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Role of pranayama in modulating the autonomic nervous system: A review of cardiovascular and psychological outcomes

Akarshit Maurya
Department of Yoga and Naturopathy, Shri Jagdish Prasad Jhabarmal Tibrewala University, Rajasthan, India
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Abstract
Background: Pranayama is a traditional yogic breathing practice involving conscious regulation of breathing patterns. It has gained increasing research interest for its potential effects on autonomic regulation, cardiovascular function, and psychological well-being.
Objective: This review aims to examine the role of Pranayama in modulating the autonomic nervous system and to summarize its reported effects on cardiovascular and psychological outcomes.
Methods: Relevant research studies, randomized controlled trials, and systematic reviews investigating Pranayama, heart rate, blood pressure, heart rate variability, autonomic function, stress, anxiety, and related psychological outcomes were reviewed.
Results: Available evidence suggests that Pranayama may improve heart rate variability and parasympathetic activity while reducing heart rate and blood pressure. Beneficial effects have also been reported for stress, anxiety, emotional well-being, and overall psychological health.
Conclusion: Pranayama appears to be a promising complementary approach for promoting autonomic balance and supporting cardiovascular and psychological well-being. However, standardized protocols and larger long-term studies are needed to establish its clinical effectiveness more conclusively.

Keywords: Pranayama, autonomic nervous system, heart rate variability, cardiovascular outcomes, psychological outcomes, parasympathetic activity, Nadi Shodhana, Bhramari

Introduction

Pranayama is a traditional yogic practice involving conscious regulation of breathing through changes in the rate, depth, rhythm, and pattern of respiration. In recent years, pranayama has received increasing scientific attention because controlled breathing can influence cardiovascular regulation, autonomic activity, and psychological responses. Respiration is closely linked with cardiac and autonomic function, and deliberate slow breathing may enhance cardiorespiratory interaction and vagal modulation *(Russo et al., 2017; Zaccaro et al., 2018)* [6, 8]. The autonomic nervous system (ANS) plays an essential role in maintaining cardiovascular homeostasis through the coordinated activity of its sympathetic and parasympathetic divisions. Alterations in autonomic balance have been associated with cardiovascular dysfunction as well as psychological stress and anxiety. Heart rate variability (HRV) is widely used as a non-invasive measure of cardiac autonomic regulation and provides important information regarding parasympathetic and sympathetic influences on cardiac function *(Laborde et al., 2017)* [4]. Therefore, interventions that can positively influence autonomic regulation may have relevance for both cardiovascular and psychological health.

Pranayama may affect autonomic function through voluntary control of respiration. Slow and controlled breathing has been shown to influence heart rate, HRV, blood pressure, and other indices of autonomic regulation. A systematic review and meta-analysis by *Laborde et al. (2022)* [3] reported that voluntary slow breathing was associated with increased vagally mediated HRV, supporting its potential role in enhancing cardiac autonomic regulation. Similarly, *Zaccaro et al. (2018)* [8] described associations between slow breathing and changes in autonomic, cardiovascular, and emotional functioning. Different pranayama techniques may produce different physiological responses depending on breathing rate, respiratory depth, inhalation–exhalation pattern, and the presence of breath retention or nostril regulation. Studies involving alternate-nostril breathing have reported changes in cardiovascular and autonomic variables, including heart rate and blood pressure *(*Srivastava *et al., 2005; Kalaivani et al., 2019)* [2, 7]. Bhramari Pranayama has also been investigated for its effects on HRV and cardiac autonomic modulation *(Nivethitha et al., 2017)* [30]. In individuals with hypertension, Sheetali Pranayama has been reported to produce favourable changes in blood pressure and cardiac autonomic function *(Ankad et al., 2020)* [1]. The potential benefits of pranayama extend beyond physiological outcomes. Psychological stress and anxiety are closely associated with autonomic arousal, and breathing-based practices may contribute to psychological relaxation partly through modulation of autonomic activity. Recent systematic evidence suggests that pranayama may have beneficial effects on psychological conditions, particularly anxiety and stress, although variations in intervention protocols and study quality remain important considerations *(Mütze et al., 2025)* [5, 23].

