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Original Article

Correlation of the Effects of Varied Degrees of Acute Heat on Electrocardiogram and Behavior of Rats

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ABSTRACT

Aim: Environmental heat alters the physiology of mammals, more specifically, the behavior and the morphology of the Electrocardiogram (ECG) subject. The objective of the current research work is to measure the impact of environmental temperature at three different ranges on the behavior and morphology of ECG waves of rats. **Materials and Methods:** A total of 32 male Wistar rats were divided into four groups (n=8 per group): control, 38°C, 40°C, and 42°C. **Results:** In contrast, R-wave amplitude remained relatively stable and the change was not statistically significant ($p > 0.05$). The heart rate significantly increased in the stress group of the rats. It is revealed that high environmental heat significantly changes the behavior and morphology of ECG waves of the subject, though it also depends on the level of environmental heat. The behavior analyses were performed just after the exposure in the Elevated Plus Maze (EPM) apparatus, the Open Field (OF), and the Y Maze. ECG waves were recorded after the removal of rats from the incubator using a Biopac MP45 recorder. Immobilisation significantly increased, and the number of rearing and time spent in the periphery decreased. Increase in the duration of transfer latency and percentage of time spent in closed arm and a significant decrease % in the percentage of time in open arm and the number of arms crossed, with an increase in body temperature. **Conclusion:** High environmental temperatures markedly alter rat behavior and ECG morphology, emphasizing careful interpretation in thermoregulatory studies.

Keywords: Acute Heat Stress, Behaviour, ECG Parameters, Hyperthermia, Heat toxicity, Rats.

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INTRODUCTION

Thermal environmental temperatures are the natural conditions in which organism perform their functions properly.[1] Extreme events like heat waves have increased in duration & and frequency over the last decades.[2] These discrete climatic events are supposed to become even more recurrent and severe.[3] Recent research indicates that the degree of thermoregulatory activity and the duration, intensity, and adjustment to high environmental heat affect various physiological functions.[4] Environmental heat causes stress in animals by creating irritations and discomfort.[5] The animal changes their physiological functions and behavior to maintain the internal temperature of the body. For mammalian survival, maintenance of the temperature of their body at a particular range is important, where they maintain the temperature in the body by many behavioral and physiological mechanisms to support many biochemical processes occurring in the body.[6,7] Mammals are sensitive to the stimulation of heat.[8]

An extreme rise in body temperature may produce different types of neurological symptoms responsible for the generation of seizures.[9] Hyperthermia increases the excitability of neurons, and susceptibility to seizures, and exerts effects on learning and memory.[10] For instance, hyperthermia negatively affects various functions of the brain (e.g., cognitive function, memory, making of decisions, and anxiety-related behavior).[11] In the recent past, a few research works have been published in which the impact of high environmental heat on behavioral parameters has been reported. Rats are a very common species that are used to study physiological and electrophysiological research due to their physiological and morphological similarity with humans.[12] There are various methods and appendices available to analyze the behavior of rodents, such as the Elevated Plus Maze (EPM), Open Field Test (OFT), and Y maze.[13]

The Electrocardiogram (ECG) is an important tool for evaluating cardiac functions by analyzing its electrical activities. Heat stress has a direct impact on the number of fundamental cardiac regulating mechanisms of stroke volume mechanisms.[14] Heat stress frequently leads to tachyarrhythmias and hypotension.[15] The changes in ECG waves, interval, and amplitude are very

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important to investigate the effect of high environmental temperature on the heart.[16] Amer and the research team displayed the significance of ECG waves and Blood Pressure (BP) due to heat stress.[17] Research work was done on the ECG wave changes during acute mental stress.[18] However, this research work on the changes in the morphological parameters of ECG waves under different degrees of hyperthermia is absent.

This research work is designed to investigate the changes in behavioral activities and morphological variations in ECG parameters in rats following exposure to high environmental heat at three different temperatures, such as 38°C, 40°C, and 42°C. Only behavioral study is not enough to explain the effects of high temperature in the body, so in this work, we have tried to study how environmental heat affects the ECG morphology and correlated these two parameters to get more information for studying the effect of a hot environment on the body.

MATERIALS AND METHODS

All the experimental works were done on thirty-two young male Wistar rats of 190±10 g weight, obtained from the Animal House, BIT, Mesra. Separately housed rats were kept in polypropylene cages of 25 cm x 13 cm x 12 cm, which were acclimated at a room temperature of 24°C and 12L: 12D (light during the hours of 7 a.m. to 7 p.m.) cycle with food and water *ad libitum*.

