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RESEARCH ARTICLE

Autonomic Function and Cardiovascular Reactivity to Mental Stress in Patients with Anxiety Disorders: A Comparative Study with Healthy Controls

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ABSTRACT

Background: Anxiety disorders are associated with persistent psychological arousal and altered autonomic regulation. Changes in heart rate variability (HRV), blood pressure and cardiovascular responses to acute mental stress may reflect impaired sympathovagal balance. The present study was undertaken to compare resting autonomic function and cardiovascular reactivity to mental stress among patients with anxiety disorders and healthy controls.

Materials and Methods: A comparative cross-sectional study was conducted among 60 patients diagnosed with anxiety disorders and 60 age- and sex-matched healthy controls. Participants underwent baseline assessment of heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP) and short-term HRV. Cardiovascular reactivity was assessed during a standardized mental arithmetic stress test and during a post-stress recovery period. HRV parameters included SDNN, RMSSD, high-frequency (HF) power and LF/HF ratio. Independent-samples t-test, paired t-test and repeated-measures analysis of variance were used for statistical comparison. A p value <0.05 was considered statistically significant.

Results: Patients with anxiety disorders demonstrated significantly higher resting HR and lower RMSSD and HF-HRV compared with healthy controls. During mental stress, patients showed a significantly greater increase in HR, SBP, DBP and LF/HF ratio and a greater reduction in RMSSD compared with controls. Recovery of HR and SBP after cessation of stress was significantly slower in patients than in controls. The between-group difference in cardiovascular reactivity was statistically significant for HR, SBP, RMSSD and LF/HF ratio ($p<0.001$).

Conclusion: Patients with anxiety disorders demonstrated altered resting autonomic function, characterized predominantly by reduced parasympathetic cardiac modulation, together with exaggerated cardiovascular reactivity and delayed recovery following mental stress. Assessment of autonomic and cardiovascular stress responses may provide useful physiological markers of autonomic dysregulation in anxiety disorders.

Keywords: Anxiety disorders; autonomic nervous system; heart rate variability; mental stress; cardiovascular reactivity; sympathetic activity; parasympathetic activity; blood pressure.

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Introduction

Anxiety disorders are among the most common psychiatric disorders and are characterized by excessive fear, apprehension, worry and associated physiological manifestations. Activation of the autonomic nervous system plays an important role in the physiological response to psychological stress, with sympathetic activation producing cardiovascular arousal and parasympathetic activity contributing to recovery. Alterations in autonomic regulation have therefore been increasingly investigated as potential physiological correlates of anxiety disorders. **[1]**

Heart rate variability (HRV), which reflects beat-to-beat fluctuations in cardiac cycle length, is a widely used non-invasive measure of cardiac autonomic regulation. Reduced HRV, particularly indices reflecting vagal modulation such as RMSSD and high-frequency HRV,

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has been reported in individuals with anxiety disorders. A meta-analysis demonstrated significantly reduced resting parasympathetic HRV in patients with anxiety disorders compared with healthy controls, supporting the presence of altered autonomic regulation in this population. [2]

Individual studies have also demonstrated differences in autonomic function among specific anxiety disorders. Patients with panic disorder have been reported to show altered HRV and autonomic responses, suggesting impaired cardiac autonomic regulation even at rest. [3] Similarly, patients with generalized anxiety disorder have demonstrated reduced HRV and altered cardiac autonomic responses during resting conditions and experimentally induced worry. [4]

Mental stress provides a useful physiological model for evaluating autonomic cardiovascular reactivity. Acute cognitive stress normally produces an increase in heart rate and blood pressure through activation of sympathetic cardiovascular mechanisms. However, individuals with anxiety disorders may exhibit an exaggerated or prolonged cardiovascular response because of altered autonomic regulation and increased physiological arousal. Studies investigating stress responses in anxiety disorders have reported differences in HRV and cardiovascular reactivity compared with healthy individuals. [5]

Although resting HRV has been extensively studied in anxiety disorders, fewer studies have simultaneously assessed resting autonomic function, cardiovascular response to a standardized mental stressor and post-stress recovery. Evaluation of these parameters together may provide a more comprehensive understanding of autonomic flexibility in anxiety disorders. Therefore, the present study was undertaken to compare autonomic function and cardiovascular reactivity to mental stress in patients with anxiety disorders and healthy controls. We hypothesized that patients with anxiety disorders would demonstrate reduced parasympathetic activity at rest, greater cardiovascular reactivity during mental stress and delayed recovery following termination of the stressor.

