

EFFECT OF STRUCTURED MEDITATION ON PERCEIVED STRESS AND NEUROPHYSIOLOGICAL PARAMETERS IN ADULTS

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ABSTRACT

Background and Objectives: Psychological stress can affect the functioning of the central and autonomic nervous systems. It may increase sympathetic activity and reduce parasympathetic influence. Meditation is considered a useful method for managing stress and improving physiological balance. This study aimed to evaluate the effects of an 8-week meditation programme on perceived stress, cardiovascular parameters, heart rate variability, and EEG alpha-band power in healthy adults. **Materials and Methods:** This prospective interventional study included 26 healthy adults aged 20–45 years. All participants followed a structured meditation programme daily for 8 weeks. Stress levels were measured using the 10-item Perceived Stress Scale (PSS-10). Resting heart rate (HR), systolic blood pressure (SBP), root mean square of successive differences between normal heartbeats (RMSSD), and occipito-parietal EEG alpha-band power (8–12 Hz) were recorded before and after the intervention under standardized laboratory conditions. The pre- and post-intervention values were compared using the paired Student's t-test. A p-value of less than 0.05 was considered statistically significant. **Results:** All 26 participants completed the study. The mean PSS-10 score decreased from 24.8 ± 4.6 before the intervention to 17.2 ± 4.1 after the intervention ($p < 0.001$). Mean resting HR decreased from 78.6 ± 7.4 to 72.8 ± 6.8 beats/min ($p = 0.002$), and mean SBP decreased from 126.4 ± 10.2 to 121.7 ± 9.1 mmHg ($p = 0.018$). RMSSD increased from 28.6 ± 8.7 to 36.9 ± 10.1 ms ($p = 0.001$). Similarly, mean EEG alpha-band power increased from 8.4 ± 2.1 to 11.2 ± 2.6 μV^2 ($p < 0.001$). Significant changes were observed in perceived stress, cardiovascular measurements, heart rate variability, and EEG alpha-band power following the meditation programme. **Conclusion:** An 8-week structured meditation programme was associated with lower perceived stress, resting heart rate, and systolic blood pressure. It was also associated with higher RMSSD and EEG alpha-band power. These findings suggest that regular meditation may help improve stress management and influence autonomic and central nervous system activity in healthy adults.

Keywords: Meditation, Perceived Stress Scale, Psychological Stress, Neurophysiology, Autonomic Function, Heart Rate Variability, Electroencephalography.

INTRODUCTION

Psychological stress is an important health concern worldwide. Long-term stress has been linked to several health conditions, including hypertension, ischemic heart disease, metabolic syndrome, and anxiety-related disorders [1,2]. The body's response to stress involves two major pathways: the sympathetic-adreno-medullary (SAM) system and the hypothalamic-pituitary-adrenal (HPA) axis [3]. The SAM system produces a rapid response, while the HPA axis is involved in the hormonal response to stress. Prolonged or repeated activation of these systems may affect hormone levels, blood vessel function, heart rate, and other physiological processes [3,4].

Heart rate variability (HRV) is a non-invasive measure used to assess variations in the time interval between successive heartbeats [5]. One commonly used measure of HRV is the root mean square of successive differences between normal R-R intervals (RMSSD) [5,6]. RMSSD mainly reflects short-term changes in heart rate associated with parasympathetic control of the heart through the vagus nerve. Its value can also be influenced by breathing, heart rate, and recording conditions [6]. Lower RMSSD values may indicate reduced cardiac vagal modulation and have been associated with cardiovascular risk. However, RMSSD alone cannot be used to diagnose cardiovascular disease [6,7].

Stress may also influence the electrical activity of the brain. Electroencephalography (EEG) is a non-invasive technique used to record electrical activity from the scalp. Different brain wave patterns may be observed during relaxation, attention, and emotional stress [8,9]. Alpha waves, generally recorded within the frequency range of 8–12 Hz in this study, are commonly seen over the occipital and parietal regions when a person is awake and resting with closed eyes [9,10]. Alpha activity may change with mental state, attention, and sensory input. Some studies have reported changes in alpha-band power during stress and meditation. However, these changes are not specific to stress alone [9,10].

