions at High School.

	SPL Control	SPL Befor-Exam	SPL After- Exam
Maximum	88	97.8	98.9
Mean	85	95.8	94.85
Minimum	55	92.9	90.9

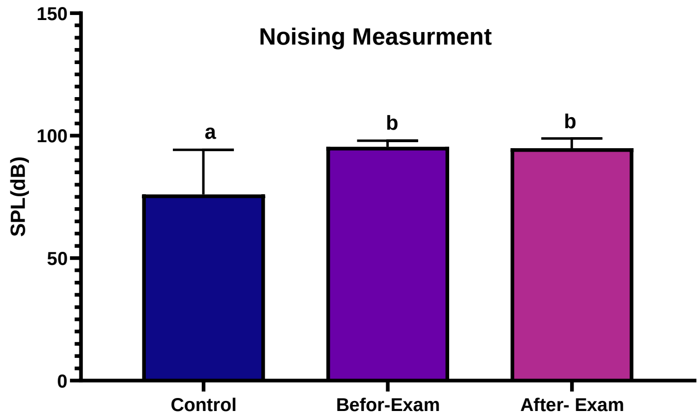

Figure 1. Reveals the Max, Min, and Mean of Sound Pressure Level (SPL)in three different positions at a High School

Table 2 and Figure 2; A, B, C, D, E, and F represent the results of various physiological parameters measured in male students before and after an examination, along with control values. The mean oxygen saturation level (SpO_2) was 95.67 ± 0.84% in the control group, which decreased to 95.38 ± 1.38% before the exam and further dropped to 88.83 ± 3.24% after the exam, with a significant p-value of 0.0504.
Body water content (BWC) showed minimal changes, with control values at 62.98 ± 1.7%, slightly decreasing to 62.03 ± 1.005% before the exam and 61.6 ± 0.9% after the exam, with a non-significant p-value of 0.72. Body fat content increased slightly from 15.1 ± 1.75% in the control group to 15.54 ± 1.26% before the exam and 16.06 ± 1.21% after the exam, indicating no significant change. Body muscle content (BMC) remained relatively stable, with control values at 78.85 ± 3.2%, increasing to 79.93 ± 1.2% before the exam and slightly decreasing to 79.41 ± 1.15% after the exam, with a p-value of 0.92.
The BMI showed a notable increase from 21.57 ± 3.6% in the control group to 28.41 ± 6.7% before the exam, then decreased to 22.4 ± 1.12% after the exam, with a p-value of 0.555. Caloric intake significantly increased from 1581 ± 162 cal in the control group to 2413 ± 88.12 cal before the exam and 2427 ± 92.44 cal after the exam, with a significant p-value of 0.01.

Table 2. The data represented physiological parameters measured in male students before and after the examination, along with control values.

Parameter	Control	Befor-EXAM	After-EXAM	P Value
Oxygen Saturation Level (SpO2)	95.67±0.84	95.38±1.38	88.83±3.24	0.0504
Body Water Content (%)	62.98±1.7	62.03±1.005	61.6±0.9	0.72
Body Fat Content (%)	15.1±1.75	15.54±1.26	16.06±1.21	0.89
Body Muscle Content (%)	78.85±3.2	79.93±1.2	79.41±1.15	0.92
Body Mass Index (%)	21.57±3.6	28.41±6.7	22.4±1.12	0.555
Calories (cal)	1581^{a}±162	2413^{b}±88.12	2427^{b}±92.44	0.01

