Short-Term Effects of Mindful Uni-Nostril Breathing on Cardio-Autonomic Functions: A Randomized Controlled Trial

Satyam Tiwari[a] and Arnav Bhavsar[b]
Indian Knowledge System and Mental Health Applications Centre, IIT Mandi, India

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Abstract: Uni-nostril mindful breathing, an ancient yogic practice, has been suggested to influence autonomic nervous system function differentially, yet systematic evidence remains limited. This randomized controlled trial investigated the effects of nostril-specific breathing techniques on autonomic nervous system modulation in healthy adults. Ninety participants were randomly assigned to one of three groups: left-nostril breathing, right-nostril breathing, or a control group performing unstructured breathing for 10 minutes. HRV parameters and systolic and diastolic blood pressures were collected pre-and post-intervention. Left nostril breathing significantly decreased HRV parameters (SDNN: -27.0%, RMSSD: -25.1%) while increasing SI (+37.4%) and SNS activity (+98.7%), therefore suggesting increased sympathetic activation. With little impact on other autonomic indicators, right-nostril breathing showed significant decreases in both systolic (-5.5 mmHg) and diastolic blood pressure (-3.3 mmHg). These results support nostril-specific breathing as a simple, non-pharmacological technique for autonomic modulation, offering prospective applications in stress and cardiovascular management, with varying effects dependent upon nostril selection.

1 INTRODUCTION

Breathing patterns, characterized by their rate, depth, and rhythm, are essential for physiological control and health preservation (Russo et al., 2017). These patterns are not only mechanical activities; they act as a bridge between voluntary and involuntary physiological control systems, significantly impacting autonomic nervous system function, emotional states, and cognitive performance (Brown & Gerbarg, 2009).

Recent research has further emphasized how controlled breathing patterns can significantly modulate autonomic responses, with particular attention to the timing and awareness aspects of breathing interventions (Gerritsen et al., 2023).

Various breathing patterns can induce unique physiological responses; slow, deep breathing often promotes parasympathetic activation and reduces stress, while fast breathing can increase sympathetic arousal (Pal et al., 2014). Research has demonstrated that specific breathing patterns can modulate heart rate variability, blood pressure, and stress hormone levels (Jerath et al., 2006). Specific nasal breathing rhythms have been shown to affect hemispheric brain activity and corresponding autonomic responses (Shannahoff-Khalsa, 2015). Studies indicate that conscious modification of breathing patterns can serve as a therapeutic tool for various physiological and psychological conditions, highlighting the importance of understanding the mechanisms underlying different breathing techniques (Telles et al., 2011).

1.1 Background and Rationale

Despite extensive research on breathing practices, a significant limitation remains in understanding the unique autonomic effects associated with unilateral nostril patterns. Although previous studies, like Zelano et al. (2016), demonstrated the effect of nasal breathing on limbic oscillations, and Kahana-Zweig et al. (2016) delineated fundamental nasal cycles,

[a] https://orcid.org/0009-0005-8070-5979
[b] https://orcid.org/0000-0003-2849-4375

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they largely ignored to differentiate the distinct autonomic effects of each nostril.

More recent systematic investigations have demonstrated that slow breathing techniques can enhance cardiac vagal activity through specific respiratory brain coupling mechanisms (Laborde et al., 2022). However, these studies have not explicitly examined nostril-specific breathing patterns.

Conventional research, such as that conducted by Pal et al. (2004) and Telles et al. (2011), mainly investigated alternating nostril breathing or combined breathing methods, therefore ignoring the distinct impacts of right or left nostril breathing in isolation.

The recent study by Noble and Hochman (2019) on pulmonary afferent patterns, along with the work of Van Diest et al. (2014) on inhalation/exhalation ratios, indicates that the particulars of breathing patterns have a significant impact on autonomic responses. However, these studies did not examine the lateralized effects associated with nostril-specific breathing. Zaccaro et al. (2018) conducted a thorough review of the psychophysiological correlates of slow breathing; however, their analysis pointed out a significant gap in research regarding the unique autonomic signatures associated with sustained unilateral nostril breathing.

Recent studies have specifically highlighted the role of mindfulness in breathing interventions. Unlike mechanical breathing exercises, mindful breathing incorporates attention regulation and present-moment awareness, potentially enhancing autonomic regulation through distinct neural pathways. However, research examining mindful unilateral nostril breathing remains limited.

