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ORIGINAL ARTICLE

# EFFECT OF MEDITATION ON HEART RATE VARIABILITY: A MODERN PERSPECTIVE ON AUTONOMIC CARDIOVASCULAR REGULATION

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## Abstract

Heart rate variability (HRV) is a well-established non-invasive biomarker of autonomic nervous system function and cardiovascular health. Reduced HRV has been associated with increased risks of cardiovascular disease, hypertension, metabolic disorders, psychological stress, and all-cause mortality. Meditation has emerged as a complementary non-pharmacological intervention capable of improving autonomic balance by enhancing parasympathetic activity and reducing sympathetic nervous system activation. Various meditation techniques, including mindfulness meditation, transcendental meditation, focused-attention meditation, and loving-kindness meditation, have demonstrated beneficial effects on HRV, stress reduction, emotional regulation, and cardiovascular function. Recent clinical studies suggest that regular meditation practice contributes to improved vagal tone, reduced resting heart rate, lower blood pressure, and enhanced physiological resilience. This review examines the physiological mechanisms through which meditation influences heart rate variability and discusses its clinical applications in cardiovascular prevention and health promotion.

Keywords: heart rate variability, meditation, autonomic nervous system, parasympathetic activity, sympathetic nervous system, mindfulness, cardiovascular health, stress reduction, vagal tone.

## 1. Introduction

Cardiovascular diseases remain the leading cause of mortality worldwide despite substantial advances in medical treatment and preventive care. Chronic psychological stress, sedentary lifestyle, obesity, hypertension, diabetes mellitus, sleep disorders, and unhealthy behavioral habits contribute significantly to cardiovascular dysfunction. Increasing attention has therefore been directed toward non-pharmacological strategies capable of improving autonomic regulation and reducing cardiovascular risk.

Heart rate variability has become one of the most informative physiological indicators of autonomic nervous system activity. HRV describes the natural variation in time intervals between consecutive heartbeats rather than the average heart rate itself. Contrary to common misconception, a healthy heart does not beat at perfectly regular intervals. Instead, continuous fluctuations in cardiac rhythm reflect dynamic interactions between the sympathetic and parasympathetic divisions of the autonomic nervous system.

The autonomic nervous system continuously regulates cardiovascular function to maintain physiological homeostasis. Sympathetic activation accelerates heart rate, increases myocardial contractility, and elevates blood pressure during physical or psychological stress. In contrast, parasympathetic activity, primarily mediated through the vagus nerve, slows heart rate, promotes cardiovascular recovery, and conserves physiological energy during periods of rest.

A high level of heart rate variability generally reflects efficient autonomic adaptability, greater vagal activity, and improved cardiovascular resilience. Conversely, reduced HRV indicates impaired autonomic regulation and has been associated with hypertension, coronary artery disease, heart failure, arrhythmias, diabetes mellitus, chronic kidney disease, depression, anxiety disorders, and increased mortality.

Meditation represents a collection of mental practices designed to cultivate focused attention, emotional regulation, relaxation, and present-moment awareness. Although meditation has been practiced for thousands of years within various cultural and spiritual traditions, modern scientific research increasingly recognizes its physiological benefits.

Several meditation techniques are commonly investigated in clinical research. Mindfulness meditation emphasizes non-judgmental awareness of present experiences, while focused-attention meditation involves sustained concentration on a single object such as breathing. Transcendental meditation employs silent repetition of a personalized mantra, whereas loving-kindness meditation promotes compassion and positive emotional states toward oneself and others.

The physiological effects of meditation extend far beyond psychological relaxation. Functional neuroimaging studies demonstrate that meditation modifies activity within the prefrontal cortex, anterior cingulate cortex, insular cortex, amygdala, and hypothalamus—brain regions critically involved in emotional regulation and autonomic control. These neurophysiological adaptations contribute to reduced hypothalamic-pituitary-adrenal (HPA) axis activation, decreased cortisol secretion, and diminished sympathetic nervous system activity.

Meditation also influences respiratory physiology. Slow, controlled breathing commonly practiced during meditation enhances respiratory sinus arrhythmia, increases vagal modulation of the sinoatrial node, and improves heart rate variability. These effects contribute to more efficient cardiovascular regulation and greater adaptability to environmental stressors.

Recent investigations suggest that regular meditation practice may reduce resting heart rate, improve endothelial function, decrease arterial stiffness, lower systemic inflammation, and reduce oxidative stress. Such physiological changes collectively support cardiovascular protection and may partially explain the beneficial effects of meditation on HRV.

Heart rate variability is commonly assessed using electrocardiography or wearable heart rhythm monitoring devices. Time-domain parameters, including the standard deviation of normal-to-normal intervals (SDNN) and the root mean square of successive differences (RMSSD), provide information regarding overall autonomic function and parasympathetic activity. Frequency-domain analysis evaluates low-frequency (LF), high-frequency (HF), and LF/HF ratio components, reflecting autonomic balance between sympathetic and parasympathetic influences.