Model of Heat Stress

The rats were placed inside a well-ventilated Biological Oxygen Demand (BOD) incubator at three different temperatures with a relative humidity of 40-50% to be exposed to a hot environment. Four equal groups were divided with a total number of rats. For the experiment, the control (24±1°C, n=8) rat and heat exposure at 38°C (n=8) for 4 hr,[19] 40°C (n=8) for 30 min[20] and 42°C (n=8) for 20 min[21] were used. The different exposure durations were chosen based on previously established models of heat stress, representing mild, moderate, and severe stress levels, respectively. These durations were carefully selected to induce progressive physiological and behavioral changes without causing immediate mortality, while ensuring reliable and ethically acceptable measurements. Despite the differences in exposure time, the effects observed on body temperature, faecal pellet output, and other stress markers were primarily driven by temperature severity, as confirmed by two-way ANOVA. Each group of rats was divided equally into two groups: (i) ECG wave recording and (ii) Behaviour recording.

ECG Waves Recording and Processing

After removal from the BOD incubator, rats were anesthetized with ether anesthesia. In the stabilized animal, the ECG wave signals were recorded continually with the help of a non-invasive clip. The digital ECG wave data were recorded with a sampling rate of 250 samples/sec using lead II electrodes and two-channel bio amplifiers (MP45, Biopac, USA). The data obtained are preprocessed for morphological analysis. The morphological studies are based on the duration and amplitudes of the parameters listed in Table 1.

Behavioural Activity Observation

With single-sense heat exposure, changes in the behavior of rats were recorded through the EPM, OFT[22] and Y maze.[23] The major purpose of the OFT was to measure the animals' instances of fear and anxiety. The EPM was utilised to assess subjects' emotional stability or level of anxiety, and the Y maze was used to measure the short-term memory in rats.

Open Field Test (OFT)

The field was an 84 cm outer circumference and a spherical arena. There were 16 squares along the periphery. Eight squares made up the 56 cm diameter of the middle, and four squares in the inner concentric circle. For the activity testing, the lamp was placed above the field to provide proper illumination. Each rat was assessed for 3 min in the OFT apparatus with the subject at the centre of the maze using the following behavioral parameters: (i) Immobilization: These rats showed open eyes and kept their heads up as anti-gravity. (ii) Grooming: Biting and pad cleaning incidents may occur during movements of the paw over the head and/or face for cleaning the face. (iii) Rearing: Constantly standing on its hind limb only. (iv) Ambulation: When all limbs of the rat are at a specific square (either centre or periphery).[24]

Elevated Plus-Maze (EPM)

The EPM had two open (50 cm × 10 cm) with open uncovered roofs and two closed arms (50 cm × 10 cm × 40 cm) at a right angle, an open central crossing (10 cm × 10 cm), and a height of 50 cm from the ground. Each rat's behavior was tested for a duration of 5 min in the EPM[25] by putting the animal at the ends of an open arm: (i) Transfer Latency: the total time taken by the animal in seconds to move from the outermost end of the open arm to any of the two closed arms. (ii) % Time in open arms: The % of total testing time spent in the open arm. (iii) % Time at the central crossing: Total time testing % percentage of total testing time spent at the crossing of open and crossed arms. (iv) Number of crossings of arms: The number of times the animal crosses the centre for going from one arm to any other of the three arms.

Y Maze Test

The Y Maze had three arms with dimensions of (50 cm × 10 cm × 20 cm). The behaviour of all rats was measured for 15 min in the Y maze by putting the animal at the C arm edges using spontaneous alternation parameters: The % spatial alternation: loss in spatial alternation occurs when the rat enters 3 different arms of the maze in each consecutive arm entries.[23,26]

Markers of Heat Stress

Two established biomarkers were used to confirm heat stress and hyperthermia produced in rats with whole-body hyperthermia at different temperatures, as mentioned during the experiment.

Body Temperature

The temperature of a rat's body was used as an important indicator for animal responses to hot environments.[27] The temperature of the rat's body was measured before and immediately after exposure to high heat and compared with the control group of the subject. The body temperature was recorded using a telethermometer (Scan-96, Micron, India), which was connected to a thermistor probe.[28]

Fecal Pellets

Fecal pellets were excreted by rats during the period of incubation and were counted on the day of the experiment.[29]

Statistical Analysis

Data were checked for accuracy and analysed using Microsoft Excel 2021 and Origin software. All data were first tested for normality using the Shapiro-Wilk test. Physiological biomarkers (body temperature and faecal pellet output) were analysed using two-way ANOVA with temperature and condition (control vs. heat-stressed) as factors for normally distributed data; non-parametric tests were applied if normality was violated. ECG morphology and behavioural parameters were analysed using one-way ANOVA among control, 38°C, 40°C, and 42°C groups, with non-parametric alternatives used when required. Data are presented as mean±Standard Error of the Mean (SEM), and significance was set at $p<0.05$. Associations between ECG morphological and behavioural parameters were assessed using Spearman rank correlation analysis.