Medicines such as anxiolytics and selective serotonin reuptake inhibitors are used to manage certain anxiety-related and stress-associated disorders. However, their use may be associated with adverse effects, and treatment response and long-term adherence may vary among individuals [11]. For this reason, non-pharmacological approaches to stress management have received increasing attention [12,13]. Meditation is one such approach. It may involve focused attention, awareness of thoughts, and controlled breathing, depending on the technique used. Regular practice may help reduce perceived stress and influence autonomic nervous system activity [13,14]. Research has also examined changes in EEG activity during meditation, although the findings vary according to the meditation technique and study conditions [14].

Although meditation has been studied for its possible effects on psychological stress, further research is needed to examine subjective stress levels together with cardiovascular autonomic measurements and brain electrical activity [15,16]. Studying these parameters together may help improve our understanding of the physiological changes associated with regular meditation practice.

Therefore, the present study was conducted to assess the effects of an 8-week structured meditation programme on perceived stress, resting heart rate, systolic blood pressure, heart rate variability, and EEG alpha-band power in healthy adults.

AIMS & OBJECTIVES

Primary Aim

To investigate the therapeutic effect of an 8-week structured meditation programme on perceived psychological stress and objective neurophysiological parameters in adult individuals.

Specific Objectives

- 1 To measure and compare perceived stress scores before and after the intervention using the 10-item Perceived Stress Scale (PSS-10).
- 2 To quantify changes in baseline cardiovascular indices, specifically resting heart rate (HR) and systolic blood pressure (SBP).
- 3 To determine changes in cardiac autonomic vagal modulation via the time-domain heart rate variability metric RMSSD.
- 4 To assess resting central electroencephalographic (EEG) alpha-band power (8–12 Hz) over

occipito-parietal leads before and after the intervention.

MATERIALS & METHODOLOGY

Study Design and Ethical Clearance

The present study was designed as a prospective, pre–post interventional clinical physiological study and was conducted in the Department of Physiology, Shri Shankaracharya Institute of Medical Sciences, Bhilai, Chhattisgarh, India. The study protocol was reviewed and approved by the Institutional Ethics Committee. All study procedures were carried out in accordance with the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from each participant before enrolment.

Participant Selection and Eligibility Criteria

A total of 26 adult volunteers, aged 20–45 years, were recruited through institutional notices and community announcements. All volunteers underwent baseline clinical screening to determine their eligibility for participation.

Inclusion criteria:

1. Adults aged 20–45 years, irrespective of sex.
2. A baseline score of ≥ 14 on the 10-item Perceived Stress Scale (PSS-10), indicating a moderate to high level of perceived stress.
3. No formal meditation training or regular yoga practice during the preceding 12 months.
4. Willingness to participate in and adhere to the prescribed eight-week meditation programme.

Exclusion criteria:

1. A history of diagnosed cardiovascular disease, including secondary hypertension, cardiac arrhythmias, or ischaemic heart disease.
2. A history of neuropsychiatric disorders or epilepsy, or current use of psychotropic medication.
3. Active tobacco smoking, alcohol dependence, or substance misuse.
4. Metabolic disorders, including diabetes mellitus and thyroid dysfunction.

Meditation Intervention Protocol

All participants underwent a standardized, structured meditation programme lasting eight weeks. During the first week, participants attended supervised morning meditation sessions of 30 minutes each, conducted by certified instructors to ensure consistency in posture, breathing, and meditation techniques. Following this initial training period, participants attended monitored group sessions twice weekly and continued their daily meditation practice at home on the remaining days. Home practice and adherence to the intervention were documented using participant-maintained compliance diaries.