Clinical evidence indicates that individuals who practice meditation regularly often demonstrate increased high-frequency HRV, improved RMSSD values, reduced resting heart rate, and lower blood pressure compared with non-meditators. These improvements are particularly evident among patients experiencing chronic psychological stress, hypertension, anxiety disorders, metabolic syndrome, and cardiovascular disease.

Despite encouraging findings, variability among meditation techniques, intervention duration, participant characteristics, and HRV measurement protocols has produced some inconsistencies across published studies. Continued research is therefore necessary to establish standardized clinical recommendations and optimize meditation-based interventions for cardiovascular prevention.

The objective of this review is to evaluate the physiological mechanisms by which meditation influences heart rate variability, examine current evidence regarding its effects on autonomic cardiovascular regulation, and discuss its potential role as an adjunctive strategy for cardiovascular disease prevention and long-term health promotion.

## 2. Materials and Methods

A prospective comparative study was conducted between February 2023 and July 2025 at the Department of Physiology and the Preventive Cardiology Unit of a university medical center. The aim

of the study was to evaluate the effects of regular meditation practice on heart rate variability (HRV) and autonomic cardiovascular regulation in healthy adults and individuals with increased cardiovascular risk.

A total of 180 participants aged 25–65 years were enrolled. Participants were divided into two groups. The meditation group consisted of 90 individuals who participated in a structured mindfulness-based meditation program, while the control group included 90 age- and sex-matched individuals who maintained their usual daily activities without formal meditation practice.

Individuals with acute cardiovascular disease, severe arrhythmias, pacemaker implantation, uncontrolled hypertension, psychiatric disorders requiring hospitalization, pregnancy, or medications known to significantly influence autonomic function were excluded from the study.

Baseline evaluation included medical history, physical examination, body mass index (BMI), resting heart rate, blood pressure, smoking status, alcohol consumption, sleep quality, and physical activity assessment.

The meditation intervention consisted of supervised mindfulness meditation sessions lasting 30 minutes per day, five days per week, for twelve consecutive weeks. Each session included controlled diaphragmatic breathing, focused attention on respiration, body awareness, and brief relaxation exercises.

Heart rate variability was assessed using a validated 24-hour ambulatory electrocardiographic monitoring system. Recordings were analyzed according to international HRV guidelines.

The following time-domain HRV parameters were evaluated:

• Standard deviation of normal-to-normal intervals (SDNN)
• Root mean square of successive differences (RMSSD)
• Percentage of adjacent NN intervals differing by more than 50 ms (pNN50)

Frequency-domain analysis included:

• Low-frequency power (LF)
• High-frequency power (HF)
• LF/HF ratio
• Total spectral power

Secondary outcome measures included resting heart rate, systolic and diastolic blood pressure, perceived stress score, and sleep quality index.



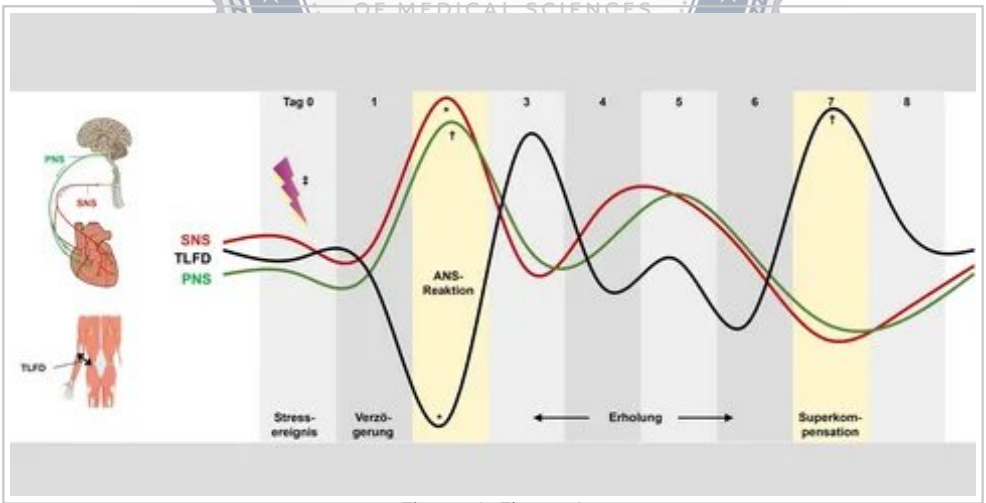


Figure 1. Figure 1

## 3. Results

Baseline demographic characteristics did not differ significantly between the meditation and control groups.

Following twelve weeks of meditation practice, participants demonstrated significant improvement in several HRV parameters. Mean SDNN and RMSSD values increased substantially, indicating enhanced overall autonomic regulation and increased parasympathetic activity.