RESULTS

Markers of Heat Stress Results

Two-way ANOVA revealed significant effects of temperature and heat exposure on physiological stress markers. Core body temperature showed significant effects of temperature ($F(2,42)=31.19$, $p<0.001$), condition ($F(1,42)=474.10$, $p<0.001$), and their interaction ($F(2,42)=72.71$, $p<0.001$), indicating a progressive increase in body temperature in heat-exposed rats across 38°C, 40°C, and 42°C. Acute heat exposure significantly increased body temperature at all tested temperatures. Faecal pellet output, used as a behavioural stress indicator, showed a significant main effect of condition ($F(1,42)=23.75$, $p<0.001$), whereas the effects of temperature ($F(2,42)=2.93$, $p=0.064$) and temperature × condition interaction ($F(2,42)=2.11$, $p=0.133$) were not statistically significant. Faecal pellet output was significantly elevated in stressed rats at 40°C and 42°C, but not at 38°C. These findings indicate that acute heat exposure significantly elevates both physiological and behavioural stress responses in rats, see Table 2.

Morphological Studies of ECG parameters results

One-way ANOVA revealed that acute heat stress significantly altered ECG morphology across all experimental conditions. Heart rate progressively increased with temperature, rising from 386±6.64 bpm in controls to 445±1.23 bpm at 42°C ($p<0.001$). This tachycardia was accompanied by temperature-dependent shortening of duration-based parameters, including RR, PP, and PR intervals ($p<0.001$). Similarly, the QRS complex and QT intervals showed significant reductions ($p<0.001$), while the QTc interval decreased moderately ($p<0.005$). Analysis of wave amplitudes demonstrated marked physiological shifts: P, Q, and T waves all changed significantly ($p<0.001$), with the T-wave notably transitioning from a positive deflection in controls to a negative deflection at 42°C, while the S-wave became increasingly negative at higher temperatures ($p<0.005$). In contrast, R-wave amplitude remained relatively stable and did not reach statistical significance ($p>0.05$). Collectively, these findings indicate that extreme thermal exposure induces substantial electrical remodelling and accelerates cardiac cycles in heat-stressed rats, see Figure 1.

Behavior Analysis Results

In comparison to the control group, the behavioral analysis findings recorded after acute heat stress at different temperatures demonstrate remarkable changes in the behavior of the rats have been recorded in OFT, EPM and Y maze.

Effect of Heat Stress on the Behavior of Rats

Behavioral assessments following acute heat exposure revealed temperature-dependent alterations in the behavioral profile of rats. Behavioral data were analyzed using one-way analysis of variance (ANOVA) to compare differences among control, 38°C,

Table 1: Description of morphological parameters of ECG waves.

Parameters	Descriptions
RR (ms)	The time intervals between consecutive heart beats
PP (ms)	Interval between the P waves due to atrial depolarization
PR (ms)	Time between arterial depolarization and conduction through Atrioventricular (AV) nodes
HR (bpm)	Heart rate in Beats per minute
QRS (ms)	Time between ventricular depolarization and ventricular repolarization
QT (ms)	Duration of ventricular depolarization and repolarization
R (mV)	Rapid ventricular depolarization

40°C, and 42°C groups. Data from the OFT, EPM, and Y-maze indicated that thermal stress significantly affected locomotor activity, exploratory behavior, anxiety-like responses, and spatial working memory. Immobilization time and rearing behavior showed significant group differences ($p<0.001$), with marked alterations observed at higher temperatures. In the EPM, transfer latency and open arm exploration were also significantly affected ($p<0.05$), particularly at 42°C exposure. Percentage spatial alternation in the Y-maze demonstrated the most pronounced decline, showing a highly significant temperature-dependent reduction ($p<0.001$), indicating impairment of spatial working memory. Periphery exploration showed an overall significant group effect ($p<0.01$), although individual comparisons were not significant. In contrast, parameters such as arm entries, grooming behavior, centre exploration, and closed arm entries did not show significant changes ($p>0.05$), suggesting relative resistance of these behaviors to acute thermal stress (Figures 2-5).