Each daily session lasted 30 minutes and consisted of the following three components:

1. Diaphragmatic breathing and relaxation (5 minutes): Participants sat comfortably with their spines upright and practised slow, rhythmic breathing at approximately six breaths per minute, with attention directed towards diaphragmatic movement and respiratory sensations.
2. Focused-attention meditation (20 minutes): Participants maintained non-judgmental awareness of the sensations associated with breathing at the tip of the nostrils. Whenever attention wandered, they were instructed to gently redirect their focus towards the breath without reacting to or judging distracting thoughts.
3. Guided somatosensory integration (5 minutes): The session concluded with a silent body scan, during which participants sequentially directed their attention towards bodily sensations while maintaining a relaxed and attentive state.

Laboratory Measurement Protocol

All physiological assessments were performed between 08:00 and 10:30 hours in a temperature-controlled laboratory maintained at 24 ± 1 °C with minimal external noise. Measurements were obtained at baseline (Day 0) and repeated within 48 hours after completion of the eight-week intervention. Participants were assessed following an overnight fast or after consuming a light, caffeine-free breakfast.

Assessment of Perceived Stress

Perceived stress was assessed using the validated 10-item Perceived Stress Scale (PSS-10), developed by Cohen and colleagues. The scale measures the extent to which individuals perceive their lives as stressful. Total scores range from 0 to 40, with higher scores indicating greater perceived stress.

Cardiovascular Parameters and Heart Rate Variability

Participants rested in the supine position for 15 minutes before cardiovascular measurements were obtained. Blood pressure was measured using a calibrated sphygmomanometer. Continuous electrocardiographic (ECG) recordings were subsequently acquired from Lead II for 10 minutes at a sampling frequency of 1,000 Hz using a Power Lab data acquisition system (AD Instruments).

The ECG recordings were processed to identify and exclude ectopic beats and other unsuitable R–R intervals. The root mean square of successive differences between normal-to-normal R–R intervals (RMSSD) was calculated as an index of short-term heart rate variability and cardiac vagal modulation.

Electroencephalographic Alpha-Band Power

Resting electroencephalographic (EEG) activity was recorded using gold-cup scalp electrodes positioned according to the International 10–20 electrode placement system. The recordings were referenced to linked earlobes (A1–A2), and electrode impedances were maintained below 5 k Ω .

Five-minute resting EEG recordings were obtained with participants' eyes closed from the parietal and occipital electrode sites (P3, P4, O1, and O2). The recorded signals were subjected to spectral analysis using the Fast Fourier Transform (FFT) with a Hanning window. Alpha-band power was quantified within the frequency range of 8.0–12.0 Hz and expressed in μV^2 .

Statistical Analysis

The distribution of continuous variables was assessed using the Shapiro–Wilk test for normality. Variables exhibiting an approximately normal distribution were expressed as mean $\pm$ standard deviation (SD). Differences between baseline and post-intervention measurements were analyzed using two-tailed paired Student's t-tests. A p-value of less than 0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA)

RESULTS

All 26 enrolled subjects completed the 8-week intervention protocol (compliance rate > 90%). Baseline demographic characteristics are summarized in Table 1 .

Table 1 : Baseline Demographic and Anthropometric Characteristics of Participants (N = 26)

Characteristic / Parameter	Value (Mean $\pm$ SD) or <i>n</i> (%)
Age (years)	31.4 $\pm$ 5.8
Sex (Male / Female)	14 (53.8%) / 12 (46.2%)
Body Mass Index (BMI, kg/m ²)	23.1 $\pm$ 2.4
Baseline Resting Heart Rate (beats/min)	78.6 $\pm$ 7.4
Baseline Systolic Blood Pressure (mmHg)	126.4 $\pm$ 10.2

Baseline Diastolic Blood Pressure (mmHg)	81.2 ± 6.3
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Table 2: Statistical Comparison of Pre- and Post-Intervention Parameters (N = 26)