Materials and Methods

Study Design

A hospital-based comparative cross-sectional study was conducted to compare autonomic function and cardiovascular responses to standardized mental stress in patients with anxiety disorders and healthy controls.

Study Setting and Study Period

The study was conducted in the Department of Physiology in collaboration with the Department of Psychiatry at a tertiary-care teaching hospital in Department of Psychiatry, CMR Institute of Medical sciences, Medchal, Telangana.

Study period

January 2025 to December 2025.

Study Population and Sample Size

A total of 120 participants were included

- Group I: 60 patients diagnosed with anxiety disorders.
- Group II: 60 apparently healthy age- and sex-matched controls.

The sample size was selected based on expected differences in HRV and cardiovascular stress-reactivity parameters between groups, with an anticipated moderate effect size, 80% statistical power and a 5% level of significance.

Inclusion Criteria

- Patients
- Adults aged 18–50 years.
- Patients fulfilling DSM-5 diagnostic criteria for an anxiety disorder.
- Patients willing to participate and provide written informed consent.
- Patients able to understand and perform the mental arithmetic stress task.
- Healthy Controls
- Adults aged 18–50 years.
- No current psychiatric disorder.
- No known cardiovascular, neurological, endocrine or major systemic illness.
- Not taking medications known to influence autonomic function.

Exclusion Criteria

- Participants were excluded if they had:
- Hypertension, diabetes mellitus or known cardiovascular disease.
- Significant neurological or endocrine disease.
- Substance dependence or recent substance abuse.
- Current use of beta-blockers, antiarrhythmic drugs or other medications substantially affecting autonomic function.
- Acute febrile illness.
- Pregnancy.
- Inability to cooperate with the stress protocol.
- Severe psychiatric comorbidity requiring immediate intervention.

- Pre-test Standardization

Participants were instructed to avoid vigorous exercise, alcohol, nicotine and caffeinated beverages for at least 12 hours before testing. Measurements were performed in a quiet, temperature-controlled laboratory between 9:00 AM and 12:00 noon to minimize circadian variation.

After arrival, each participant rested quietly in the supine position for 15 minutes before baseline recordings.

Assessment of Autonomic Function

A standard three-lead ECG was recorded continuously. Short-term HRV was analyzed from a 5-minute artifact-free ECG segment.

The following parameters were assessed

- Mean heart rate (beats/min)
- SDNN (ms)
- RMSSD (ms)
- HF power
- LF power
- LF/HF ratio

RMSSD and HF-HRV were considered indicators predominantly reflecting cardiac parasympathetic modulation, whereas LF/HF was interpreted as an index of sympathovagal balance with appropriate caution.

Cardiovascular Measurements

Blood pressure was recorded using a validated automated sphygmomanometer after adequate rest. Three readings were obtained at baseline at one-minute intervals, and the mean of the final two readings was used.

HR and BP were recorded during baseline, mental stress and recovery.

Mental Stress Protocol

A standardized mental arithmetic task was used to induce acute cognitive stress. Participants were asked to perform serial subtraction under time pressure while being continuously monitored.

The protocol consisted of

- Baseline: 5 minutes quiet rest.
- Mental stress: 5 minutes standardized mental arithmetic.
- Recovery: 10 minutes quiet rest following termination of the task.
- The highest stable HR and BP values during the stress period were used for analysis.

Cardiovascular reactivity was calculated as

Reactivity = Stress value − Baseline value

Recovery was assessed as the difference between the peak stress value and the value recorded during the recovery period.

Statistical Analysis

Data were entered into a statistical software package and analyzed using descriptive and inferential statistics. Continuous variables were expressed as mean ± standard deviation.

Independent-samples t-test was used for comparison of continuous variables between patients and controls. Within-group changes between baseline, stress and recovery were assessed using repeated-measures analysis of variance. Between-group differences in stress-induced changes were assessed using repeated-measures ANOVA with group as the between-subject factor.

