Original Article

Heart Rate Variability during Nostril-Regulated Yoga Breathing: A Randomized Crossover Study

Abstract

Background: Previous studies of nostril-regulated yoga breathing have focused on unilateral breathing with both inspiration and expiration through a specified nostril. However, traditionally described yoga breathing involves inspiration through one nostril and expiration through the other, called *suryabhedan pranayama* (SBP) (right nostril inspiration) and *chandrabhedan pranayama* (CBP) (left nostril inspiration). The effects of these practices were investigated here. **Methods:** Forty-seven healthy male participants (group mean age ± standard deviation [SD]; 26.34 ± 6.38 years) with prior experience of yoga breathing (group mean age ± SD; 43.64 ± 32.84 months) were randomly assigned to four sessions on separate days: (i) SBP, (ii) CBP, (iii) Breath awareness, and (iv) Quiet rest. The heart rate variability (HRV) and breath rate were recorded pre, during, and post each practice. **Results:** There was a significant increase in low frequency (LF) power and SD of NN intervals during SBP and CBP in comparison to the respective preceding ($P < 0.05$; repeated measures analyses of variance with Bonferroni adjusted *post hoc* analysis), while LF increased post-CBP alone. During both interventions, there were significant reductions in respiration rate. **Conclusion:** The changes in HRV suggest common rather than distinct changes in SBP and CBP suggestive of respiration-related increased cardiac parasympathetic activity. The involvement of both nostrils in SBP and CBP may have contributed to the comparable effects of the two practices.

Keywords: *Cardiac parasympathetic activity, heart rate variability, nostril regulation, respiration rate, yoga breathing*

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Introduction

The nasal cycle is an ultradian rhythm characterized by a change in the internasal airflow with a phase length ranging between 30 min and 6 h.[1,2] Phases of the nasal cycle are associated with changes in functions regulated by the autonomic nervous system.[3,4] Asymmetrical nasal vasomotor oscillations mediated through oscillations in sympathetic activity are believed to give rise to the nasal cycle and produce both psychological and physiological effects unique to each nostril in humans. Yoga practice includes nostril-regulated breathing, hence allowing for research on these practices for extended periods.[4] Most investigations on nostril-regulated yoga breathing reported the effects of volitionally breathing through one nostril exclusively. There is some support for right uninostril breathing as activating (i.e. increasing oxygen consumed and blood pressure and reducing blood flow to the skin of the hand[5,6] with less clear effects of left uninostril breathing.[5-9]

However, breathing through one nostril exclusively is not mentioned in the ancient yoga texts [viz., *Hatha Pradipika Circa 1500 CE*[10] and *Gheranda Samhita Circa 1700 CE*,[11] but is mentioned in present-day commentaries on yoga.[12] In the traditional texts,[10,11] regulated nostril breathing is not unilateral but involves inspiration through one nostril and expiration through the other.[10,11] In the traditional texts, inspiration through the right nostril and expiration through the left nostril (called *suryabhedan* = *surya* is the "sun" [hence stimulating] and *bhedan* means "to pierce") have been described.[10,11] The corresponding practice (i.e., inspiration through the left nostril with expiration through the right nostril [called *chandrabhedan* = *chandra* is the "moon" hence calming]) has evolved in contemporary practice.[10,11]

Unlike uninostril yoga breathing techniques, to our knowledge, there are no reports on

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how these traditionally described, nostril-regulated yoga breathing practices influence heart rate variability (HRV).

Hence, the present randomized, crossover trial was planned to assess the effects of traditionally described nostril-regulated yoga breathing on the HRV. All participants were assessed in four sessions, namely, right nostril inspiration breathing (*suryabhedan pranayama* [SBP]), left nostril inspiration breathing (*chandrabhedan pranayama* [CBP]), breath awareness (BAW) (as an interventional control), and quiet rest (QR) (as a control session) on different days in random order. It was hypothesized that in SBP*,* the changes would be consistent with the description as activating, whereas in CBP*,* the changes would be consistent with the description as calming.