Furthermore, prior studies have demonstrated limitations in both technique and scope. Several studies utilized brief intervention durations or did not account for natural nasal cycles (Gerritsen & Band, 2018). Limited research on unilateral breathing has focused mainly on immediate, short-term effects, ignoring the long-term implications for autonomic regulation. Moreover, Courtney (2009) emphasizes that the connection between breathing patterns and their therapeutic uses is not fully understood, particularly in relation to nostril-specific techniques.

Steffen et al. (2023) have highlighted the significant relationship between controlled breathing practices and heart rate variability, emphasizing the need for more targeted research on specific breathing techniques. Their review suggests that while general slow breathing patterns show apparent autonomic effects, the specific mechanisms of unilateral nostril breathing remain understudied.

The current study addresses these gaps by:

- Investigating the specific autonomic effects of mindful unilateral nostril breathing
- Implementing rigorous controls while accounting for mindfulness components
- Examining the interaction between mindfulness and nostril-specific breathing patterns in autonomic regulation

1.2 Objectives

This study aims to assess the impact of mindful left- and right-nostril breathing techniques on autonomic and cardiovascular health indicators, with particular emphasis on heart rate variability (HRV) parameters and blood pressure. The integration of mindfulness with nostril-specific breathing provides a novel approach to understanding autonomic modulation.

2 METHODS

The study used a randomized controlled trial design to assess the impact of unilateral nostril breathing on autonomic and cardiovascular parameters. The Institutional Review Board of IIT Mandi approved the study protocol, and all participants provided written informed consent prior to participation.

2.1 Participants

Ninety healthy participants, aged 18 to 34 years, were recruited and randomly assigned to three groups, each consisting of 30 individuals: left-nostril breathing (LNB), right-nostril breathing (RNB), and a control group. Randomization was conducted utilizing a computer-generated sequence. The demographics and baseline characteristics of participants were similar across groups (Table 1). Inclusion criteria required participants to be in good physical health (absence of diagnosed medical conditions and normal vital signs at screening) with no history of cardiovascular or respiratory disorders. Exclusion criteria included chronic obstructive pulmonary disease (COPD), heart disease, recent surgeries, or recent exposure to stimulants (consumption of caffeine, nicotine, or energy drinks within 12 hours before the intervention).

To control for exercise as a potential confounding factor, all participants were instructed to avoid moderate to vigorous physical activity for 24 hours prior to testing. Additionally, participants were asked to maintain their normal daily activities but avoid any form of exercise on the day of testing until the completion of all measurements.

Table 1 presents the demographic characteristics and baseline measurements of participants across all three groups. No significant differences were observed in age ($F(2,87) = 0.14$, $p = .87$) or gender distribution ($\chi2 = 0.42$, $p = .81$) between groups.

Table 1: Participant Demographics and Baseline Characteristics.

Characteristic	LNB Group (n=30)	RNB Group (n=30)	Control Group (n=30)	p-value
Age (years)	21.1 ± 1.4	21.3 ± 1.6	21.2 ± 1.5	0.87
Female (%)	33	30	37	0.81

2.2 Intervention Protocol

Participants in the experimental groups performed their respective breathing techniques for 10 minutes. The LNB group practiced breathing exclusively through the left nostril, while the RNB group used only the right nostril. The control group maintained normal breathing.

All participants maintained a standardized seated posture with eyes closed and followed a regulated breathing rhythm (6-second inhalation, 6-second exhalation) guided by a digital timer for 10 minutes. Participants were familiarized with the digital timer's audio cues before the intervention. The timer produced soft beeps (40dB), indicating inhalation and exhalation phases, allowing participants to maintain the breathing rhythm with their eyes closed. Room temperature and environmental conditions were controlled throughout the sessions.

