Evaluation of Stress Levels by Monitoring Trapezius Muscle Activity using EMG & EDA

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Abstract. Stress is a common leading factor for both physical and mental issues among students and professionals due to different tasks and lifestyle. The upper trapezius muscle reacts strongly to stress, making it ideal for surface EMG recording[4].Electrodermal activity (EDA) reflects changes in skin conductance and resistance controlled by the autonomic nervous system. The EMG and EDA are recorded during the performance of tasks which involves physiological, psychological, visual and problem solving. The features extracted from the recorded EMG signal and the parameters of EDA helps in analysing the response of stress in the body. This helps to develop non-invasive, real-time stress monitoring tools for health and ergonomic use.

Keywords: Stress assessment, Upper trapezius muscle, Real-time stress detection.

1 INTRODUCTION

Stress has been a common amoung students and proffesionals leading to various musculoskeletal and mental issues. This takes place due to the frequent use of laptops and mobile phones and poor sleep habits causing neck and shoulder strain, mainly affecting the upper trapezius muscle. Studying stress-related changes in this muscle can help promote healthier habits and reduce such issues.

Electromyography (EMG) measures the electrical activity in muscles which is generated when muscle contraction takes place. These electrical signals show how motor units are recruited and how the muscle responds during activity.

This study uses surface EMG along with electrodermal activity (EDA) to determine the response of stress. EMG and EDA signals are recorded simultaneously during different tasks[4] to record both muscle signals and skin paramaters. The features extracted are then analyzed using machine language to determine the stress levels.[2] By this noninvasive method it offers a reliable approach for the real-time stress monitoring and future health applications.

2 LITERATURE SURVEY

Veneri et al. (2025)[5][6][7][8][9] compared the muscle activity while standing and seated yoga poses for 26 healthy adults using the Noraxon TeleMyo 2400GT system. It was found that standing poses activated leg muscles more, while seated poses increased the core muscle activity.

Pourmohammadi and Maleki (2020) used EMG and ECG signals of 34 students while performing mental and time-pressure tasks to detect stress. The machine learning models used by them showed high accuracy of 95-100% for two to four levels stress detection—proving the reliability of EMG in stress analysis.

Kelley et al.[10][11] (2019) studied the EMG activity of ten females during yoga poses like tree, half-moon, and warrior III. This resulted showing that single-leg poses increased demand on stabilizing muscles, with higher RMS values in ankle muscles compared to thigh muscles.

Wijsman et al. (2010) found that upper trapezius EMG signals effectively reflected the mental stress during arithmetic, logic, and memory tasks. The EMG amplitude rose and relaxation time decreased, also the mean and median frequencies dropped, this showed that the EMG can be used for real-time stress monitoring through muscle tension changes.

3 METHODOLOGY

The investigation of the stress was analysed based on the study of surface electromyography (sEMG) signals from the upper trapezius muscle and electrodermal activity (EDA) from the skin. Surface electromyography (sEMG) electrodes are placed on the upper trapezius muscle to record muscle signals from trapezius muscle. Simultaneously, electrodermal activity (EDA) will measure skin resistance and conductance. Each participant will perform various task for determining the stress levels.[4] The tasks are:
(1) visual
(2) physiological (hands raised at 45, 90 deg and squat)
(3) psychological
(4) problem solving

Each task will be conducted under controlled laboratory conditions for a time period of 5–10 minutes, by which the stress is analysed for each individual.

Prior to electrode placement, the skin is carefully prepared by cleaning with alcohol swabs to remove oils and dead cells, thereby lowering skin impedance and improving signal quality. The electrodes are then secured using medical-grade adhesive or straps to minimize motion artifacts during tasks. All connections are verified before data collection to ensure stable baseline readings.

Fig.1. EMG and EDA electrode placement

For EMG recording, surface electrodes are positioned on the upper trapezius muscle, typically at the midpoint between the C7 vertebra (base of the neck) and the acromion (tip of the shoulder), which is the region of maximal muscle activity during postural and stress-related tasks. This placement ensures optimal detection of muscle activation with minimal cross-talk from adjacent muscles. To complete the circuit and reduce electrical noise, a reference (ground) electrode is attached to a bony, electrically inactive site such as the clavicle or forearm. For EDA recording, two small electrodes are placed on the palmar surface of the fingers or the thenar/hypothenar region of the palm, where sweat gland density is high and skin conductance responses are most pronounced. This standardized placement improves signal quality and consistency across participants.