Methods

Participants

Forty-seven healthy male participants (group mean age ± standard deviation [SD]; 26.34 ± 6.38 years; with average body mass index ± SD, 21.2 ± 2.2 kg/m^2) with ages between 18 and 46 years were recruited for the present study from a state private university in North India. Recruitment was carried out with flyers displayed on notice boards and announcements made in lecture halls. With the sample size of 47, and Cohen's *d* of 1.49 (obtained from change in low frequency [LF] power during SBP compared to pre), the power obtained was 1.00 for the present study which was determined using the G-Power program.[13] The criteria for inclusion in the trial were as follows: (i) apparent normal health based on a semi-structured interview and regular clinical examination, (ii) a minimum of 6-month experience practicing yoga breathing as specified in traditional yoga texts,[14] and (iii) participants' availability for recording on four separate days at the same time of day. The exclusion criteria for the trial were (i) females were excluded from the study to reduce intra-individual variability, based on variations in phases of the menstrual cycle,[15] though this is acknowledged as a limitation of the study, (ii) regular consumption of alcohol or tobacco (in any form), (iii) disturbed sleep routine in the night before the assessment, (iv) intense physical exercise within 24 h of the assessment, and (v) extrasystole in the electrocardiogram (EKG) (to avoid abnormal HRV recordings). The exclusion criteria (ii to v) mentioned above were selected to reduce the variability in HRV based on suggestions for HRV recording.[16] None of the participants were required to be excluded for these reasons. The participants' signed informed consent forms were taken before enrolment. The study was approved by the institutional ethical committee (YRD-018/007). The baseline characteristics of the participants are provided in Table 1.

Study design

The participants were informed about the schedule of the study. There were three stages of randomization and allocation. (i) A person who was unaware of the study protocol assigned each of the four sessions a serial number from the four digits between 1 and 4. (ii) 47 sets of random sequences of the four digits, namely, 1, 2, 3, and 4, were generated using an online randomizer (www.randomizer.org). (iii) Each of the 47 participants was assigned one sequence of four digits, which determined the order of the four sessions (i.e., SBP, CBP, BAW, and QR) for that

Table 1: Baseline characteristics of the participants

	Characteristics	Details
Sample	Number of participants	47
	Gender	Males
Age	Age range (years)	18-46
	Group mean age±SD (years)	26.34±6.38
BMI (Kg/M^2)	Group mean±SD	21.16±2.22
Education in years (number)	10-12 years of education	27
	15 years of education	12
	17 years of education	8
Yoga experience	Group average yoga experience±SD (months)	43.64±32.84
	Yoga experience range (months)	6-144
Time spent in practicing yoga in a day (in minutes)	Group mean±SD	98.19±44.24
Marital status	Unmarried (number)	47
Health status	Presence of any disease (number)	0
	Taking any medication (number)	0
Diet	Lacto-vegetarians	47
Sleep quality	Self-rating of sleep quality on a 10 cm analog scale	8.80±0.79
	Duration of sleep (in minutes)	338.44±4.22
Duration of physical activity/day (in minute)	Physical activity in a day (in minutes)	48.04±58.18
	Physical activity in a day range (in minutes)	8-244
Tobacco & alcohol	Consumption of tobacco including smoking (number)	0
	Consumption of alcohol (number)	0

participant. The order of the sessions to which the participants were assigned was unknown to the participants. Each session was for 33 min. All sessions were divided into three states: pre, during, and post. (i) The prestate was for 5 min, (ii) the during state was for 18 min (three, 5 min periods of practice with 1 min of rest after each), and (iii) the postperiod of 10 min after the intervention. Figure 1 shows a flow diagram showing the study process flow. Figure 2 shows a schematic representation of the design of the study. The recordings were carried out between January 2020 and March 2021.

Assessments

Assessments were carried out at fixed times (i.e., between 05:00 and 07:30 h) in a sound-attenuated and air-conditioned laboratory.[16] Participants were asked to empty their urinary bladder before the beginning of the assessments. HRV and respiration were recorded with a two-channel EKG and respiration recording system (MP 45 BIOPAC Student Lab, BIOPAC System Inc, U. S. A.). The EKG was recorded using Ag/AgCl pregelled electrodes for a standard limb lead III configuration (the right hand was required to manipulate the nostrils; hence the lead III configuration involving the left arm-left leg was selected). Data were acquired at the sampling rate of 1024 Hz and analyzed offline. Noise-free data were included for analysis. The respiration rate was obtained from the recording made with a respiratory stethograph transducer fixed around the trunk 8 cm below the lower costal margin when the participant sat erect and fastened after expiration.