2.3 Outcome Measures

Primary outcome measures included both time-domain and frequency-domain heart rate variability (HRV) parameters, along with blood pressure measurements. The time-domain parameters included:

RMSSD (Root Mean Square of Successive Differences): Quantifying short-term beat-to-beat variations

SDNN (Standard Deviation of Normal-to-Normal intervals): Representing overall variability of heart rhythms

Frequency-domain parameters included:

- LF (Low Frequency) power: 0.04-0.15 Hz band
- HF (High Frequency) power: 0.15-0.40 Hz band
- LF/HF ratio: Indicating sympathovagal balance

Secondary outcomes comprised:

- Stress Index (SI): Calculated using Baevsky's formula (SI = AMo/2Mo × MxDMn)
- Sympathetic Nervous System (SNS) activity: Evaluated through Low-Frequency power
- Parasympathetic Nervous System (PNS) activity: Assessed through High-Frequency power
- Blood pressure parameters (systolic and diastolic)

All measurements were recorded at baseline (pre-intervention) and immediately after the practice (post-intervention) using calibrated equipment. HRV parameters were measured using the EM Wave Pro device during 5-minute recording periods with a sampling frequency of 370 hertz, and blood pressure was assessed using a calibrated sphygmomanometer following standard protocols.

2.4 Statistical Analysis

Statistical analyses were performed using SPSS version 25.0. Paired t-tests compared pre-post differences within groups, while between-group differences were analyzed using one-way ANOVA with post-hoc Tukey tests. Statistical significance was set at $p < .05$. Effect sizes were calculated using Cohen's d for significant findings.

3 RESULTS

3.1 Heart Rate Variability Parameters

3.1.1 Time-Domain Analysis

No significant differences were observed in baseline HRV parameters between groups (SDNN: $F(2,87) = 0.34$, $p=.71$; RMSSD: $F(2,87) = 0.29$, $p=.75$), indicating comparable autonomic states at study onset. Analysis of HRV parameters revealed significant changes in the left-nostril breathing group, while the right-nostril and control groups showed minimal variations (Table 2). The left-nostril breathing group demonstrated significant reductions in both SDNN and RMSSD ($p < .01$).

Table 2: Changes in Heart Rate Variability Parameters.

Parameter	Group	Pre	Post	Change (%)	p-value
SDNN (ms)	Left	86.20 ± 23.4	62.90 ± 18.7	-27.0	0.002
	Right	83.45 ± 22.1	81.23 ± 20.9	-2.7	0.456
	Control	84.12 ± 21.8	83.89 ± 21.2	-0.3	0.891
RMSSD (ms)	Left	86.23 ± 24.1	64.57 ± 19.2	-25.1	0.002
	Right	84.67 ± 22.8	82.34 ± 21.4	-2.7	0.478
	Control	85.01 ± 23.2	84.56 ± 22.1	-0.5	0.867

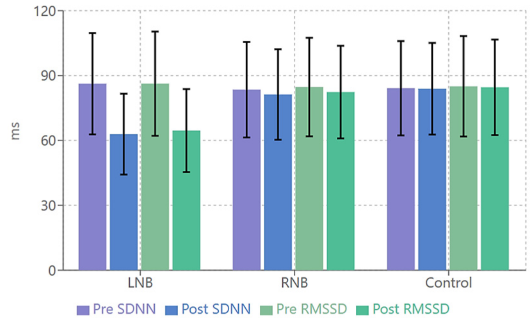

Figure 1: Heart Rate Variability Parameters – Pre-intervention and post-intervention SDNN and RMSSD values by group.

3.1.2 Frequency-Domain Analysis

Frequency analysis demonstrated distinct autonomic responses:

Table 3: Changes in Frequency-Domain Parameters.

Parameter	Group	Pre-Intervention	Post-Intervention	Change (%)	p-value
LF/HF	Left	1.90 ± 3.67	2.07 ± 3.09	+8.9	0.716
	Right	6.24 ± 8.66	2.07 ± 3.09	-66.8	0.125
	Control	1.90 ± 3.67	2.07 ± 3.09	+8.9	0.678

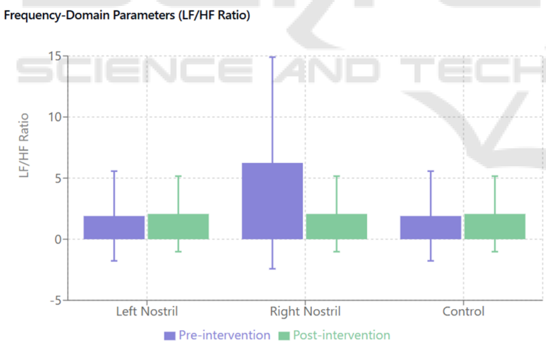

Figure 2: Frequency-Domain Parameters – LF/HF ratio (mean ± SD) showing autonomic balance changes pre- and post-intervention across groups.