The EMG signals obtained using the BIOPAC MP45 from the upper trapezius muscle were preprocessed using the BIOPAC analysis to remove noise and improve accuracy in stress analysis. A two-step filtering method was used: a high-pass filter at 70 Hz removed low-frequency noise from movements and electrode drift, and an IIR bandpass filter (70–250 Hz) kept only the frequencies related to muscle activity. This improved the signal quality for analysis.Power Spectral Density (PSD) and Fast Fourier Transform (FFT) were then processed using the BIOPAC analysis which is used to study the frequency features of the EMG signals. Both methods show how signal power is spread across frequencies, mainly between 70 Hz and 250 Hz. FFT converts the signals into the frequency domain to find dominant frequencies, while PSD measures how power changes within this range. During stress, higher power and frequency shifts were seen, showing increased muscle activity. From these analyses, important features such as peak frequency, mean frequency, median frequency, frequency ratio, total spectral power, and zero crossing were extracted using the BIOPAC analysis. Time-domain features included mean, standard deviation, skewness, and kurtosis, while frequency-domain features included peak frequency, mean frequency, frequency ratio, and zero crossing.

Simultaneously, electrodermal activity (EDA) is measured using electrodes to determine the parameters like skin resistance and skin conductance and their correlation coefficient was calculated to determine the relationship between the parameters and analysed their stress levels. The extracted EMG and EDA features are then compared, after which machine language is applied to classify the subject's stress level. This integrated, multi-modal approach enhances both the reliability and accuracy of stress detection.

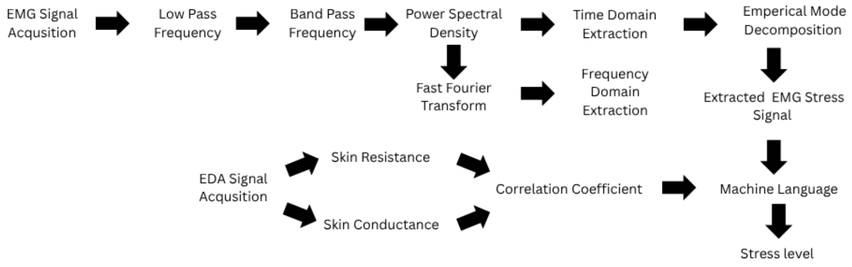

Fig.2. Block Diagram

4 RESULT

Stress levels are measured for the subjects of age 18–25 years old. For accurate stress analysis the BMI was maintained at a normal range of 18.5-24.9 kg/m².

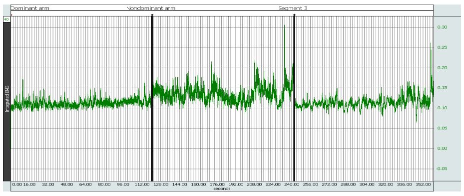

Fig.3. Recorded EMG Signal-Exercise (Male)

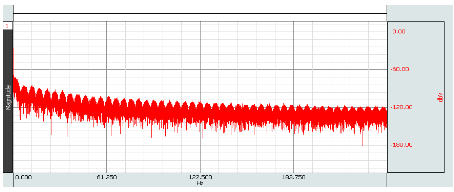

Fig.5.FFT-Exercise (Male)

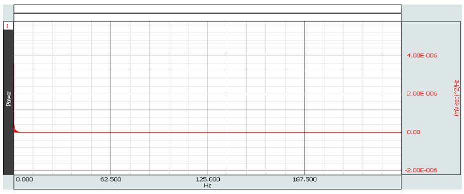

Fig.4.PSD-Exercise (Male)

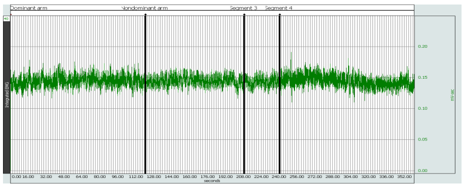

Fig.6. Recorded EMG Signal-Exercise (Female)

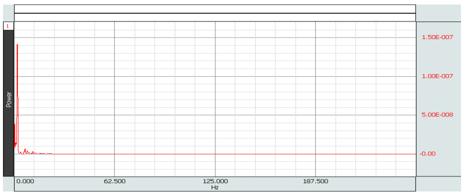

Fig.7.PSD-Exercise (Female)

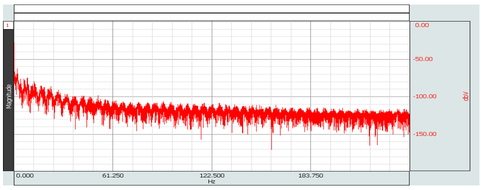

Fig.8.FFT-Exercise (Female)