Interventions

The following interventions were given for 18 min each: SBP *or* right nostril inspiration yoga breathing, CBP or left nostril inspiration yoga breathing, BAW, and QR when the participants lay in a semi-recumbent posture.

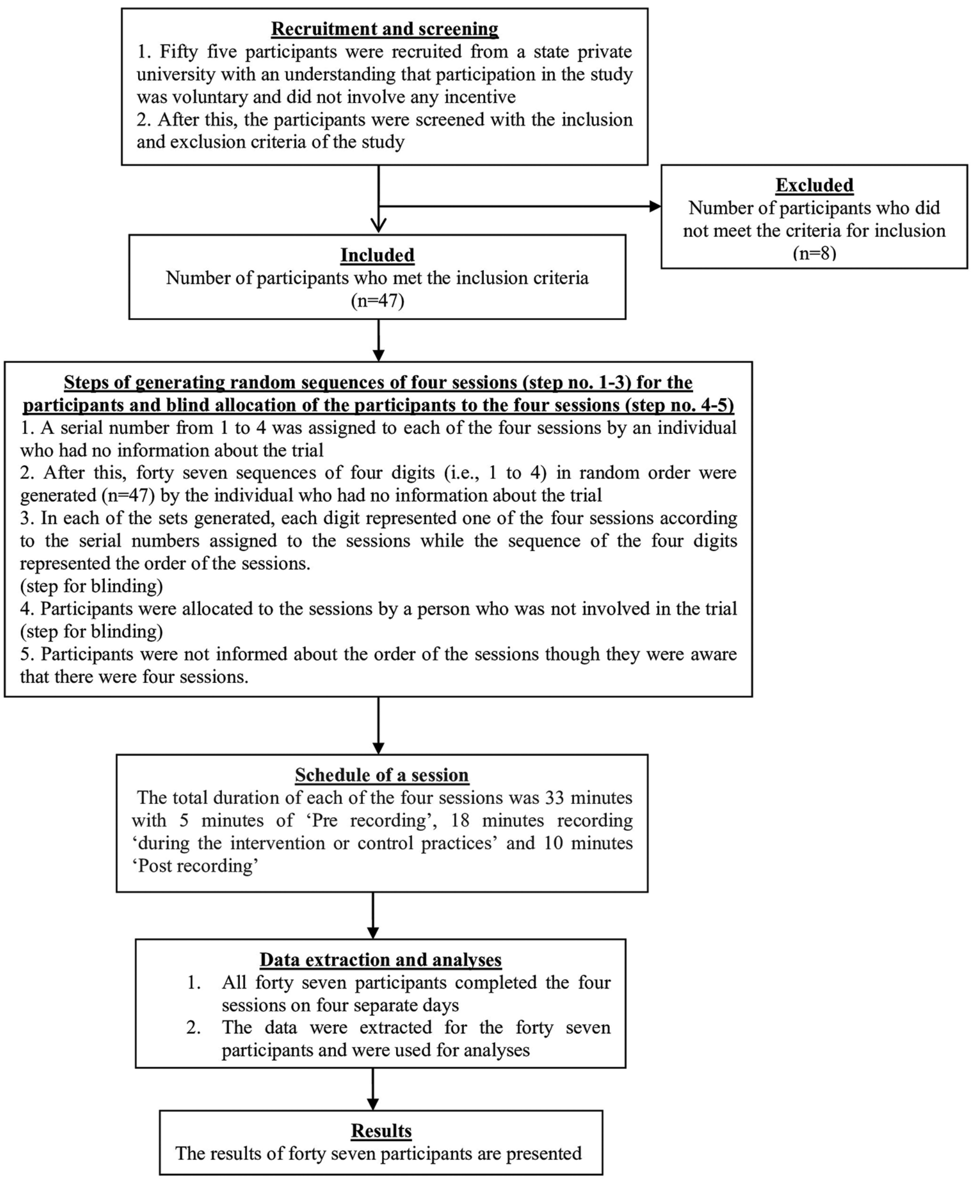

Figure 1: The flow diagram showing the study process flow

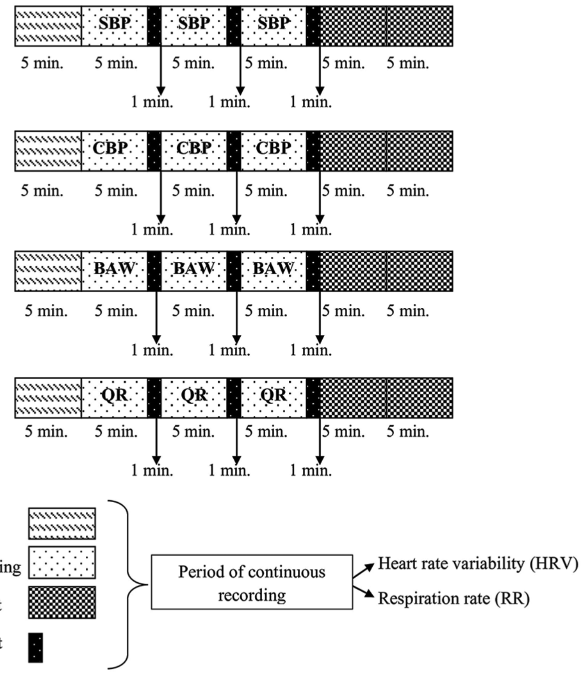

Figure 2: Schematic representation of the design of the study

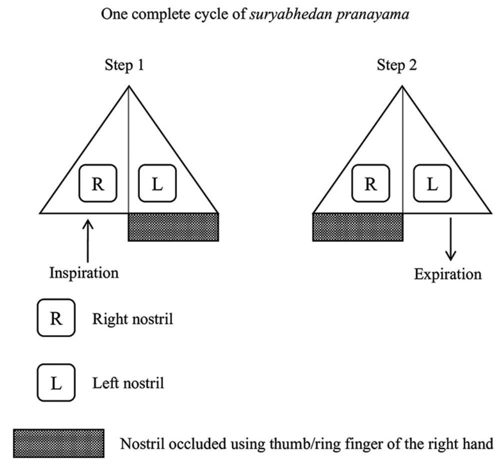

Figure 3: Schematic representation of the procedure of *suryabhedan Pranayama*

Suryabhedan pranayama or right nostril inspiration yoga breathing

The cycle begins with inspiration through the right nostril, followed by an occlusion of the right nostril with the right thumb and expiration through the unoccluded left nostril. The middle and ring fingers of the right hand were used to close the left nostril. All participants were right-hand dominant based on specific questions asked from the participants about their handedness (e.g., which hand do you use to brush your teeth or writing or to throw). There was no retention of breath (*kumbhaka*) during the practice. (It is to be noted that in the traditional texts, SBP is mentioned as having a period of breath hold between inspiration and expiration).[10,11] The cycle continues. Figure 3 shows a schematic representation of the procedure of SBP.

Chandrabhedan pranayama or left nostril inspiration yoga breathing

The thumb of the right hand occluded the right nostril. The cycle begins with inspiration through the left nostril, following which the left nostril was occluded with the right middle and ring fingers while expiration through the unoccluded right nostril. The cycle continues. There was no retention of breath (*kumbhaka*) during the practice. Figure 4 shows a schematic representation of the procedure of CBP.

Breath awareness