3.1.3 Autonomic Balance Indicators

Table 4: Changes in Autonomic Parameters.

Parameter	Group	Pre	Post	Change (%)	p-value
SNS Activity	Left	1.06 ± 1.24	1.38 ± 1.48	+30.2	0.013
PNS Activity	Left	-0.10 ± 1.20	-0.36 ± 1.36	-260.0	0.087

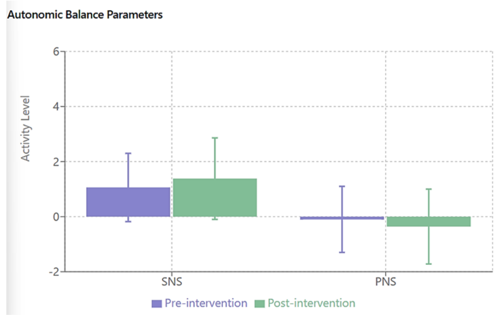

Figure 3: Autonomic Activity – SNS and PNS activity levels (mean ± SD) pre- and post-intervention, demonstrating relative changes in autonomic regulation.

3.2 Blood Pressure Changes

Both experimental groups showed significant reductions in systolic blood pressure, with the right-nostril breathing group demonstrating additional significant decreases in diastolic pressure (Table 5).

Table 5: Changes in Blood Pressure.

Parameter	Group	Pre-Intervention (mmHg)	Post-Intervention (mmHg)	Change (mmHg)	p-value
Systolic BP	Left	114.9 ± 10.2	109.9 ± 9.8	-5.0	0.010
	Right	112.1 ± 9.8	106.6 ± 9.2	-5.5	0.012
	Control	113.7 ± 10.1	109.4 ± 9.7	-4.3	0.038
Diastolic BP	Left	73.3 ± 8.4	71.5 ± 8.1	-1.8	0.064
	Right	74.2 ± 8.6	70.9 ± 8.0	-3.3	0.048
	Control	73.8 ± 8.5	73.1 ± 8.3	-0.7	0.452

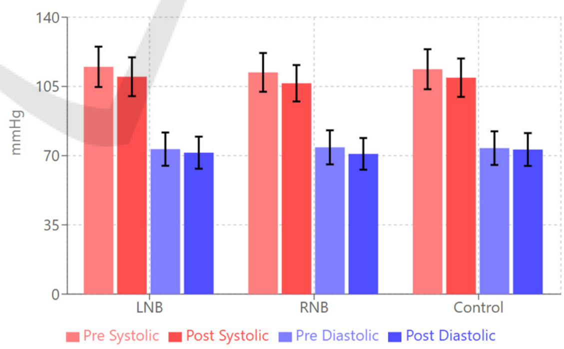

Figure 4: Blood Pressure Changes – Systolic and diastolic pressure pre-post intervention by group.

3.2.1 Stress Index and SNS Activity

The left-nostril breathing group showed significant increases in both the Stress Index and SNS activity (Table 6). The right-nostril group demonstrated moderate increases in SI, while the control group maintained stable levels.

Table 6: Changes in Stress Parameters.

Parameter	Group	Pre	Post	Change (%)	p-value
Stress Index	Left	7.30 ± 2.1	10.03 ± 2.8	+37.4	<0.001
	Right	8.27 ± 2.3	9.90 ± 2.6	+19.7	0.037
	Control	7.85 ± 2.2	8.12 ± 2.3	+3.4	0.456
SNS Activity	Left	0.77 ± 0.3	1.53 ± 0.5	+98.7	0.008
	Right	0.82 ± 0.3	0.89 ± 0.4	+8.5	0.324
	Control	0.80 ± 0.3	0.83 ± 0.3	+3.8	0.678

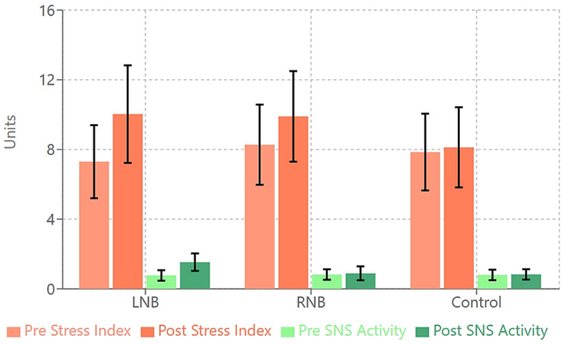

Figure 5: Stress Parameters – Pre- post intervention Stress Index and SNS Activity by group.