For the male subjects, the FFT shown in fig.5 shows strong low-frequency components below 60 Hz and a PSD in fig.4 shows a peak of about 1.2 × 10^{-7} mV²·s/Hz, this indicates moderate muscle stress without fatigue. The EMG signal (fig.3) ranged from 0.10 to 0.18 mV·s, with higher activity in the dominant arm, showing greater muscle effort. For the female subjects, the EMG (fig.6) showed 0.10–0.18 mV·s which is stable, showing low and balanced muscle activity. The FFT in fig.8 also showed low-frequency dominance, and the PSD (fig.7) peak is ~1.5 × 10^{-7} mV²·s/Hz suggested minimal stress. Overall, the male subjects showed moderate muscular stress due to higher contraction effort, while the female subjects exhibited a low-stress, steady muscle response.

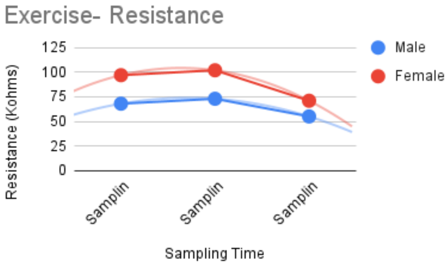

Fig.9. Resistance-Exercise

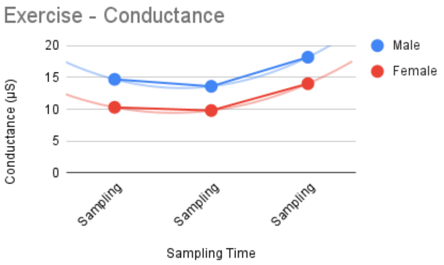

Fig.10. Conductance-Exercise

The results of EDA shown in fig.9 and fig.10 for the physiological task shows that conductance increases while resistance decreases under stress, confirming their inverse relationship. Male subjects recorded higher conductance values (15–20 µS) and lower resistance (60–75 kΩ), indicating greater physiological stress and sympathetic activation. In contrast, female subjects showed lower conductance (10–15 µS) and higher resistance (80–110 kΩ), reflecting lower stress levels and reduced sympathetic response during exercise.

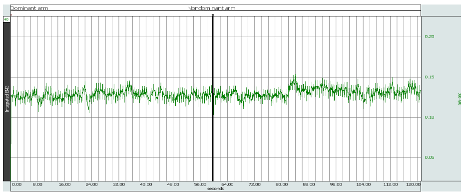

Fig.11. Recorded EMG Signal-Mnemonic Image (Male)

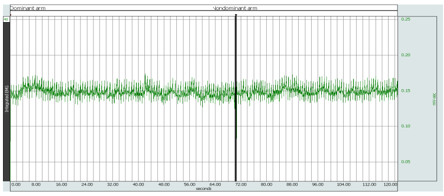

Fig.14. Recorded EMG Signal-Mnemonic Image (Female)

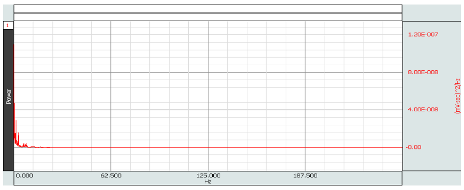

Fig.12.PSD-Mnemonic Image (Male)

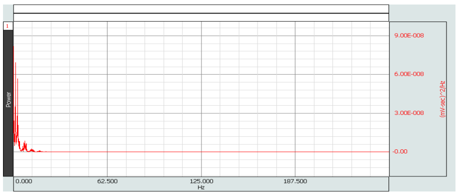

Fig.15.PSD-Mnemonic Image (Female)

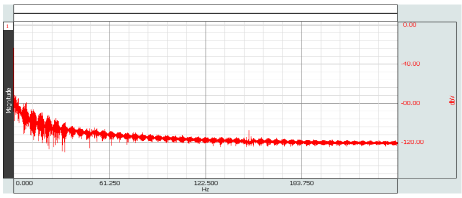

Fig.13.FFT-Mnemonic Image (Male)

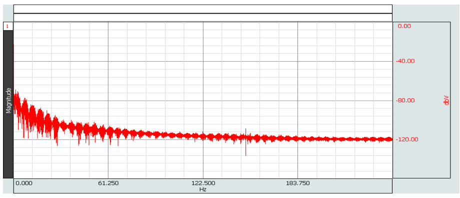

Fig.16.FFT-Mnemonic Image (Female)