Correlation between changes in behavior and ECG

Spearman correlation analysis revealed significant associations between behavioural parameters and ECG morphological indices ($p<0.05$). Grooming showed a negative correlation with the QTc interval (R=-0.7596, $p=0.0423$), while transfer latency was negatively correlated with QRS duration (R=−0.7985, $p=0.0232$). Open arm activity demonstrated negative correlations with QT (R=−0.7835, $p=0.0238$) and QTc (R=−0.5611, $p=0.0411$) intervals. Although overall group differences for mean R-wave amplitude were not statistically significant ($p>0.05$), spatial alternation was negatively correlated with R-wave amplitude (R = -0.6312, $p=0.0357$), and central activity showed a positive correlation with R-wave amplitude (R = 0.8018, $p=0.0321$), whereas immobilization (R=0.7715, $p=0.0381$) and number of arm entries (R=0.9370, $p=0.0048$) were positively correlated with Q-wave amplitude.

DISCUSSION

Body temperature and the number of faecal pellets released are well-established indicators of heat stress & and hyperthermia, and the study has shown that exposure to heat at different temperatures causes significant variation in the given parameters. The current report's changes in stress indices are similar to the clinical symptoms.[30,31] An increase in body temperature has a major role in the activation phenomenon, which releases body heat.[31] The body temperature is monitored by the preoptic nucleus of the autonomic nervous system (ANS).[32] The mammalian brain hypothalamus contains thermosensory neurons, which

Table 2: Physiological responses to acute heat exposure. Data are expressed as mean±SEM (n=8 per group). Statistical analysis was performed using two-way Analysis of Variance (ANOVA) with temperature and condition (control vs. heat-stressed) as factors. Exact p-values are reported in the table. Statistical significance is indicated by an asterisk (*) for $p<0.05$, representing a significant difference between control and heat-stressed groups at the same temperature.

Parameters	Temperature (°C)	Control Mean±SE	Stress Mean±SE	*p*-value
Body temperature (°C)	38°C	37.90±0.02	38.77±0.03*	<0.0001
	40°C	38.00±0.11	39.10±0.16*	<0.0001
	42°C	37.60±0.07	40.46±0.06*	<0.0001
Faecal pellet (number)	38°C	1.5±0.26	2.25±0.49	0.2011
	40°C	1.5±0.42	2.88±0.39*	0.0328
	42°C	1.62±0.18	3.88±0.35*	<0.0001

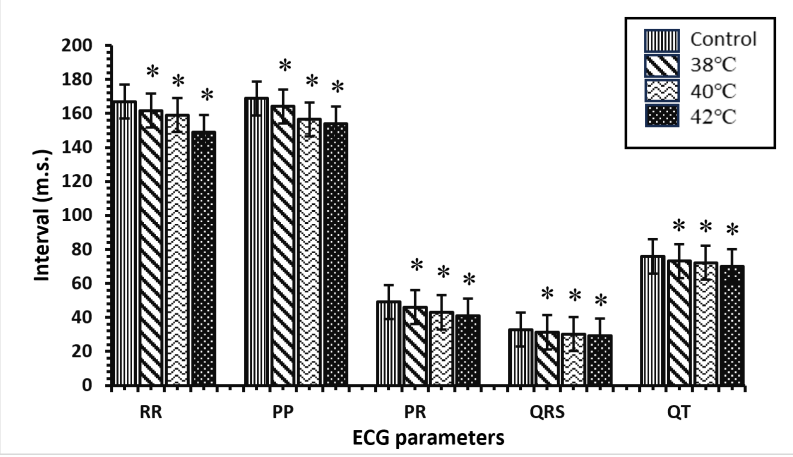

Figure 1: Effect of acute heat exposure on ECG interval parameters. Bar graphs showing RR, PP, PR, QRS, and QT intervals in control and heat-exposed groups (38°C, 40°C, and 42°C). Data are presented as mean±SE (n=8 per group). One-way Analysis of Variance (ANOVA) followed by post-hoc multiple comparison analysis revealed a significant, temperature-dependent shortening of all interval parameters compared with the control group. *$p<0.05$ versus control.