Participants were instructed to pay close attention to the flow of air as it passed through the nasal passage. Participants were told not to change their breathing in any way and to focus solely on the breath. BAW was chosen as an intervention because it is part of all yoga breathing techniques. The breath rate and other aspects of breathing were not altered on purpose.

Quiet rest

During this practice, participants were asked to avoid conscious regulation of their breath or thoughts, which were hence free to wander.

Self-report of ease of practice

A 10-cm horizontal line with word descriptions at both ends served as the scale was used for participants to self-report their ease of practice.[17] "Worst possible" and "Excellent" were the two adjectives used at the end of the line. Participants were asked to judge their ease of practice immediately after each of the four sessions by placing a vertical mark on a horizontal line that represented how well they were able to follow the practice instructions.

Data extraction

Heart rate variability

The data were visually inspected for movement artifacts, if any. None of the data were required to be edited for movement artifacts. The square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD) and the SD of NN intervals (SDNN) were noted. Furthermore, the power in the HRV series for the LF band (0.04–0.15 Hz) and the high frequency band (0.15–0.40 Hz) were determined. LF power, HF power, SDNN, and RMSSD were transformed to natural logarithm to standardize the data and have been presented as log-transformed low-frequency component power (LnLF), log-transformed high frequency component power (LnHF), log-transformed standard deviation of the N-N interval (LnSDNN), and log-transformed root mean square of successive differences between normal heartbeats (LnRMSSD), respectively, in the results section. The respiration rate was calculated as the average number of breaths/minutes (bpm).

