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Effects of Pranayama on Heart Rate Variability: Insights from Randomized Controlled Trials

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Abstract

Heart Rate Variability (HRV) is a reliable indicator of autonomic balance. Various Pranayama techniques differentially influence the parasympathetic and sympathetic nervous systems. This brief communication presents a synthesis of findings from seven randomised controlled trials (RCTs) investigating the effects of different Pranayama practices on HRV. While slow-paced Pranayama practices predominantly enhance parasympathetic activity, rapid breathing exercises demonstrate heterogeneous autonomic effects. These findings highlight the therapeutic potential of Pranayama in modulating autonomic tone, promoting cardiovascular health, and managing stress-related conditions.

Keywords: Pranayama, Heart Rate Variability (HRV), Autonomic Nervous System, Parasympathetic Activation, Randomized Controlled Trials (RCTs).

Introduction

Heart Rate Variability (HRV) reflects the oscillation in time intervals between consecutive heartbeats and is widely utilised as a noninvasive marker of autonomic nervous system activity. Elevated HRV indicates an enhanced parasympathetic tone, which is associated with improved cardiovascular and psychological health. Pranayama, an integral component of yoga, encompasses various controlled breathing techniques that influence the balance between the sympathetic and parasympathetic branches of the autonomic nervous system.

The term pranayama is derived from two Sanskrit words, prana (vital energy) and ayama (expansion or control), emphasising the regulation of life energy through breath control Pranayama practices are categorised as slow (e.g. Nadi Shodhana and Bhramari) and fast (e.g. Kapalbhati), each eliciting a distinct physiological response [1]. Research suggests that these practices enhance physical and mental health by improving cardiovascular, respiratory, and autonomic function [2]. For instance, slow breathing exercises increase vagal tone, reduce blood pressure, and improve emotional regulation, whereas fast techniques can increase alertness and sympathetic activation with subsequent parasympathetic recovery [3].

Studies have demonstrated the broad therapeutic potential of Pranayama under various conditions, including asthma, hypertension, anxiety, and depression [2]. Moreover, practices such as Bhramari Pranayama, which involves humming exhalation, exhibit unique benefits in stimulating the vagus nerve, contributing to autonomic balance and stress reduction [4]. This communication aims to summarise the findings from seven RCTs to explore the specific impact of Pranayama on HRV, providing insights into its preventive and therapeutic applications [5-11].

Methods

This brief communication is predicated upon a selection of randomised controlled trials (RCTs) examining the effects of Pranayama on heart rate variability (HRV). The study incorporated English-language publications from the inception of the databases to the present day. A comprehensive literature search was conducted using PubMed, Web of Science, Scopus, and Cochrane Library. The selected studies evaluated both time-domain parameters (e.g. Root Mean Square of the Successive Differences [RMSSD], Standard Deviation of Normal-to-Normal Intervals [SDNN]), and frequency-domain parameters (e.g. low-frequency [LF] and high-frequency [HF]) of HRV. The trials encompassed diverse populations, including healthy individ-

uals, patients with hypertension, and those experiencing stress, with Pranayama interventions such as Nadi Shodhana, Bhramari, Kapalbhati, and Sheetali.

Results

The selected RCTs provided insights into how various Pranayama techniques affect HRV and related physiological parameters across different populations. In hypertensive patients, studies on Nadi Shodhana and Bhramari Pranayama have demonstrated improvements in autonomic regulation [5, 6]. Both techniques were associated with a significant shift towards parasympathetic activity, reflected by a reduction in the LF/HF ratio and improvements in HRV parameters. Studies on the effects of Sheetali pranayama have highlighted its immediate and long-term effects on blood pressure and HRV [7, 8]. Practising Sheetali Pranayama for 5 min induced a significant reduction in heart rate and systolic and diastolic blood pressure among healthy volunteers. Over a longer period, participants exhibited enhanced parasympathetic activity and reduced cardiovascular stress, suggesting that cooling Pranayama is a potentially beneficial practice for managing hypertension and promoting relaxation.

A study on Kapalbhati Pranayama reported an initial sympathetic activation with a transient reduction in parasympathetic tone, as indicated by decreased RMSSD and HF components immediately post-practice [9]. However, following a 20-minute recovery period, parasympathetic dominance was restored, highlighting the potential of this technique to induce temporary arousal followed by autonomic recovery. Several trials have compared the autonomic effects of different Pranayama techniques. Bhramari pranayama and Buteyko breathing were found to have comparable effects in lowering systolic blood pressure, although Bhramari was particularly effective in enhancing vagal tone [10]. In another study, Sheetali pranayama outperformed control interventions in reducing mean arterial pressure and heart rate, reinforcing its potential suitability for stress reduction and cardiovascular regulation [8]. The superiority of Sheetali in reducing Mean Arterial Pressure (MAP) may reflect its cooling effect, which directly modulates autonomic tone in stressed individuals.