For the male subjects, the EMG of fig.11 ranged from 0.10 to 0.18 mV·s, showing moderate muscle activation in the dominant arm. The FFT in fig.13 showed low frequencies below 60 Hz, and the PSD in fig.12 showed peak ~1.2×10^{-7} mV²·s/Hz indicating moderate stress without fatigue. For the female subjects, the EMG in fig.14 showed 0.12–0.18 mV·s which is steady, showing low and balanced activation. The FFT in fig.16 showed smooth low-frequency activity below 60 Hz, and the PSD in fig.15 showed peak of ~9×10^{-8} mV²·s/Hz indicating minimal stress. Overall, male subjects showed moderate muscular stress from higher effort, while female subjects remained in a low-stress, relaxed state.

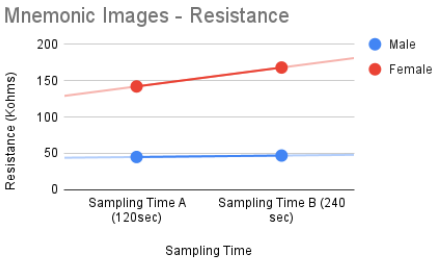

Fig.17. Resistance-Mnemonic Image

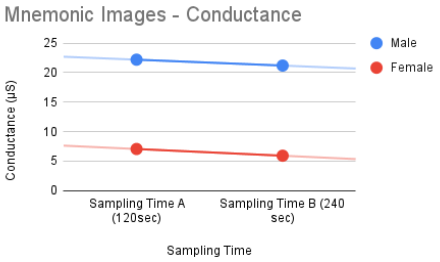

Fig.18. Conductance-Mnemonic Image

The results of EDA in fig.17 and fig.18 for visual task shows that male subjects had higher skin conductance (22–20 µS) than female subjects (7–5 µS), indicating greater physiological arousal and stress. The resistance of female subjects increased from 140 kΩ to 165 kΩ, showing reduced stress, while the resistance of male subjects remained steady at 45–50 kΩ, reflecting sustained moderate stress. Since conductance and resistance are inversely related, male subjects experienced moderate-to-high stress, whereas female subjects maintained a low-stress state

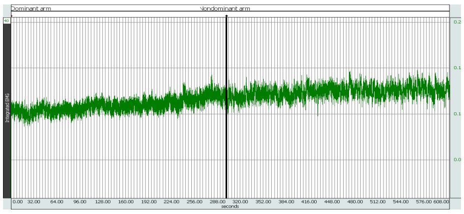

Fig.19. Recorded EMG Signal-Vedio game (Male)

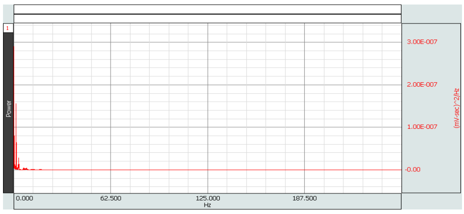

Fig.20.PSD-Video game (Male)

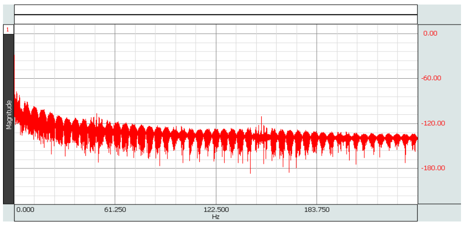

Fig.21.FFT-Video game (Male)

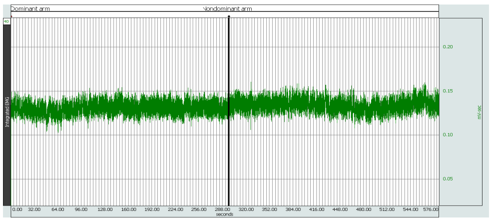

Fig.22.Recorded EMG Signal-Video game (Female)

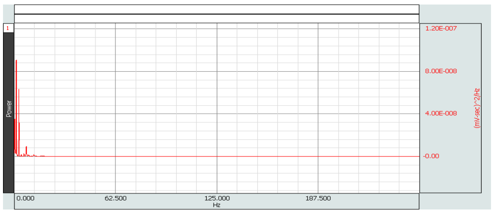

Fig.23.PSD-Video game (Female)