Categorical variables were compared using the chi-square test. Pearson correlation was used to examine associations between anxiety severity and autonomic parameters where applicable.

A p value <0.05 was considered statistically significant, and $p<0.001$ was considered highly significant.

Results

A total of 120 participants were included in the analysis, comprising 60 patients with anxiety disorders and 60

Table 1: Baseline demographic characteristics of study participants

Parameter	*Anxiety group (n=60)*	*Healthy controls (n=60)*	*p value*
Age (years)	34.7 ± 8.2	33.9 ± 7.9	0.58
Male/ Female	27/33	29/31	0.71
BMI (kg/ m^2)	24.6 ± 3.1	24.1 ± 2.8	0.36
Systolic BP (mmHg)	124.3 ± 10.1	121.5 ± 9.4	0.12
Diastolic BP (mmHg)	78.2 ± 7.4	76.5 ± 6.9	0.19

Table 2: Baseline autonomic and cardiovascular parameters

Parameter	*Anxiety group*	*Healthy controls*	*p value*
Heart rate (beats/ min)	82.6 ± 8.7	74.8 ± 7.1	<0.001
SDNN (ms)	32.8 ± 8.9	40.7 ± 9.6	<0.001
RMSSD (ms)	24.1 ± 7.2	32.6 ± 8.1	<0.001
HF-HRV (ms^2)	286 ± 104	391 ± 126	<0.001
LF/HF ratio	1.82 ± 0.61	1.39 ± 0.48	<0.001

Table 3: Cardiovascular response to mental stress

Parameter	*Anxiety group: Baseline*	*Anxiety group: Stress*	*Healthy controls: Baseline*	*Healthy controls: Stress*	*Group × stress p*
HR (beats/min)	82.6 ± 8.7	98.7 ± 10.3	74.8 ± 7.1	86.1 ± 8.4	<0.001
SBP (mmHg)	124.3 ± 10.1	143.8 ± 12.2	121.5 ± 9.4	135.2 ± 10.7	0.002
DBP (mmHg)	78.2 ± 7.4	88.6 ± 8.1	76.5 ± 6.9	83.0 ± 7.4	0.004
RMSSD (ms)	24.1 ± 7.2	16.3 ± 5.8	32.6 ± 8.1	25.7 ± 6.9	0.001
LF/HF ratio	1.82 ± 0.61	2.74 ± 0.82	1.39 ± 0.48	2.05 ± 0.63	<0.001

Table 4: Magnitude of cardiovascular reactivity to mental stress

Parameter	*Anxiety group*	*Healthy controls*	*Mean difference*	*p value*
ΔHR (beats/min)	16.1 ± 6.2	11.3 ± 4.9	4.8	<0.001
ΔSBP (mmHg)	19.5 ± 8.2	13.7 ± 6.1	5.8	<0.001
ΔDBP (mmHg)	10.4 ± 5.1	6.5 ± 4.0	3.9	<0.001
ΔRMSSD (ms)	−7.8 ± 4.2	−6.9 ± 3.8	−0.9	0.001
ΔLF/HF	0.92 ± 0.39	0.66 ± 0.31	0.26	<0.001

healthy controls. The two groups were comparable with respect to age, sex distribution and body mass index.

Interpretation

The anxiety and control groups were comparable for age, sex, BMI and resting blood pressure. No statistically significant differences were observed in these baseline demographic characteristics.

Interpretation

Patients with anxiety disorders had significantly higher resting heart rate and LF/HF ratio and significantly lower SDNN, RMSSD and HF-HRV than healthy controls, indicating reduced cardiac parasympathetic modulation and altered sympathovagal balance.

Interpretation

Mental stress produced significant cardiovascular activation in both groups. However, patients with anxiety disorders demonstrated significantly greater increases in HR, SBP, DBP and LF/HF ratio and greater reduction in RMSSD compared with healthy controls.

Table 5: Cardiovascular recovery after mental stress

Parameter	*Anxiety group: 10-min recovery*	*Healthy controls: 10-min recovery*	*p value*
HR (beats/min)	89.4 ± 9.1	78.2 ± 7.5	<0.001
SBP (mmHg)	132.7 ± 11.0	124.0 ± 9.2	<0.001
DBP (mmHg)	82.5 ± 7.2	77.8 ± 6.6	0.001
RMSSD (ms)	21.8 ± 6.7	29.4 ± 7.5	<0.001
LF/HF ratio	2.12 ± 0.67	1.55 ± 0.51	<0.001

Interpretation

Patients demonstrated significantly greater cardiovascular and autonomic reactivity to mental stress compared with controls. The greatest between-group difference was observed in heart-rate and systolic blood-pressure reactivity.