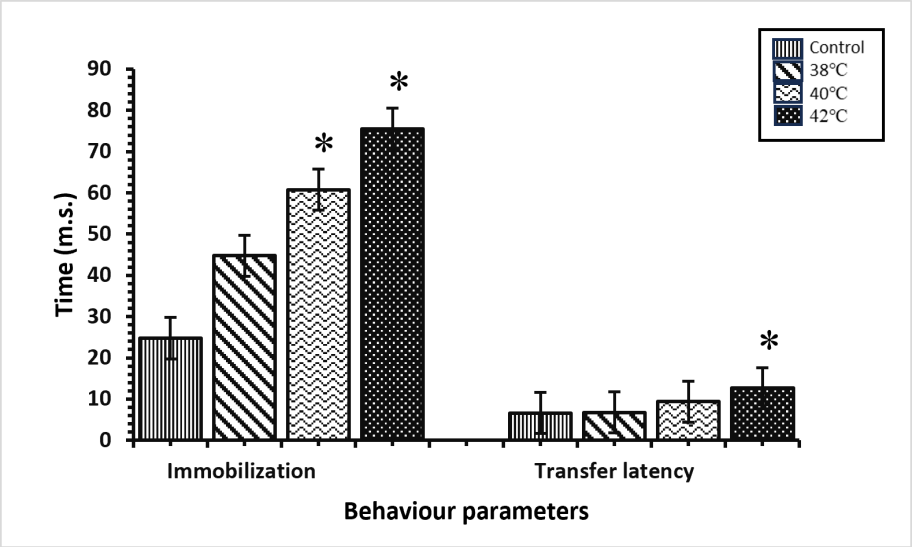

Figure 2: Immobilization (sec) in OFT and transfer latency (sec) in EPM results in a hot environment at three different temperatures. Data are represented as Mean (± S.E.) and compared with the control group. *$p<0.05$ indicates statistical significance compared with the control group.

sense a change in core body temperature, and it also merges the peripheral and central heat information to elicit the release of body heat. When the hypothalamus temperature increases above the normal range, many heat dissipation responses begin to decrease the body temperature so that the temperature can be returned to the hypothalamic temperature set point.

Fecal pellet output is widely used as an indicator of emotionality and physiological stress in rodents. Increased defecation during stressful conditions is generally associated with activation of the autonomic nervous system and heightened emotional reactivity. Previous studies have reported that stress can alter gastrointestinal motility through autonomic imbalance, leading to increased pellet elimination. Therefore, the elevated number of fecal pellets observed in the heat-exposed groups in the present study likely reflects a stress-induced autonomic response and increased emotionality rather than a specific neural stimulation mechanism.[33]

In the current study, the changes in behavior caused by a single heat exposure were analysed[34] in the rats. The changes in behavior caused by acute exposure at different temperatures to a hot environment are investigated in the OFT, Y maze, and EPM apparatus while considering the results in changes in stress indices. Hot environmental stress activates the limbic areas and projects pathways to the hypothalamus from these areas, which stimulates the release of Corticotropic Hormones (CRH) into the Hypothalamic-Pituitary-Adrenal (HPA) axis[35,36] CRH stimulates the pituitary gland to increase the secretion of corticotropes and also enhances the sympathetic outflow to the adrenals, which results in the enhanced output of corticomedullary hormones and may also cause abnormality in the behavior of the subject. Increased immobility in OFT and increased transfer latency in EPM were caused by prolonged single exposure to high ambient heat. Hypoactivity in OFT follows total inactivation or enhanced inhibition of neuronal activity in the ventral hippocampus, in line with the view that ventral hippocampus activity reduces locomotor activity.[37] In addition to these alterations, the decrease in rearing and ambulation also demonstrated that acute heat exposure led to fatigue and altered nervous system excitability. Heat exposure can influence neurochemical pathways involved in stress and emotional regulation. However, the relationship between acute heat stress and serotonergic (5-HT) activity remains complex and not consistently reported.[38] Therefore, the anxiety-like behavioural changes observed in the present study may reflect general stress-induced neurochemical alterations, which may contribute to the decreased rearing behaviour in heat-exposed rats. Furthermore, the reduced locomotor activity observed in the elevated plus maze should be interpreted cautiously. Decreased arm crossings and increased immobility may reflect fatigue, reduced exploratory behaviour, or stress-induced hypoactivity rather than sleep, as sleep parameters were not directly measured. The increase in grooming is because they spread the saliva over themselves to maintain their body temperature.[39] Interestingly, the time spent grooming was not increased in rats, suggesting that heat-acclimatized rats develop their thermolytic organs, such as the tails, and increase the density of arteriovenous anastomoses to enhance heat dissipation without saliva-spreading.[40] Subsequently, while ambulation testing with the OFT, subjects displayed increased immobility.