Measured Parameter	Pre-Int (Mean ± SD)	Post-Int (Mean ± SD)	Δ Change	% Change	t-statistic	p-value
PSS-10 Stress Score	24.8 ± 4.6	17.2 ± 4.1	-7.6	-30.6%	8.45	< 0.001*
Resting Heart Rate (bpm)	78.6 ± 7.4	72.8 ± 6.8	-5.8	-7.4%	3.42	0.002*
Systolic BP (mmHg)	126.4 ± 10.2	121.7 ± 9.1	-4.7	-3.7%	2.54	0.018*
RMSSD (ms)	28.6 ± 8.7	36.9 ± 10.1	+8.3	+29.0%	-3.78	0.001*
EEG Alpha Power (μV ²)	8.4 ± 2.1	11.2 ± 2.6	+2.8	+33.3%	-6.12	< 0.001*

*Statistically significant ($p < 0.05$). Values are expressed as Mean ± Standard Deviation. Paired Student's *t*-test.

Following the 8-week structured meditation protocol, statistically significant improvements were observed across all parameters (Table 2). Subjective perceived stress fell by 30.6% ($p < 0.001$). Concurrently, resting heart rate decreased by 5.8 beats/min ($p = 0.002$) and systolic blood pressure fell by 4.7 mmHg ($p = 0.018$). In parallel, cardiac parasympathetic vagal tone rose markedly, with RMSSD increasing by 29.0% ($p = 0.001$), while central occipito-parietal EEG alpha power increased by 33.3% ($p < 0.001$).

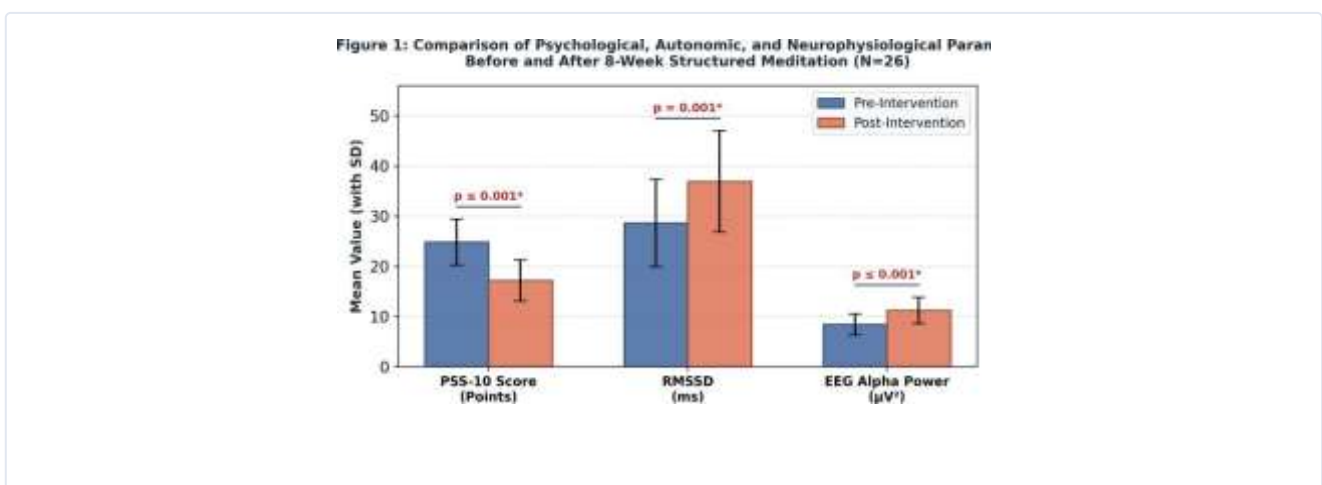


Figure 1 : Pre- and post-intervention comparison of mean PSS-10 scores, cardiac vagal tone (RMSSD), and EEG alpha-band power in adults (N = 26). Error bars denote standard deviation. * $p \leq 0.001$.