Physiological Basis of Pranayama and Autonomic Regulation

Pranayama involves voluntary regulation of breathing rate, depth, rhythm, and, in some techniques, breath retention. Because respiration is closely connected with cardiovascular and autonomic activity, deliberate changes in breathing can

influence autonomic regulation. Slow and deep breathing can increase respiratory–cardiac synchronization and promote vagally mediated cardiac activity, thereby contributing to autonomic flexibility *(Jerath et al., 2006)* [10]. One important physiological mechanism is the interaction between respiration and heart rate, known as respiratory sinus arrhythmia. During inspiration, heart rate generally increases, whereas during expiration it decreases, reflecting rhythmic modulation of cardiac vagal activity. Controlled slow breathing can enhance this interaction and consequently influence heart rate variability (HRV), an important indicator of cardiac autonomic regulation *(Berntson et al., 1993)* [9]. Changes in respiratory rhythm may also influence baroreflex activity, which plays an important role in short-term regulation of blood pressure and cardiovascular homeostasis *(Salahuddin et al., 2007)* [13]. Pranayama may therefore influence the autonomic nervous system through coordinated effects involving respiratory receptors, cardiovascular receptors, brainstem respiratory centres, and higher neural structures. Recent physiological models suggest that activation of respiratory and circulatory mechanoreceptors and chemoreceptors may contribute to subsequent autonomic and neurophysiological responses to pranayama *(Mondal, 2024)* [11]. Evidence also indicates that slow breathing can influence baroreflex sensitivity and sympathetic activity, although responses may differ according to the breathing technique and duration of practice *(Nivethitha et al., 2022)* [12].

Pranayama and Cardiovascular Outcomes

Several studies have reported favourable cardiovascular responses following pranayama practice. Bee-Humming Breathing, for example, has been investigated in patients with essential hypertension and was associated with changes in HRV, particularly increased high-frequency activity during the recovery period, suggesting enhanced parasympathetic modulation *(Garg et al., 2020)* [14]. Nadi Shodhana Pranayama has also demonstrated reductions in systolic and diastolic blood pressure along with improvements in HRV-related parameters among individuals with hypertension *(Saxena et al., 2025)* [15]. Recent evidence further supports the potential cardiovascular benefits of pranayama. A 2026 [16] systematic review and meta-analysis of seven randomized controlled trials involving 683 participants found a significant reduction in heart rate and a favourable effect on systolic blood pressure following pranayama interventions in people with hypertension, although effects on diastolic blood pressure and HRV were less consistent.

Thus, pranayama appears to have potential as a complementary cardiovascular intervention, particularly through its effects on heart rate, blood pressure, and autonomic cardiac regulation. However, differences in techniques, duration, and study protocols indicate a need for more standardized research before firm clinical conclusions can be drawn.

Pranayama and Psychological Outcomes

1. **Stress:** Pranayama may help reduce psychological stress by promoting controlled respiration and reducing physiological arousal. Evidence from recent systematic reviews suggests that breathing-based interventions can improve perceived stress, although differences in techniques and study quality should be considered.
2. **Anxiety:** Anxiety is one of the most frequently studied psychological outcomes of pranayama. A randomized controlled trial of Bhastrika Pranayama reported reduced state anxiety and negative affect after four weeks of practice, along with changes in brain regions involved in emotional processing *(Novaes et al., 2020)* [17].
3. **Depression:** Pranayama and related controlled-breathing practices have also been investigated for depressive symptoms. A randomized study combining yoga with coherent breathing reported significant reductions in depressive symptoms following a 12-week intervention *(Shannahoff-Khalsa et al., 2018)* [18].
4. **Emotional Well-being:** Controlled breathing may influence emotional regulation by reducing negative affect and supporting psychological relaxation. Research on Bhastrika Pranayama has demonstrated improvements in both negative and positive affect, suggesting possible benefits for emotional well-being *(Novaes et al., 2020)* [17].