Later on, in EPM, animals prefer to remain in the closed arms of the apparatus, perhaps because they are seeking protective shelter. Eventually, it was found that they fell asleep, which decreased the number of arms crossed and the percentage of time spent in open arms. Ventral hippocampal (v CA1) contains calbindin1 positive neurons (calb 1+) neurons activated at to close arm transition, which helps in decision making. The posterior Basolateral amygdala (BLp) connection controls decision-making towards

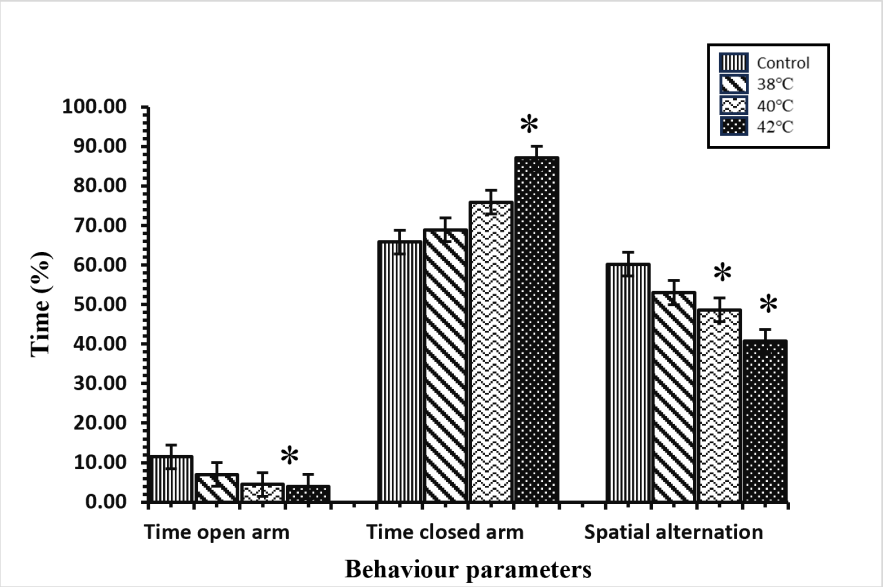

Figure 3: Time spent in open arm and closed arm in elevated plus maze and instantaneous loss in spatial alternation memory (% age) like behaviors using Y maze in a hot environment at different temperatures. Data represented as mean (±S.E.) and compared with the control group. *p<0.05 indicates statistical significance compared with the control group.