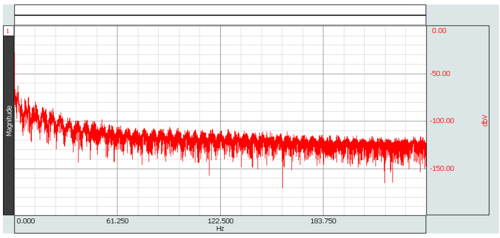

Fig.24.FFT-Video game (Female)

The EMG analysis during the gaming task shows that male subjects experienced higher neuromuscular stress compared to female subjects. For male subjects, the integrated EMG (fig.19) amplitude increased from 0.10 to 0.17 mV·s, and the PSD in fig.20 showed that peak reached about 3 × 10^{-7} mV²·s/Hz, indicating stronger muscle activation and greater stress. In contrast, female subjects showed a more stable EMG (fig.22) range of 0.10 to 0.15 mV·s with a lower PSD (fig.23) peak of around 1.2 × 10^{-7} mV²·s/Hz, suggesting lighter muscle activity and reduced stress. Overall, male subjects exhibited greater muscular effort and physiological stress during gameplay, while female subjects maintained a more relaxed, low-stress state.

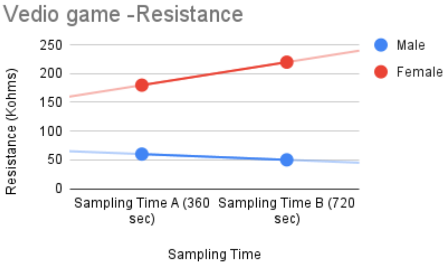

Fig.25. Resistance-Video game

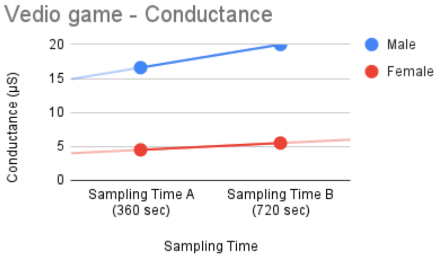

Fig.26. Conductance-Video game

Based on the EDA results shown in fig.25 and fig.26 during the gaming task, male subjects exhibited higher skin conductance values, increasing from approximately 16 µS to 20 µS, indicating greater sympathetic activation and higher stress levels. In contrast, female subjects showed lower conductance values, ranging from about 4 µS to 5 µS, suggesting lower physiological arousal. The resistance data followed an inverse trend, with female subjects showing an increase from approximately 170 kΩ to 220 kΩ, reflecting reduced stress, while male subjects showed a slight decrease from 55 kΩ to 45 kΩ, indicating sustained moderate stress. Overall, these results demonstrate that male subjects experienced higher stress levels than female subjects during the gaming task.

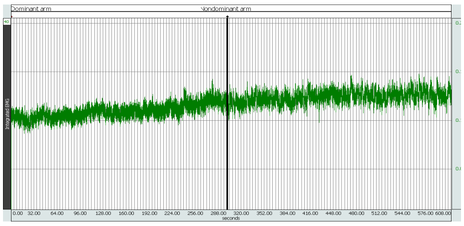

Fig.27. Recorded EMG Signal-Problem Solving (Male)

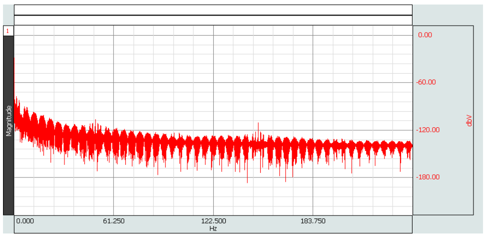

Fig.29.FFT-Problem Solving (Male)

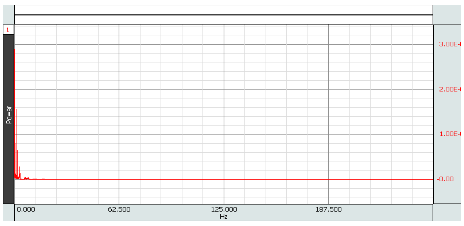

Fig.28.PSD-Problem Solving (Male)

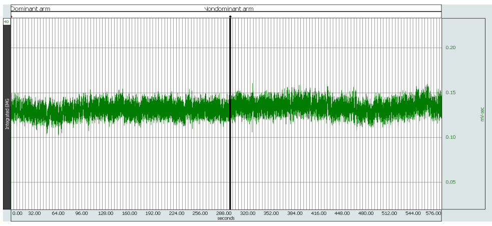

Fig.30. Recorded EMG Signal-Problem Solving (Female)