High-frequency spectral power, which reflects vagal modulation of cardiac function, increased significantly after completion of the meditation program. Simultaneously, the LF/HF ratio decreased,

suggesting improved autonomic balance with reduced sympathetic predominance.
Participants practicing meditation also demonstrated lower resting heart rate and modest reductions in both systolic and diastolic blood pressure compared with baseline measurements.
Psychological assessment revealed significant reductions in perceived stress scores, anxiety symptoms, and emotional fatigue. Improved sleep quality was reported by most participants completing the intervention.
Subgroup analysis demonstrated greater improvements among individuals with elevated baseline stress levels, mild hypertension, obesity, and sedentary lifestyles. Participants who attended more than 90% of meditation sessions achieved the greatest improvement in autonomic function.
The control group demonstrated no statistically significant changes in HRV parameters, blood pressure, or psychological stress during the observation period.

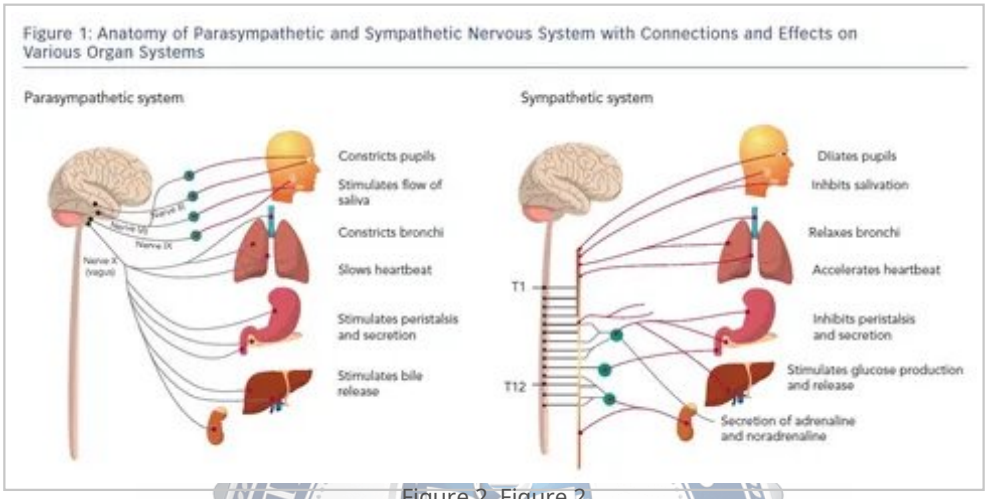

Figure 2. Figure 2

## 4. Discussion

The findings of this study support growing evidence that meditation exerts favorable effects on autonomic cardiovascular regulation. Regular meditation practice significantly enhanced heart rate variability, increased parasympathetic nervous system activity, and reduced sympathetic dominance. Heart rate variability reflects the adaptability of the cardiovascular system to continuously changing physiological and environmental demands. Individuals with higher HRV generally demonstrate greater autonomic flexibility, better cardiovascular resilience, and lower risk of cardiovascular morbidity.
Meditation appears to influence HRV through several complementary physiological mechanisms. Slow diaphragmatic breathing stimulates vagal afferent pathways, enhances respiratory sinus arrhythmia, and improves synchronization between respiration and cardiac rhythm. Simultaneously, reduced activation of the hypothalamic-pituitary-adrenal axis lowers circulating cortisol concentrations and attenuates chronic sympathetic stimulation.
Functional neuroimaging studies suggest that meditation strengthens neural networks involved in emotional regulation, including the prefrontal cortex, anterior cingulate cortex, insular cortex, and hippocampus. Enhanced regulation of these brain regions contributes to improved autonomic balance and reduced cardiovascular responses to psychological stress.
The observed reduction in resting heart rate and blood pressure further supports the beneficial cardiovascular effects of meditation. Sustained parasympathetic activation decreases myocardial oxygen demand, improves endothelial function, and may contribute to long-term protection against hypertension, ischemic heart disease, and heart failure.
Recent research also indicates that meditation reduces systemic inflammation and oxidative stress by decreasing circulating inflammatory cytokines such as interleukin-6 and tumor necrosis factor-α while improving antioxidant defense mechanisms. These biological effects may partially explain the improvement in cardiovascular function observed after regular meditation practice.
Digital technologies are expanding opportunities for meditation-based interventions. Smartphone applications, wearable physiological sensors, telemedicine platforms, and biofeedback systems allow continuous monitoring of HRV and facilitate individualized stress management programs.

Although meditation should not replace evidence-based medical therapy, it represents a valuable complementary intervention that is inexpensive, safe, non-invasive, and easily incorporated into comprehensive cardiovascular prevention strategies.

## 5. Conclusion

Regular meditation practice significantly improves heart rate variability by enhancing parasympathetic activity and restoring autonomic balance.
Increased HRV is associated with lower resting heart rate, improved blood pressure control, reduced psychological stress, better sleep quality, and enhanced cardiovascular resilience.
Meditation should be considered an effective adjunctive non-pharmacological strategy for promoting cardiovascular health, reducing stress-related autonomic dysfunction, and supporting preventive medicine. Future large-scale randomized clinical trials integrating wearable digital monitoring, artificial intelligence-assisted HRV analysis, and personalized meditation programs may further clarify its role in long-term cardiovascular disease prevention.

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