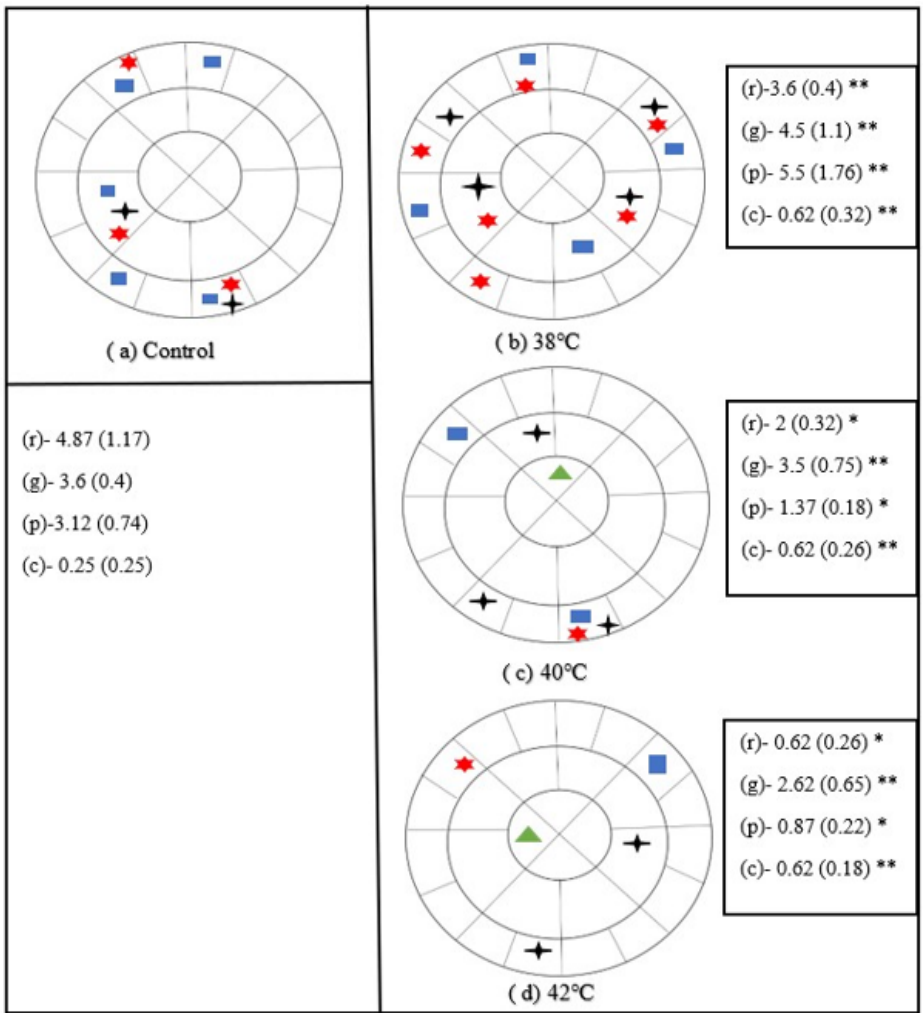

Figure 4: Anxiety-related behaviors to the hot environment using the Open Field Test. (A) Control (B) 38ºC (C) 40ºC (D) 42ºC. Data are represented as Mean (±S.E.) and compared with the control group *p<0.05, p<0.01; ns = non-significant. Rearing (r) (number), Grooming (g) (number), Periphery (p) (number), Central (c) (number) . Rearing (r), Grooming (g), Periphery (p), Central (c). Rearing (r) Grooming (g) periphery (p) Central (c).

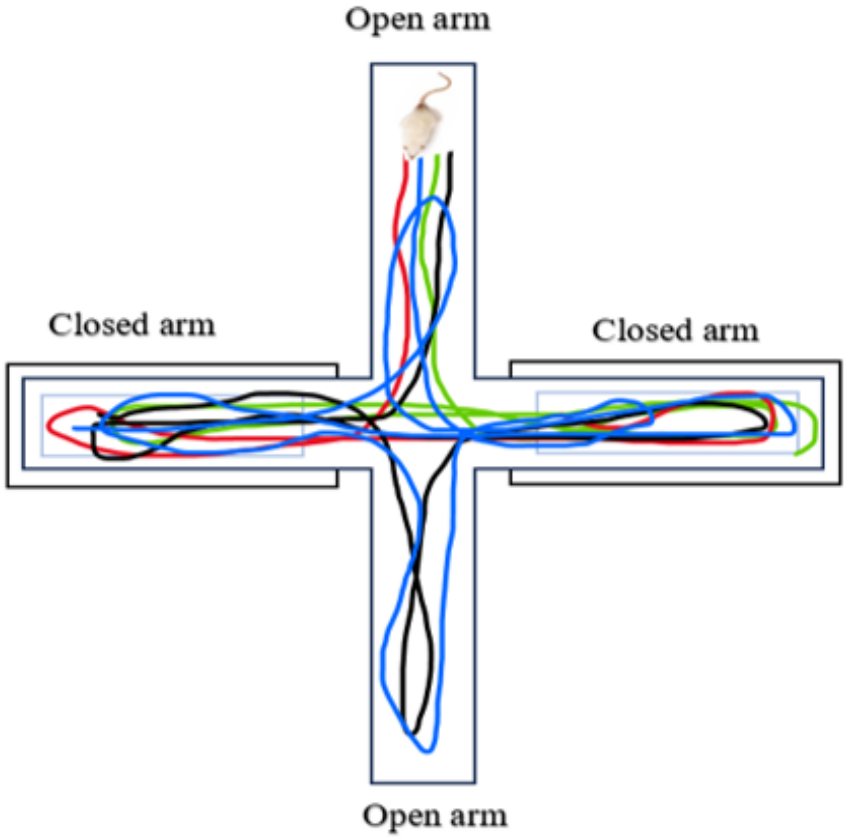

Figure 5: Movement track by a rat in elevated plus maze Control - Blue, 38ºC- Black-, 40ºC- Red, and 42ºC- Green.

the approach.[41] Time spent in the centre square, which serves as an index of exploratory behavior,[42] was higher in all the stressed groups than in the control. These results suggest that rats of the stressed group might have had increased antinociception owing to higher NA (noradrenaline) levels, which increased their exploration behavior.

Based on the literature, the % instantaneous loss in spatial alternation decreased with an increase in body temperature due to the activation of caspase 3, which is associated with an increase in the number of pyknotic neurons and Fluoro-Jade C (FJ-C) positive cells in the Cornu Ammonia (CA3) region of the hippocampus in the rat.[43] An increase in anxiety may also be caused by the anterior Basolateral Amygdala (BLa) -ventral hippocampal CA1(vCA1) synapse. Glutamergic excitatory projections from BLA to the VCA1 are sufficient to mediate anxiety.[44]