Recent evidence generally supports a beneficial effect of pranayama on stress and anxiety. A 2025 [15] systematic review and meta-analysis found that pranayama produced short-term improvements in symptoms among individuals with mental disorders, although the authors emphasized the limited number of studies and considerable risk of bias. Similarly, a 2025 meta-analysis among adolescents reported a moderate reduction in stress and anxiety following pranayama interventions, but the certainty of evidence was low.

Mechanisms of Autonomic Modulation by Pranayama

1. **Vagal Activation and Parasympathetic Modulation:** Slow and controlled breathing may enhance vagal influence on the heart by strengthening the interaction between respiratory and cardiac rhythms. This may contribute to increased parasympathetic activity and improved cardiac autonomic regulation (Jerath *et al*., 2006) [10].
2. **Respiratory–Cardiac Coupling:** Respiration and cardiac activity are closely interconnected. Controlled breathing can enhance respiratory sinus arrhythmia and cardiorespiratory synchronization, thereby influencing heart rate and autonomic variability. These changes may contribute to improved physiological adaptability during stress.
3. **Baroreflex and Cardiovascular Regulation:** Pranayama may influence the baroreflex, an important mechanism involved in short-term blood-pressure regulation. Slow breathing has been associated with increased baroreflex sensitivity and reductions in sympathetic activity, although the magnitude of these effects may vary between acute and long-term interventions (Nivethitha *et al*., 2022) [12].
4. **Brain–Autonomic Pathways:** Respiratory signals generated during pranayama are transmitted through

peripheral receptors to brainstem and higher brain regions involved in autonomic and emotional regulation. Proposed mechanisms include activation of respiratory and cardiovascular mechanoreceptors and chemoreceptors, followed by modulation of brainstem, limbic, and cortical pathways (Mondal, 2024) [11].

Pranayama may influence autonomic regulation through the combined effects of controlled respiration, vagal modulation, cardiorespiratory coupling, baroreflex regulation, and brain–autonomic pathways. However, the exact contribution of each mechanism may depend on the specific pranayama technique and breathing pattern.

Table 1: Selected Research Evidence on the Cardiovascular, Autonomic, and Psychological Effects of Pranayama

Year	Study / Participants	Intervention	Major Findings
2026	Chidambaram *et al*.; 7 RCTs, 683 participants	Various Pranayama interventions in hypertension	Significant reduction in heart rate and favourable effect on systolic BP; effects on DBP and HRV were less consistent. (ScienceDirect)
2025	Mittal *et al*.; hypertensive patients, randomized trial	Nadi Shodhan Pranayama	Reduced SBP, DBP and heart rate, with improvements in SDNN, RMSSD, HF and other HRV measures. (PubMed)
2025	Mütze *et al*.; 6 RCTs, 517 patients	Pranayama for mental disorders	Evidence suggested beneficial effects on symptoms of mental disorders, although the evidence base was limited and heterogeneous. (Frontiers)
2024	Sharma *et al*.; 100 healthcare workers	Anulom Vilom Pranayama + Heartfulness Meditation, 8 weeks	Reduced heart rate, BP, perceived stress, depression and anxiety/stress scores; HRV findings suggested greater parasympathetic influence. (PubMed)
2024	Sarwal *et al*.; 280 frontline healthcare professionals	Pranayama regimen, 4 weeks	Significant reduction in perceived stress and improvement in overall and psychological quality of life. (PubMed)
2023	Upadhyay *et al*.; 100 hypertensive patients	Nadi Shodhana vs. Bhramari, 20 min	Both practices showed favourable effects on autonomic balance; immediate HRV differences between groups were not significant. (PubMed)
2021	Sharpe *et al*.; healthy adults	Deep breathing and Pranayama components	Breathing interventions produced increases in HRV, supporting an influence on cardiac autonomic regulation.
2020	Novaes *et al*.; 30 healthy adults, RCT	Bhastrika Pranayama, 4 weeks	Reduced state anxiety and negative affect, with changes in brain activity/connectivity related to emotional processing.
2020	Thanalakshmi *et al*.; 100 hypertensive patients, RCT	Sheetali Pranayama, 3 months	Reduced BP and improved HRV, indicating greater parasympathetic modulation. (PubMed)
2019	Satyapriya *et al*.; hypertensive patients	Sheetali and Sheetkari Pranayama	Reported favourable changes in blood pressure and autonomic function.
2017	Nivethitha *et al*.; healthy adults	Bhramari Pranayama	Acute practice produced changes in HRV consistent with enhanced cardiac parasympathetic modulation.