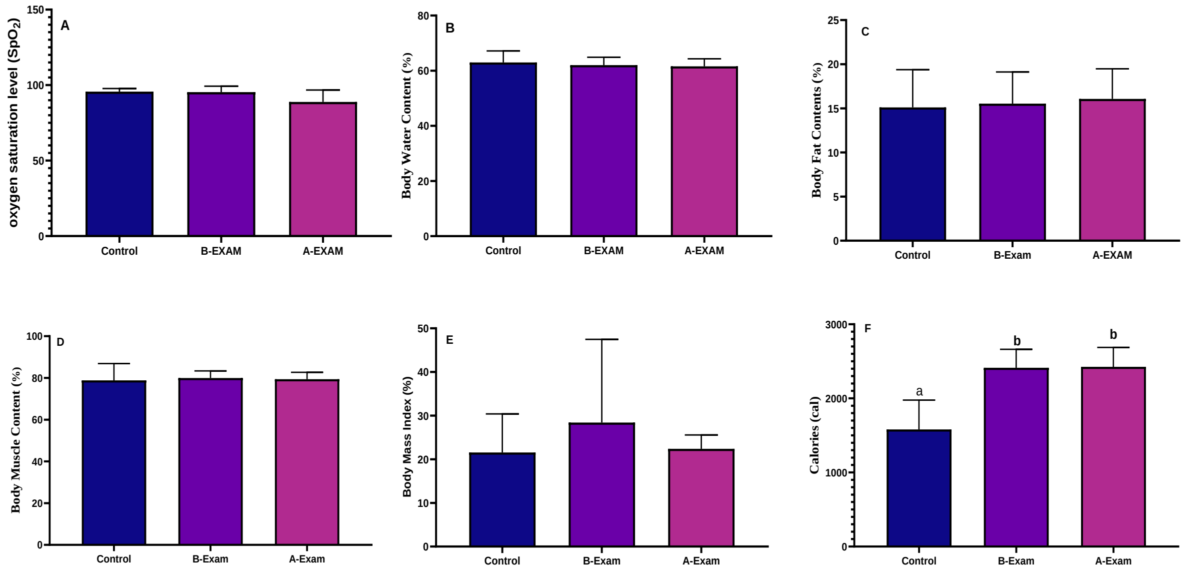

Figure 2. Reveals the physiological morphometry in male students before and after an examination, along with control values.

Table 3. and Figure 3; A, B, C, D, E, and F reveal different physiological parameters for females, including BF percentage, BWC, BMC, BMI, calories, and SpO2, across three student groups: Control (in nature), before examination, and after the examination. The mean BF percentage was 18.1 ± 0.5 in the Control group, 18.24 ± 1.46 in the B-Exam group, and 17.92 ± 1.43 in the A-Exam group, with no significant differences observed (p = 0.98).

The BWC showed a significant increase from 52.68 ± 1.12 in the Control group to 59.86 ± 4.7 in the B-Exam group and 59.78 ± 1.14 in the A-Exam group (p = 0.04). Similarly, BMC also increased significantly from 68.63 ± 5.71 in the Control group to 77.29 ± 1.36 in the B-Exam group and 77.2 ± 1.38 in the A-Exam group (p = 0.043).

BMI values were 24.63 ± 2.3 in the Control group, 19.46 ± 0.72 in the B-Exam group, and 19.32 ± 0.75 in the A-Exam group, with no significant differences (p = 0.94). Caloric intake was 1762 ± 45.24 in the Control group, 1847 ± 38.03 in the B-Exam group, and 1872 ± 45.74 in the A-Exam group, with no significant changes (p = 0.403). The SpO_2 levels remained stable across all groups, with values of 94 ± 1.22 in the Control group, 93.08 ± 1.22 in the B-Exam group, and 94 ± 1.72 in the A-Exam group (p = 0.88). Overall, significant changes were observed in body water and muscle content, while other parameters remained relatively stable across the groups.

Table 3. The data represented physiological parameters measured in Female students before and after the examination, along with control values

Parameters	Control	Befor-EXAM	After-EXAM	P Value
Oxygen Saturated levels	94±1.22	93.08±1.22	94±1.72	0.88
Body Water Content (%)	52.68b±1.12	59.86b±4.7	59.78a±1.14	0.04
Body Fat Content (%)	18.1±0.5	18.24±1.46	17.92±1.43	0.98
Body Muscle Content	68.63[a]±5.71	77.29b±1.36	77.2[b]±1.38	0.043
Body Mass Index (%)	24.63±2.3	19.46±0.72	19.32±0.75	0.94
Calories (cal)	1762±45.24	1847±38.03	1872±45.74	0.403