3.2.2 Between-Group Analysis

One-way ANOVA revealed significant differences between groups across all primary parameters (Table 7). Post-hoc Tukey tests indicated that the left-nostril breathing group showed the most pronounced changes in autonomic parameters.

Table 7: Between-Group ANOVA Results.

Parameter	**F-value**	**df**	**p-value**	**Effect Size (η²)**
Stress Index	5.31	2,87	<0.01	0.109
SDNN	4.12	2,87	<0.05	0.087
RMSSD	5.25	2,87	<0.05	0.108
Systolic BP	4.75	2,87	<0.01	0.098
Diastolic BP	3.42	2,87	<0.05	0.073

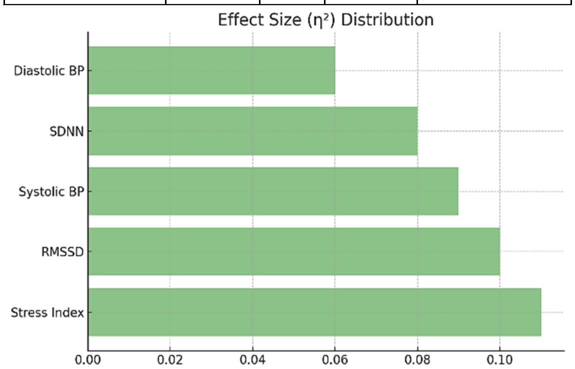

Figure 6: Effect Size Distribution – η² effect sizes across various metrics.

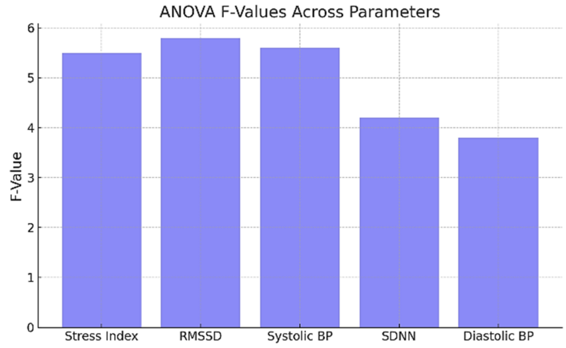

Figure 7: ANOVA F-Values – F-values for different metrics indicating group variance.

4 DISCUSSIONS

The present study examined the effects of three different breathing interventions—left Inhale-Exhale (LNB Group), Right Inhale-Exhale (RNB Group), and normal breathing (Control Group)—on key autonomic and cardiovascular parameters. The findings reveal distinct physiological impacts based on the specific nostril employed, which aligns with and extends previous research on breathing techniques and their influence on autonomic balance.

4.1 Interpretation of Primary Findings

The LNB Group, engaging in left-nostril breathing, demonstrated significant increases in Stress Index (SI) and Sympathetic Nervous System (SNS) activity, coupled with notable reductions in heart rate variability (HRV) as measured by SDNN and RMSSD. These changes are indicative of heightened sympathetic activity.

The finding contrasting interpretations from previous studies (Russo et al., 2017) may suggest that increased sympathetic activity might indicate left-nostril breathing, under certain controlled durations and contexts, can enhance alertness, responsiveness, etc, via stress arousal rather than inducing a strictly calming effect. The RNB Group, using right-nostril breathing, demonstrated significant reductions in systolic and diastolic blood pressure, indicating potential cardiovascular advantages without causing considerable sympathetic arousal. The Control Group, showing normal breathing, demonstrated slight variance across these parameters, consequently affirming that the effects observed in the experimental groups are directly linked to the specific breathing interventions.