In Wistar rats, the ECG delineation provides fundamental features such as the duration and amplitude of each cardiac beat. This information can be utilized to evaluate the effects of heat on the environment in the body. In this respect, very good performance is required to identify the peaks, waves, and boundaries of ECG points. Neurohumoral agents primarily activate a variety of G-Protein-Coupled Receptors (GPCR) in the sarcolemma of (sinoatrial node) SAN myocytes.[45] A change in HR results from GPCR activating second messenger cascades that target intracellular components involved in SAN automaticity.[46] Numerous variables that affect SAN activity have been well investigated and are recognized as being crucial for the regulation of HR. Due to hyperthermia, an increase in heart rate and increased sympathetic activity are elicited by a hot environment. Hyperthermia is known to activate the sympathetic nervous system while suppressing parasympathetic tone as part of the thermoregulatory response. This autonomic shift leads to tachycardia and shortening of cardiac cycle intervals, including RR and QT intervals. Similar reductions in ECG intervals during hyperthermia have been reported in experimental and clinical studies, primarily due to increased heart rate and enhanced sympathetic drive an increase in heart rate shortens the QT interval, as similarly reported by Magri and coworkers.[47] When beagle dogs undergo artificial heating,[48] they found that hyperthermia shortens the QT interval. This can be explained by tachycardia, which reduces the QT interval by shortening the cardiac cycle associated with heat. On the other hand, research[49] found that individuals with heat stroke had prolonged QT intervals. As all ECG waves and intervals shortened with an increase in heart rate, the RR interval was considered representative of overall ECG changes.

Thus, it can be suggested that the changes in behavior in rats are effectively correlated with physiological variables. The data

of the research indicates that the single heat stress induces minor changes in emotionality and behavior parameters in the 38°C-temperature group of rats, but high alternation can be seen in the other two different temperature (40°C and 42°C) groups of rats. So, the assessment and monitoring of behavioral activities in a hot environment can be considered an important parameter in psychophysiological monitoring.

CONCLUSION

The findings of this study may aid in the development of a novel strategy for understanding mammals' activities in thermoregulation in different high environmental temperatures. It is revealed that high environmental heat significantly changes the behavior and morphology of ECG waves of the subject, though it also depends on the level of environmental heat & artificial temperatures. The current work may help minimize misinterpretation of the Electrocardiogram (ECG) in rodents and advance experimental cardiology's knowledge of electrocardiography.

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ABBREVIATIONS

ANS: Autonomic Nervous System; **AV:** Atrioventricular; **BLA:** Basolateral Amygdala; **BLp:** Posterior Basolateral Amygdala; **BOD:** Biological Oxygen Demand (Incubator); **BP:** Blood Pressure; **CA1:** Cornu Ammonis 1 (region of hippocampus); **CA3:** Cornu Ammonis 3 (region of hippocampus); **CRH:** Corticotropin-Releasing Hormone; **ECG:** Electrocardiogram; **EPM:** Elevated Plus Maze; **FJ-C:** Fluoro-Jade C; **GPCR:** G-Protein Coupled Receptors; **HF:** High Frequency (HRV component, if needed); **HR:** Heart Rate; **HRV:** Heart Rate Variability; **HPA:** Hypothalamic-Pituitary-Adrenal (axis); **ms:** Milliseconds; **mV:** Millivolt; **OF:** Open Field; **OFT:** Open Field Test; **PP:** P wave interval; **PR:** PR interval (time between atrial depolarization and conduction through AV node); **QT:** QT interval (ventricular depolarization and repolarization duration); **QRS:** QRS complex interval (ventricular depolarization); **REM:** Rapid Eye Movement; **RR:** R-R interval (time between consecutive heartbeats); **SAN:** Sinoatrial Node; **SD:** Standard Deviation; **SE:** Standard Error; **vCA1:** Ventral Cornu Ammonis 1 (region of hippocampus); Y **Maze:** Y-shaped Maze for spatial memory assessment.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICAL STATEMENT

The experimental works were done at Birla Institute of Technology (BIT), Mesra, Ranchi, (India, with the principles of ethics in animal experiments, with the approval of the Institutional Animal Ethics Committee (IAEC), ethical community on the animal experimentations (protocol #1972/PH/BIT/05/23/IAEC) dated 21 January 2023.

FUNDING

The authors received no funding from their institutes for this work.

SUMMARY

This study examined the effects of acute heat exposure (38°C, 40°C, 42°C) on Electrocardiogram (ECG) morphology and behavior in Wistar rats. Thirty-two rats were divided into control and experimental groups, exposed to heat in a BOD incubator, and assessed using ECG recordings and behavioral tests (Open Field Test, Elevated Plus Maze, and Y Maze). Heat stress significantly reduced RR, PR, QRS, and QT intervals and increased heart rate, while R-wave amplitude remained relatively stable ($p > 0.05$). Behavioral results showed higher immobilization and anxiety-like responses, along with reduced rearing, locomotion, and memory performance. Overall, acute hyperthermia caused notable disturbances in both cardiac and behavioral functions, with severity depending on temperature. These findings highlight a strong connection between cardiovascular changes and behavioral alterations under heat stress.

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