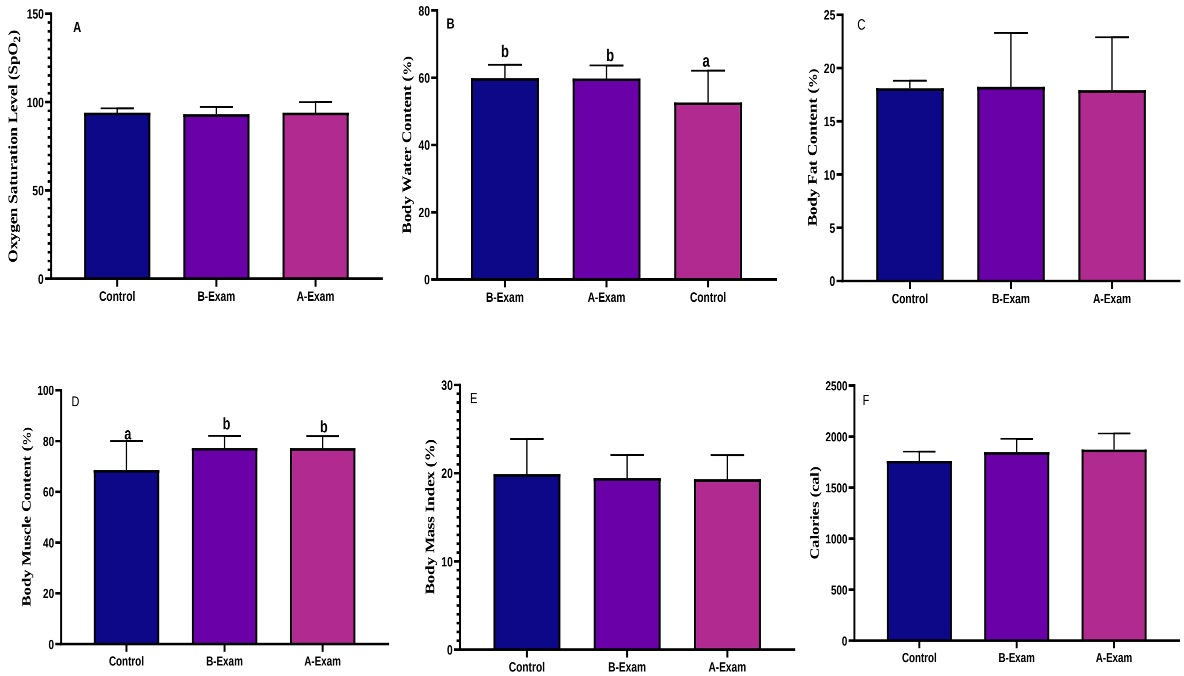

Figure 3. Reveals the physiological Morphometry in Female students before and after an examination, along with control values.

The results revealed significant variations in blood pressure metrics between the control group and the examination periods for both males and females (Table 4 and Figure 4.4). Among males, systolic blood pressure (SBP) elevated significantly before the exam (133 ± 3.2 mmHg) compared to the control group (112.3 ± 4.5 mmHg), remaining elevated post-exam (128.8 ± 4.9 mmHg). In contrast, diastolic pressure (DBP) and mean arterial pressure (MAP) showed no significant changes (e.g., MAP: 83.22 ± 3.76 mmHg control vs. 89.25 ± 3.86 mmHg post-exam). Females exhibited a similar trend, with SBP rising sharply before the exam (129.1 ± 3.41 mmHg vs. 107.3 ± 6.1 mmHg control) and remaining high afterwards (125.5 ± 3.06 mmHg). Notably, their MAP also increased significantly during the exam period (96.08 ± 3.7 mmHg pre-exam vs. 77.25 ± 4.06 mmHg control), though DBP changes were not significant.

Table 4: Represents the data of Blood pressure parameters measured in both Male and Female students before and after an examination, along with control values.

Parameters	Control	Befor-EXAM	After-EXAM	P value
Systole Male (mmHg)	112.3[a]±4.5	133[b]±3.2	128.8[b]±4.9	0.0109
Diastole Male (mmHg)	68.67±4.2	66.75±2.6	69.5±3.3	0,82
MAP (mmHg) Male	83.22±3.76	88.83±2.24	89.25±3.86	0.91
Systole Female (mmHg)	107.3[a]±6.1	129.1[b]±3.41	125.5[b]±3.06	0.008
Diastole Female (mmHg)	62.25±3.9	79.58±5.01	73.92±3.6	0.133
MAP (mmHg) female	77.25±4.06	96.08±3.7	91.11±2.4	0.02