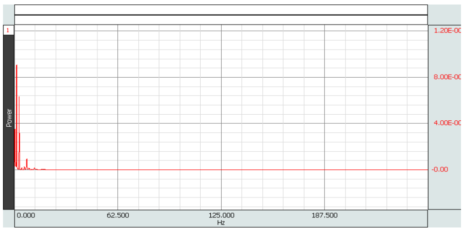

Fig.31.PSD-Problem Solving   Female)

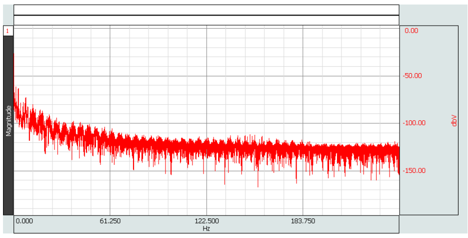

Fig.32.FFT-Problem Solving (Female)

Based on EMG analysis shown in fig.27 during the Problem Solving task, the integrated EMG (iEMG) for female subjects ranged from 0.12 to 0.19 mV·s, while for male subjects it was 0.10 to 0.17 mV·s, indicating greater muscle activation in female subjects. In the frequency spectrum (FFT), both gender subjects(fig.29 and fig.32) showed main activity below 60 Hz, typical for normal muscle function. However, the female spectrum was broader, showing more muscle effort and variability.The power spectral density (PSD) was also higher in female subjects as shown in fig.28 (≈2.6 × 10^{-7} mV^2·s/Hz) than in male subjects as shown in fig.31 (≈1.2 × 10^{-7} mV^2·s/Hz), confirming greater muscle activity. Overall, these results demonstrate that female subjects experienced higher neuromuscular stress, while male subjects showed more stable and controlled muscle activation, indicating a lower stress response.

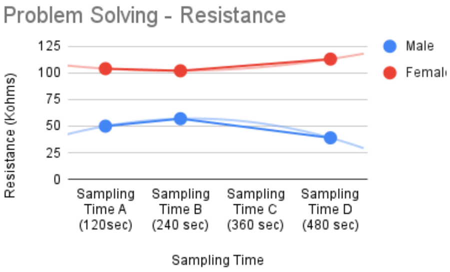

Fig.33. Resistance- Problem Solving

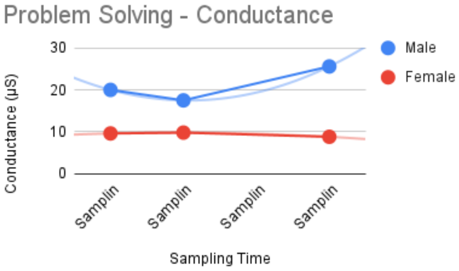

Fig.34. Conductance- Problem Solving

Based on the EDA results shown in fig.33 and fig.34 for the problem-solving task male subjects showed an increase in conductance (from ~18 µS to 28 µS) and a decrease in resistance (from ~60 kΩ to 30 kΩ), indicating higher stress and stronger sympathetic activation during the task. Female subjects had steady conductance (~9–10 µS) and high resistance (~100–115 kΩ), showing low stress and stable physiological responses. Overall, male subjects experienced greater stress during problem-solving, while female subjects remained calm and less physiologically affected.

Correlation analysis of the EDA parameters showed a strong relationship between skin resistance and conductance, providing a correlation coefficient of approximately 0.8705. This proves that the potential of EDA as a complementary measure to EMG for stress detection. The integration of both modalities forms the basis for developing a reliable, non-invasive classification model for stress levels.

Table 1 Correlation coefficient of EDA parameters -resistance and conductance

Task	Sample A	Sample B	Sample C
Maths Problem	-0.8967	-0.923	0.4754
Video game	-0.8802	-0.8404	-
Mnemonic image	-0.9021	-0.9111	-
Hands at 90 deg	-0.9576	-	-
Hands at 45 deg	-0.9536	-	-
Squat	-0.9657	-	-

5 CONCLUSION

The analysis reveals that the variations in the stress response were based on task-specific and gender. Male participants exhibited higher neuromuscular and physiological stress during exercise, mnemonic image tasks, and video game activities, as indicated by increased iEMG amplitudes, higher PSD peaks, and elevated skin conductance levels, while the female participants showed lower stress levels in these activities but showed higher stress during the task of problem-solving , dealing with psychology. Overall males experience greater physical stress, whereas females exhibit greater stress under cognitive challenge conditions, highlighting gender differences in physiological and cognitive stress adaptation.

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