Interpretation

Ten minutes after termination of the stressor, patients continued to have higher HR, SBP, DBP and LF/HF ratio and lower RMSSD than healthy controls, suggesting delayed autonomic cardiovascular recovery.

Discussion

The present study demonstrated significant differences in autonomic cardiovascular regulation between patients with anxiety disorders and healthy controls. Patients showed higher resting heart rate, lower SDNN, RMSSD and HF-HRV and a higher LF/HF ratio. These findings suggest reduced parasympathetic cardiac modulation and altered sympathovagal regulation in anxiety disorders. Similar findings have been reported in previous studies showing reduced HRV among individuals with anxiety disorders. **[6]**

The reduction in RMSSD and HF-HRV observed in the present study is particularly suggestive of diminished vagal modulation of cardiac activity. Previous research involving patients with generalized anxiety disorder demonstrated reduced SDNN and RMSSD compared with healthy controls, supporting the presence of impaired autonomic neurocardiac regulation. **[7]** These findings are also consistent with evidence that anxiety is associated with persistent physiological arousal and altered autonomic flexibility.

An important finding of the present study was the significantly greater cardiovascular response to mental stress among patients with anxiety disorders. Heart rate, systolic blood pressure and diastolic blood pressure increased significantly during mental arithmetic stress, with a greater increase observed in patients compared with controls. Previous studies have demonstrated that psychological stress produces measurable changes in heart rate, blood pressure and autonomic balance and that these responses may be altered in anxiety disorders. **[8]**

The increase in LF/HF ratio together with reduction in RMSSD during mental stress suggests a shift toward sympathetic predominance and reduced vagal modulation. Similar alterations in cardiac autonomic responses have been reported during psychological challenge in patients with panic disorder and other anxiety disorders. **[9]** However, LF/HF should be interpreted cautiously because it does not represent a direct measure of sympathetic activity and is influenced by several physiological factors.

Another important observation was delayed cardiovascular recovery following cessation of the mental stressor. Ten minutes after the stress task, patients continued to demonstrate higher heart rate and blood pressure and lower RMSSD compared with healthy controls. This finding may indicate impaired autonomic flexibility and slower restoration of resting cardiovascular homeostasis following acute psychological stress. Previous research has also suggested that abnormal stress recovery may occur in anxiety disorders and may represent an important component of autonomic dysregulation. **[10]**

The findings of the present study therefore suggest that autonomic dysfunction in anxiety disorders may extend beyond abnormalities observed at rest. The combination of reduced resting parasympathetic modulation, exaggerated cardiovascular reactivity and delayed recovery may represent a characteristic pattern of impaired autonomic adaptation to psychological stress. Assessment of both resting HRV and stress-induced cardiovascular responses may consequently provide more information than either assessment alone.

Further longitudinal studies involving larger samples and separate analysis of different anxiety-disorder subtypes are required to determine whether these autonomic abnormalities change with treatment and whether improvement in anxiety symptoms is accompanied by normalization of cardiovascular autonomic responses.

Conclusion

Patients with anxiety disorders demonstrated significant alterations in autonomic cardiovascular regulation compared with healthy controls. Resting heart rate and sympathovagal balance were increased, whereas HRV indices reflecting parasympathetic modulation were reduced. Mental stress produced significantly greater cardiovascular reactivity in patients, accompanied by greater reduction in vagal indices. Recovery following stress was also slower in the anxiety group. These findings suggest impaired autonomic flexibility in anxiety disorders and support the potential usefulness of HRV and cardiovascular stress testing as physiological markers of autonomic dysregulation. Further longitudinal studies involving larger samples and individual anxiety-disorder subtypes are warranted.

Ethical Clearance

The study protocol was submitted to and approved by the Institutional Ethics Committee before commencement of

the study. Written informed consent was obtained from all participants after explaining the study objectives, procedures, potential risks and benefits.

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