Ease of practice

Participants' scores for their ease to practice the yoga breathing techniques were obtained by measuring the distance between the participant's mark on the line and the end anchored with "not satisfactory," using a standard measuring scale. A higher score indicated better ease of practice. If the score was <7.0, the session was repeated. None of the sessions had to be repeated for this reason.

Statistical analysis

Statistical analyses were done using separate repeated measures analyses of variance (RM-ANOVA) through IBM SPSS Version 24.0 (IBM SPSS [Version 24.0], New York, USA) followed by *post hoc* analyses with Bonferroni adjustment. Each RM-ANOVA had two "Within subjects" factors, i.e. Sessions (with four levels; SBP, CBP, BAW, and QR) and States (with six levels, i.e. pre, during 1, during 2, during 3, post 1, and post 2). The level of significance (α) was set at 0.05 (two-tailed).

Results

Forty-seven healthy male participants were assigned to four randomly ordered sessions on separate days. The group mean ± SD values for the ease of practice assessed with the visual analog scale were (i) 9.03 ± 1.27 for SBP, (ii) 8.99 ± 1.09 for CBP, (iii) 8.69 ± 1.28 for BAW, and (iv) 8.97 ± 1.33 for QR. The baseline characteristics of the participants are presented in Table 1.

Repeated measures analyses of variance

There was a significant difference between States for (i) LnLF (Huynh-Feldt: $F_{1.46,67.10} = 6.33$, $P = 0.007$), (ii) LnSDNN (Huynh-Feldt: $F_{3.46,159.33} = 12.88$, $P < 0.001$), and (iii) respiration rate (bpm) (Huynh-Feldt: $F_{2.64,121.58} = 46.47$, $P < 0.001$). A significant difference between Sessions was noted for (i) LnLF (Huynh-Feldt: $F_{1.54,71.00} = 7.01$, $P = 0.004$), (ii) LnSDNN (Huynh-Feldt: $F_{3,138} = 6.52$, $P < 0.001$), and (iii) respiration rate (bpm) (Huynh-Feldt: $F_{2.54,117.01} = 26.64$, $P < 0.001$). Furthermore, a significant interaction between Sessions × States was found in (i) LnSDNN (Huynh-Feldt: $F_{9.06, 416.56} = 5.62$, $P < 0.001$), and (ii) respiration rate (bpm) (Huynh-Feldt: $F_{7.95,365.82} = 20.42$, $P < 0.001$).

Post hoc analyses

The LnLF increased in the three during states (i.e. during 1, during 2, and during 3) for (i) SBP ($P < 0.001$, with 95% confidence interval [CI] of [−0.826, −1.792] for during 1; $P < 0.001$, with 95% CI of [−0.764, −1.713] for during 2; $P < 0.001$, with 95% CI of [−0.864, −1.784] for during 3) and (ii) CBP ($P < 0.001$, with 95% CI of [−0.475, −1.703] for during 1; $P < 0.001$, with 95% CI of [−0.431, −1.572] for during 2; $P < 0.001$, with 95% CI of [−0.665, −1.621] for during 3; $P = 0.004$, with 95% CI of [−0.109, −0.918] for post 1). The LnRMSSD decreased in the poststate for SBP ($P = 0.015$, with 95% CI of [0.309, 0.020] for post1). The LnSDNN increased in the three during states (i.e. during 1, during 2, and during 3) for (i) SBP ($P < 0.001$, with 95% CI of [−0.110, −0.477] for during 1; $P < 0.001$, with 95% CI of [−0.109, −0.479] for during 2; $P < 0.001$, with 95% CI of [−0.128, −0.505] for during 3) and (ii) CBP ($P = 0.051$, with 95% CI of [0.0004, −0.443] for during 1; $P = 0.001$, with 95% CI of [−0.084, −0.433] for during 2; $P = 0.011$, with 95% CI of [−0.039, −0.495] for during 3). The respiration rate (bpm) decreased in the three during states (i.e. during 1, during 2, and during 3) for (i) SBP ($P < 0.001$, with 95% CI of [5.471, 2.920] for during 1; $P < 0.001$, with 95% CI of [4.861, 2.191] for during 2; $P < 0.001$, with 95% CI of [5.095, 2.300] for during 3) and (ii) CBP ($P < 0.001$, with 95% CI of [4.825, 2.387] for during 1; $P < 0.001$, with 95% CI of [4.204, 1.547] for during 2; $P < 0.001$, with 95% CI of [4.437, 1.897] for during 3).