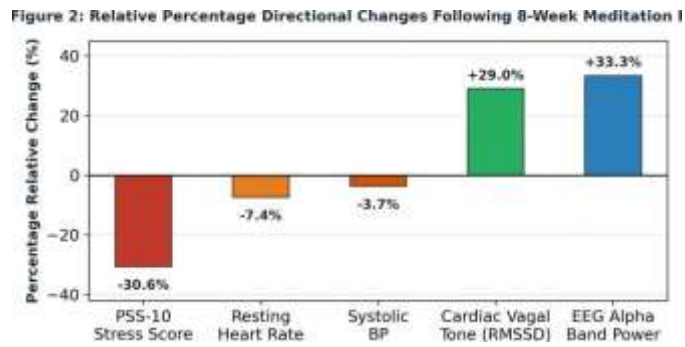


Figure 2: Relative percentage directional changes observed across psychological, cardiovascular, autonomic, and neuroelectric indices following the 8-week structured meditation programme.

DISCUSSION

This prospective interventional study shows that an 8-week meditation programme may improve both autonomic nervous system activity and brain electrical activity while reducing psychological stress in adults. The findings suggest that regular meditation may support better stress management through changes in both the brain and the cardiovascular system.

The PSS-10 score decreased by 30.6%, from 24.8 to 17.2 ($p < 0.001$), indicating a significant reduction in perceived stress after meditation [1,12]. Persistent stress is often associated with repeated negative thinking and increased emotional responses involving brain regions such as the amygdala [13]. Previous neuroimaging studies suggest that meditation may improve the regulation of emotional responses through interactions between the prefrontal cortex, anterior cingulate cortex (ACC), and amygdala [13,14]. These changes may help individuals manage stressful situations more calmly and reduce excessive emotional reactions [12,14].

The study also found a decrease in resting heart rate by 5.8 beats per minute and systolic blood pressure by 4.7 mmHg. In addition, RMSSD increased by 29.0%, from 28.6 to 36.9 ms ($p = 0.001$). RMSSD is a measure of heart rate variability that primarily reflects cardiac parasympathetic activity mediated by the vagus nerve under resting conditions [5,6]. Chronic stress may disturb the balance between sympathetic and parasympathetic activity, contributing to increased cardiovascular strain [3,4]. The rise in RMSSD observed in this study suggests improved cardiac parasympathetic regulation following meditation [5,6]. Slow and controlled breathing during meditation may enhance respiratory sinus arrhythmia (RSA) and activate sensory pathways involved in cardiovascular regulation [15]. These mechanisms may influence the arterial baroreflex and the Central Autonomic Network (CAN), which includes the insular cortex, ventromedial prefrontal cortex, and nucleus tractus solitarius. Such changes may promote a shift towards parasympathetic activity and potentially support cardiovascular health [4,6,15,16].

The study further showed a 33.3% increase in resting parietal-occipital EEG alpha-band power, from 8.4 to 11.2 μV^2 ($p < 0.001$), suggesting changes in cortical electrical activity after meditation. Alpha waves, which occur at frequencies of 8–12 Hz, are associated with interactions between the thalamus and cerebral cortex [9,10]. Increased alpha activity is commonly linked to a state of calm alertness, in which attention is maintained while responses to unnecessary sensory information may be reduced [8,10]. Psychological stress has been associated with increased cortical arousal and changes in faster EEG rhythms, including beta activity [8,9]. The increase in

alpha power after the intervention may therefore indicate improved relaxation and altered cortical activity. These findings are consistent with the concept of neurovisceral integration, which describes the functional relationship between brain networks involved in emotional regulation and peripheral autonomic control [6,10,15,16].

CONCLUSION

An 8-week structured meditation programme effectively alleviates subjective psychological stress and establishes objective neurophysiological equilibrium in adults. The observed physiological improvements—marked by reductions in resting heart rate and systolic blood pressure, enhanced cardiac vagal modulation (RMSSD), and increased central electroencephalographic alpha synchrony—demonstrate that meditation exerts a coordinated, beneficial modulation across both autonomic and central divisions of the human stress axis. Structured meditation represents a safe, accessible, cost-effective, and evidence-based non-pharmacological lifestyle intervention for stress mitigation and proactive cardiometabolic health promotion.

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