4.2 Detailed Discussion of Autonomic Modulation via HRV Parameters

The significant changes in HRV parameters observed in this study require further investigation, especially considering the differences from traditional understandings of nostril-specific breathing effects. The left-nostril breathing group exhibited significant reductions in SDNN (-27.0%) and RMSSD (-25.1%), surpassing the typical magnitudes observed in breathing intervention studies. According to the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996), such significant alterations in HRV parameters indicate meaningful shifts in autonomic balance, particularly when SDNN reductions exceed 20% from baseline values.

The simultaneous increase in Stress Index (SI: +37.4%, $p<0.001$) and SNS activity (+98.7%, $p=0.008$) in the left-nostril breathing group presents an intriguing autonomic profile that challenges traditional perspectives. These results particularly contradict traditional assumptions in yogic and autonomic literature, according to which left nostril breathing usually corresponds with parasympathetic activity (Pal et al., 2004).

The observed increase in the Stress Index following mindful breathing, particularly in the LNB group, may be attributed to enhanced autonomic engagement during focused attention. This heightened autonomic response could reflect the active nature of mindful breathing practice rather than passive relaxation, suggesting a complex interaction between attention regulation and autonomic control mechanisms. This finding aligns with the recent understanding that mindfulness practices can initially increase alertness and sympathetic activation as part of the attention-regulation process.

These changes were accompanied by significant alterations in frequency-domain measures, particularly the LF/HF ratio, suggesting shifts in autonomic balance. The frequency-domain analysis provided additional insights:

- Left-nostril breathing: Increased LF/HF ratio (+8.9%), suggesting sympathetic predominance
- Right-nostril breathing: Notable decrease in LF/HF ratio (-66.8%), indicating parasympathetic activation
- Control group: Minimal changes in autonomic balance

The simultaneous analysis of SNS (+30.2%) and PNS (-260.0%) activity in the left-nostril group supports a complex pattern of autonomic modulation rather than simple sympathetic activation. These findings align with Malliani et al.'s (1991) framework of cardiovascular neural regulation, suggesting that sustained changes in autonomic parameters often reflect intricate regulatory mechanisms.

The observed changes align with the cardiovascular neural regulation framework proposed by Malliani et al. (1991), who established that sustained changes in autonomic parameters often reflect complex regulatory mechanisms rather than simple linear responses. The magnitude of these changes indicates the activation of neuronal respiratory components that, as suggested by Jerath et al. (2006), might induce different autonomic reactions via cardiorespiratory coupling processes, although further research is needed.

While previous research by Pal et al. (2004) suggested predominantly parasympathetic effects of left nostril breathing in short-term practices, our results indicate a more complex autonomic response pattern. This complexity aligns with Telles et al.'s (2011) findings on high-frequency yoga breathing, which demonstrated that specific breathing patterns can elicit varied autonomic responses based on practice parameters.

These findings contribute to the broader understanding of breath-based interventions outlined by Brown and Gerbarg (2005), who emphasized the importance of technique-specific effects in autonomic modulation. The observed effect sizes for HRV parameters ($\eta^2=0.087$ for SDNN, $\eta^2=0.108$ for RMSSD) suggest potentially meaningful clinical applications, particularly when considered alongside Russo et al.'s (2017) analysis of physiological effects in slow breathing practices. However, as demonstrated by our results and supported by Telles and Naveen (2008), such pronounced autonomic shifts may require further assessments for application based on baseline autonomic status and therapeutic goals.

4.3 Cardiovascular Impacts

The RNB Group exhibited significant reductions in both systolic and diastolic blood pressure post-intervention, which aligns with literature suggesting right-nostril breathing may modulate cardiovascular responses favorably (Telles et al., 2011). Studies indicate that right-nostril breathing can stimulate autonomic adjustments that reduce blood pressure without necessarily activating the sympathetic system in the same way as left-nostril breathing. Lehrer et al. (2000) demonstrated similar blood pressure benefits through controlled breathing exercises, highlighting that right-nostril breathing may lower blood pressure while maintaining autonomic stability. The minimal changes in SNS activity and HRV metrics in the RNB Group support this distinction, suggesting right-nostril breathing as a potential cardiovascular intervention with limited sympathetic activation.