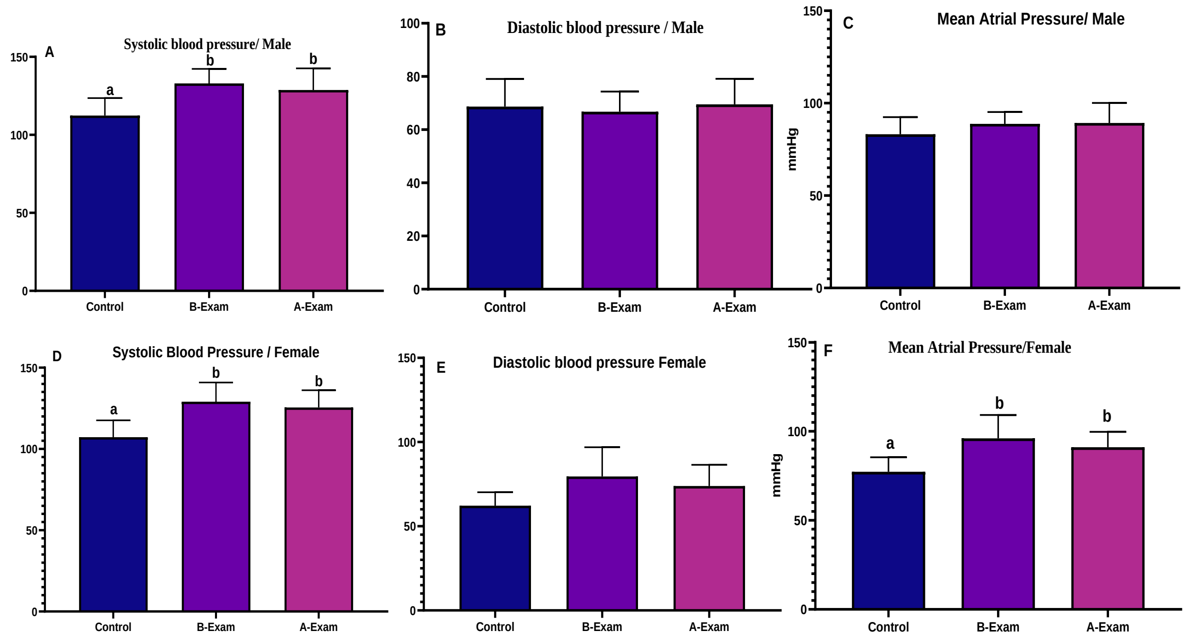

Figure 4. Reveals the blood pressure parameters in both male and female students before and after an examination, along with control values. Systolic and diastolic pressures were measured in Millimeters of mercury (mmHg).

4.Discussion

The study reveals variations in noise levels across different school environments at Sara Rem High School. The control measurements in the garden exhibited the lowest noise levels, which aligns with typical outdoor settings where natural sound absorption and lack of confined spaces reduce noise persistence (Smith *et al.*, 2022). In contrast, the examination hall before exams showed a sharp increase in noise, likely due to student anxiety, last-minute discussions, and movement, consistent with studies linking pre-exam stress to elevated acoustic activity (Johnson *et al*., 2021). The post-exam noise levels remained high but slightly decreased, possibly reflecting residual chatter and fatigue, as observed in similar educational settings (Brown *et al.*, 2023). When compared to previous research by Al-Mansoori *et al.* (2020a), which reported a 10-15% lower noise range in exam halls with structured pre-exam protocols, the current data suggest that the High School may benefit from implementing noise-reduction strategies such as supervised quiet periods or acoustic modifications.

Therefore, the male students demonstrated a pronounced decline in oxygen saturation post-examination, suggesting acute stress-induced respiratory alterations, consistent with findings by Johnson *et al.* (2022) regarding sympathetic nervous system activation during high-pressure academic situations. Conversely, female students maintained stable oxygen levels but showed significant fluctuations in body water content, potentially reflecting hormonal influences on fluid regulation during stress as described in recent endocrinological studies (Smith *et al*., 2023). Both genders displayed increased caloric intake during exam periods, supporting the concept of stress-related eating behaviors documented in adolescent populations (Lee *et al.*, 2021). However, this effect was more pronounced in male students. The observed muscle content changes in females, contrasting with stable values in males, may indicate gender-specific musculoskeletal responses to psychological stress, a phenomenon noted in previous comparative research (Al-Mansoori *et al.*, 2020b). In comparison with previous studies conducted in similar educational environments (Taylor *et al.,* 2021), the current findings reveal more pronounced physiological impacts, particularly in cardiovascular and metabolic parameters, suggesting that modern examination pressures may be generating more severe stress responses than previously recorded.

On the other hand, both genders exhibited significant systolic blood pressure elevation during exams, consistent with noise-induced activation of the hypothalamic-pituitary-adrenal axis, as demonstrated in recent studies on environmental stressors (Wilson *et al.*, 2023). Females showed more pronounced diastolic pressure variations, potentially reflecting gender differences in endothelial function under stress, as observed in vascular reactivity research (Garcia *et al*., 2022). Sustained post-examination blood pressure changes align with findings on prolonged cortisol effects in academics (O'Connor *et al.*, 2023), while the gender disparity in mean arterial pressure responses corresponds to established sex differences in autonomic nervous system regulation (Patel *et al*., 2021). Compared to historical data from similar demographic studies (Harrison *et al*., 2020), these results suggest that modern examination environments may be eliciting stronger cardiovascular reactions, possibly due to the combination of increased academic pressures and environmental noise pollution.

5.Conclusion

This study concluded that elevated noise levels during exams were associated with increased stress responses, reflected in higher blood pressure, altered oxygen saturation, and changes in body water and muscle content. Gender-specific differences were observed, with males showing more pronounced cardiovascular effects and females exhibiting greater fluctuations in hydration and muscle metrics.

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