The group mean ± SD for (i) LnLF, (ii) LnHF, (iii) LnRMSSD, (iv) LnSDNN, and (v) respiration rate (bpm) pre, during, and postyoga breathing (i.e. SBP, CBP, BAW and QR) are given in Table 2.

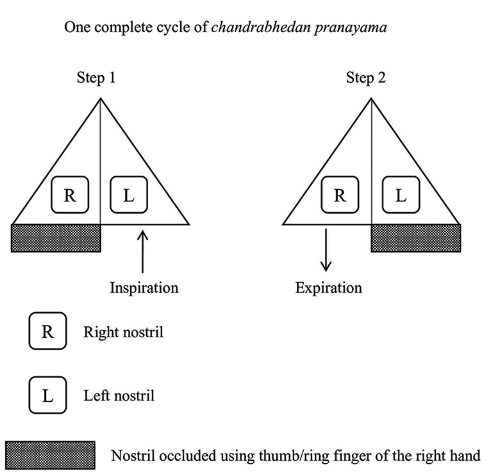

Figure 4: Schematic representation of the procedure of *chandrabhedan pranayama*

Discussion

The two breathing practices (i.e. SBP and CBP) had comparable effects. This finding was contrary to the hypothesized unique effects of each breathing practice. The changes included an increase in LF and SDNN during both SBP and CBP compared to the respective preceding values.

The LF band (0.04–0.15 Hz) is believed to be generated by (i) both parasympathetic and sympathetic nervous system activity, or (ii) by parasympathetic nervous system activity alone,[18-22] or (iii) by baroreflex activity

Table 2: Values of the (i) LnLF, (ii) LnHF, (iii) LnRMSSD, (iv) LnSDNN, and (v) Respiration rate (bpm) in the four sessions. Data presented as mean±SD

Variables	States	*Suryabhedan pranayama* (SBP)	*Chandrabhedan pranayama* (CBP)	Breath awareness (BAW)	Quiet rest (QR)
LnLF	Pre	7.10±0.91	7.18±1.11	7.11±1.08	6.95±1.02
	During 1	8.40±0.92***	8.27±1.05***	7.38±1.16	7.24±0.77
	During 2	8.33±0.96***	8.18±0.94***	7.45±0.96	7.29±1.01
	During 3	8.42±0.86***	8.32±0.85***	7.45±1.01	7.17±1.02
	Post 1	7.22±0.99	7.69±0.99**	7.32±0.98	7.16±1.03
	Post 2	7.31±0.94	7.56±0.99	8.50±7.80	7.18±0.91
LnHF	Pre	7.32±1.11	7.53±1.37	7.27±1.27	7.33±1.29
	During 1	7.25±1.20	7.23±1.59	7.22±1.12	7.45±0.97
	During 2	7.24±1.14	7.38±1.65	7.31±1.07	7.51±1.09
	During 3	7.39±1.24	7.33±1.44	7.12±1.00	7.41±1.19
	Post 1	7.16±0.98	7.50±1.10	7.33±1.17	7.41±1.14
	Post 2	7.33±1.00	7.56±1.18	7.19±1.17	7.40±1.07
LnRMSSD	Pre	4.33±0.52	4.39±0.63	4.40±0.53	4.34±0.58
	During 1	4.33±0.50	4.31±0.67	4.30±0.51	4.28±0.50
	During 2	4.29±0.56	4.38±0.67	4.30±0.50	4.35±0.50
	During 3	4.37±0.57	4.38±0.68	4.28±0.49	4.34±0.51
	Post 1	4.17±0.50*	4.29±0.65	4.27±0.57	4.32±0.55
	Post 2	4.28±0.50	4.33±0.55	4.22±0.51	4.27±0.56
LnSDNN	Pre	4.14±0.43	4.19±0.52	4.19±0.45	4.11±0.52
	During 1	4.43±0.39***	4.41±0.46*	4.23±0.49	4.11±0.43
	During 2	4.43±0.42***	4.45±0.43**	4.15±0.51	4.16±0.44
	During 3	4.46±0.39***	4.46±0.48**	4.20±0.42	4.18±0.43
	Post 1	4.07±0.41	4.24±0.42	4.14±0.46	4.15±0.49
	Post 2	4.14±0.41	4.21±0.46	4.12±0.42	4.12±0.45
Respiration rate (bpm)	Pre	15.54±2.03	15.44±1.92	15.34±2.31	15.78±2.02
	During 1	11.34±2.64***	11.83±2.62***	14.45±3.07	16.11±1.86
	During 2	12.01±2.83***	12.57±2.56***	14.77±2.85	15.80±1.87
	During 3	11.84±3.02***	12.27±2.44***	14.81±2.65	15.67±2.01
	Post 1	14.72±2.46	14.91±2.09	15.59±2.24	15.67±2.11
	Post 2	15.05±2.15	15.21±1.94	15.45±1.95	15.52±2.00