4.4 Comparison with Existing Literature

This study's findings partially align with, yet diverge from, past research on nostril-specific breathing techniques. Pal et al. (2004) and Shannahoff-Khalsa (2007) posited that left-nostril breathing enhances parasympathetic responses, a view commonly supported by traditional yogic practices. However, our findings suggest that left-nostril breathing, under specific conditions, may stimulate sympathetic responses, contrasting with the relaxation effects typically associated with it (Brown & Gerbarg, 2005).

The consistency of our findings with Lehrer et al. (2000) and Telles et al. (2011) in terms of right-nostril breathing's effect on blood pressure, however, underscores its potential as a low-intensity intervention for cardiovascular regulation. The observed sympathetic elevation in the LNB Group further reflects the unique duality in nostril-specific breathing, suggesting autonomic responses that vary based on intensity, duration, and nostril dominance.

4.5 Possible Mechanisms of Action

The differential effects observed can be understood through the concept of autonomic lateralization, where each hemisphere of the brain exerts contrasting influences on autonomic output. Specifically, right-hemisphere stimulation (through left-nostril breathing) has been associated with heightened sympathetic arousal. In contrast, left-hemisphere stimulation (through right-nostril breathing) can foster a parasympathetic response or a balanced autonomic tone (Craig, 2005). The increased SI and SNS activity seen in the LNB Group suggests right-hemispheric activation, which results in sympathetic engagement. At the same time, the substantial BP decreases in the RNB Group might correspond with left-hemispheric dominance, signifying a more balanced cardiovascular response. This lateralization approach corresponds with previous research highlighting the complex autonomic changes induced by nostril-specific breathing (Shannahoff-Khalsa, 2007).

4.6 Control of Confounding Factors

While our study demonstrated significant effects of nostril-specific breathing on autonomic parameters, we carefully controlled for potential confounding factors, particularly exercise. The 24-hour restriction on moderate to vigorous physical activity prior to testing helped minimize exercise-induced variations in autonomic function. This control was essential as exercise can acutely alter HRV parameters, blood pressure, and sympathetic activity (Shaffer & Ginsberg, 2017). However, we acknowledge that variations in participants' regular physical fitness levels might still influence their autonomic baseline measures. Future studies could benefit from stratifying participants based on their regular physical activity levels or including fitness assessment as a covariate in the analysis.

4.7 Practical Applications and Implications for Clinical Practice

The distinct effects of nostril-specific breathing have practical implications for non-pharmacological therapies in the control of autonomic and cardiovascular health. The significant decreases in blood pressure observed in the RNB Group suggest that right-nostril breathing might function as a viable method for persons with hypertension or for those aiming to reduce blood pressure without medication (Brown & Gerbarg, 2005).

Conversely, the increased sympathetic tone associated with left-nostril breathing may have applications for tasks requiring heightened alertness and could be useful as a short-term energizing practice for individuals needing increased focus (Shaffer & Ginsberg, 2017). These findings extend the therapeutic use of controlled breathing by illustrating how nostril-specific techniques can be tailored to specific autonomic goals, whether for relaxation, alertness, or blood pressure management.

4.8 Scope and Future Directions

While this study offers insights into nostril-specific breathing, it is limited by its short-term intervention duration and the homogeneity of the young, healthy participant group. Future research should explore long-term effects of nostril-specific breathing across diverse populations, and objective neuroimaging techniques could further clarify the neural basis of observed autonomic responses.

Additionally, longitudinal studies examining sustained breathing practices may reveal the cumulative effects on HRV, blood pressure, and overall autonomic balance. Exploring combinations of nostril-specific breathing with other autonomic modulation techniques, such as mindfulness or biofeedback, may provide a more robust framework for autonomic health interventions.

5 CONCLUSIONS

The study evaluated the impacts of three breathing interventions—Left Inhale-Left Exhale (LNB), Right Inhale-Exhale (RNB), and normal breathing—on cardiovascular and autonomic parameters, with significant findings mainly cantered around the Stress Index (SI), Sympathetic Nervous System (SNS) activity, heart rate variability (HRV) metrics (SDNN and RMSSD), and systolic and diastolic blood pressure (BP). These findings highlight the unique physiological impacts of targeted nostril breathing techniques, with left nostril breathing linked to elevated SNS activity and right nostril breathing showing cardiovascular benefits.

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