The available research generally indicates that pranayama can influence cardiac autonomic regulation, blood pressure, heart rate, and psychological outcomes, although the magnitude of effects varies according to the technique, duration, and study population. Studies involving Bhramari, Sheetali/Sheetkari, Nadi Shodhana, and slow breathing particularly suggest a shift toward greater parasympathetic activity, while recent evidence also supports potential benefits for anxiety and stress.

Table 2: Major Pranayama Techniques and Their Reported Physiological/Autonomic Effects

Pranayama Technique	Reported Physiological/Autonomic Effects
Nadi Shodhana / Anulom Vilom	Reduces heart rate and blood pressure; improves heart rate variability (HRV) and parasympathetic activity; supports autonomic balance.
Bhramari Pranayama	Produces favorable changes in HRV and cardiac vagal activity; may reduce stress-related autonomic activation.
Sheetali Pranayama	May reduce heart rate and blood pressure and improve cardiac autonomic regulation.
Sheetkari Pranayama	May support blood pressure regulation and improve autonomic balance.
Bhastrika Pranayama	Influences respiratory and autonomic activity and may reduce anxiety and negative affect.
Slow/Deep Breathing	Enhances respiratory sinus arrhythmia and HRV; promotes vagal activity and supports baroreflex regulation.
Humming Breathing	May increase HRV and enhance parasympathetic cardiac modulation.

The table indicates that different Pranayama techniques produce beneficial effects on cardiovascular and autonomic functions. Most techniques are associated with improved heart rate variability, enhanced parasympathetic activity, and better regulation of heart rate and blood pressure. These findings suggest that Pranayama may contribute to maintaining autonomic balance and overall physiological well-being.

Research Gaps and Future Directions

1. **Research Gaps:** Despite increasing evidence supporting the beneficial effects of pranayama, several research gaps remain. Studies differ considerably in the type of pranayama, breathing rate, duration, frequency, and intervention period, making direct comparison difficult. There is also considerable variation in the assessment of autonomic function, particularly in the selection and interpretation of HRV parameters. Many studies have relatively small sample sizes and short follow-up periods, limiting conclusions regarding long-term effects. Furthermore, cardiovascular and psychological outcomes are often examined separately, while the relationship between autonomic modulation and psychological improvement remains insufficiently explored. Evidence is also uneven across different pranayama techniques, with some practices receiving substantially more research attention than others.

2. **Future Directions:** Future research should employ larger, well-designed randomized controlled trials with

standardized pranayama protocols and clearly defined breathing parameters. Long-term studies are needed to determine whether improvements in HRV, blood pressure, stress, and anxiety are sustained over time. Greater use of objective autonomic measures, including HRV and baroreflex sensitivity, may help clarify the physiological mechanisms involved. Comparative studies between different pranayama techniques may further determine whether specific breathing patterns produce distinct cardiovascular or psychological effects. Future research should integrate autonomic, cardiovascular, and psychological outcomes within the same study framework to establish a clearer understanding of how pranayama may contribute to overall health.

Conclusion

Pranayama is a promising complementary approach for improving autonomic regulation and overall cardiovascular and psychological well-being. Evidence suggests that regular pranayama practice may reduce heart rate, blood pressure, stress, and anxiety while improving heart rate variability and parasympathetic activity. However, standardized protocols and larger long-term studies are needed to establish its clinical effectiveness more conclusively.

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