*P<0.05, **P<0.01, ***P<0.001; Multiple comparisons with *post hoc* (Bonferroni) adjustment when pre values were compared with D1, D2, D3 and post values of the respective session

alone.[23] During periods of slow respiration, vagal activity generates oscillations in the heart rhythm within the LF band frequency. Hence, respiratory-related, efferent, vagally mediated influences are present in the LF band when breathing with a slow respiration rate.[24,25] SDNN is also contributed to by both the sympathetic and parasympathetic nervous systems.[26,27] However, in short-term recordings of around 5 min involving slow regulated breathing, as in the present study, the main source of SDNN is parasympathetically-mediated respiratory sinus arrhythmia.[27,28]

In the present study, the respiration rates during the two yoga breathing practices were significantly lower than the respective preceding baselines, i.e., *suryabhedan* (breath rate 11.7 breaths per minute, a decrease of 3.8 breaths per minute compared to the preceding state) and *chandrabhedan* (breath rate 12.2 breaths per minute, a decrease of 3.2 breaths per minute compared to the preceding state). Hence, activity due to the lower frequency respiration may have contributed to the increased LF band activity, even though the contribution of respiration to the LF band usually occurs when the breath frequency is <9 breaths per minute.[29]

The common changes in HRV during the two yoga breathing practices may be related to the way, in which nostril regulation was carried out. Unlike earlier studies on nostril-regulated yoga breathing which involved unilateral airflow through either the left or right nostril exclusively,[5-8] in the present study, the two breathing techniques involved a “crossover of airflow” through both nostrils in different phases of respiration. The mechanism for unilateral breathing influencing the autonomic nervous system is not precisely understood. In early reports, asymmetrical changes in sympathetic activity led to vasomotor changes in the nostrils leading to asymmetrical patency and occlusion in the nostrils in the spontaneously breathing cat.[30,31] Similar mechanisms were believed to underlie the nasal cycle in spontaneously breathing humans.[7] The nasal cycle is associated with a wide range of physiological activities,[32] including axillary sweat production,[33] pupil size,[34] rhinal activity,[34] rhythms of the neuroendocrine, cardiovascular and insulin systems,[35,36] and with brain activity.[3] More recent research also supports that breathing through specific nostrils influences brain activity with specificity, i.e. left-nostril and nondominant breathing (usually the left-nostril) being associated with greater EEG power in posterior areas of the brain.[4] The connection between nostril patency and these physiological effects is unclear. The changeover in airflow through the nostrils during inhale–exhale in both yoga breathing practices studied here (i.e. right nostril inspiration yoga breathing and left nostril inspiration yoga breathing) may activate both nostrils equally leading to common rather than unique physiological effects. As an application in health, both traditionally described nostril-regulated breathing practices can be practiced to increase cardiac vagus nerve activity and counter the physiological effects of stress, irrespective of whether the practice begins with right nostril inspiration or left nostril inspiration.

Limitations

The findings are limited to short-term effects of the breathing practices, with no longitudinal follow-up or yoga-naïve group for comparison. Furthermore, the generalizability of the findings is limited by selecting yoga-experienced, male participants alone.

Conclusion

In summary, the two yoga breathing practices, namely, right nostril inspiration yoga breathing and left nostril inspiration yoga breathing are associated with increased respiration-related cardiac parasympathetic activity. Hence, in nostril breathing with a crossover between nostrils during inspiration–expiration, there appear to be common rather than unique effects.

Ethical statement

The approval of the Institutional Ethics Committee was obtained (approval number YRD 018/007).

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Nil.

Conflicts of interest

There are no conflicts of interest.

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