Lathadevi et al. examined the cardiovascular effects of Ujjayi Pranayama combined with Shavasana in 60 healthy men [11]. The intervention group showed significant decreases in heart rate, systolic and diastolic blood pressure, pulse pressure, mean arterial pressure, and rate pressure product, indicating increased parasympathetic activity and reduced sympathetic function, suggesting autonomic balance. The control group displayed no significant cardiovascular changes.

These RCTs also highlight the applicability of Pranayama across diverse populations. In addition to healthy volunteers, individuals with chronic conditions such as hypertension benefited significantly from regular practice. Techniques such as Nadi Shodhana and Sheetali have demonstrated both immediate and sustained effects on HRV, suggesting that they could potentially complement conventional therapies for long-term cardiovascular management. Although these studies have provided valuable insights, certain limitations need to be acknowledged. Several trials had small sample sizes and most lacked adequate blinding, raising the possibility of selection and performance bias. Furthermore, the short follow-up duration in many studies limits the understanding of the long-term effects. These factors should be considered when interpreting the results and planning future research.

Discussion

The findings from these trials elucidate the distinct impact of slow and fast Pranayama techniques on HRV. Slow Pranayama practices, such as Nadi Shodhana and Bhramari, enhance parasympathetic activity, rendering them suitable for stress management and cardiovascular health. Conversely, rapid techniques such as Kapalbhati demonstrate mixed effects, with initial sympathetic activation followed by parasympathetic rebound during recovery. These autonomic responses reflect fundamental differences in breathing patterns and regulatory strategies employed in slow and fast pranayama.

Mechanistically, Pranayama influences autonomic regulation via neural modulation. Slow-mindful breathing activates the vagus nerve, promoting parasympathetic dominance and reducing sympathetic output via top-down control of the prefrontal cortex. These changes not only stabilise HRV but also enhance emotional regulation and resilience to stress [3,4]. Techniques, such as Bhramari, which incorporate humming vibrations, further stimulate the vagus nerve, enhance autonomic balance, and promote relaxation.

These findings align with previous reviews, suggesting that Pranayama offers a non-invasive method for improving autonomic function and cardiovascular health [12]. The transient sympathetic activation observed in rapid practices, such as Kapalbhati, highlights the importance of incorporating structured recovery phases to maximise benefits. The differences in autonomic responses between slow and fast pranayama underscore the necessity of tailoring practices to specific therapeutic goals such as stress management or heightened alertness. Individualising pranayama routines can support not only individuals with chronic conditions but also healthy individuals seeking improved mental clarity and emotional resilience.

Although these results are promising, the studies reviewed are not without limitations. Many trials had small sample sizes, lacked adequate blinding, and featured short follow-up periods, introducing potential bias. Future research should address these gaps by employing larger, well-controlled trials with longer follow-up durations to assess the sustained effects of Pranayama on HRV.

Conclusion

Pranayama practices significantly influence heart rate variability, with slow-paced techniques favouring parasympathetic activity and promoting autonomic balance, whereas rapid techniques induce temporary sympathetic activation followed by recovery. These findings support the inclusion of Pranayama as an adjunct to therapeutic protocols for managing stress, hypertension, and cardiovascular health. The integration of pranayama into regular healthcare practices offers a cost-effective, non-invasive approach to reduce reliance on pharmacological treatment. Further research is required to confirm these benefits in larger, more diverse populations and to explore the long-term impact of various Pranayama techniques. Tailoring Pranayama techniques

to specific objectives— relaxation or heightened alertness— can further enhance their therapeutic value in both clinical and non-clinical settings. In conclusion, Pranayama presented a promising avenue for preventive care and therapeutic interventions that contribute to overall well-being.

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Author Contributions
All the authors have read and approved the final version of the manuscript.

Ethical Statement
Ethical approval was not required for this study as it was a review article with data obtained through a literature search.

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Conflict of Interests
The authors declare no conflicts of interest regarding the publication of this paper.

Data Availability Statement
The data analysed in this review were obtained from publicly available sources, including peer-reviewed articles, observational studies, and surveys, accessible via databases, such as PubMed, Scopus, and Web of Science.

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