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Effect of slow breathing on autonomic tone & baroreflex sensitivity in yoga practitioners

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***Background & objectives*: Slow breathing increases parasympathetic activity and baroreflex sensitivity (BRS) in healthy individuals, also similarly observed in yoga practitioners. *Pranayama* which is an important component of yoga when practiced at a slow pace was at a respiratory frequency of around 0.1 Hz (6 breaths/min). Therefore, it was hypothesized that yoga practitioners might have adapted to slow breathing. This study was aimed to decipher the role of yoga on cardiovascular variability during slow breathing (0.1 Hz) in yoga practitioners.**

***Methods*: A cross-sectional study was undertaken in naïve-to-yoga individuals (n=40) and yoga practitioners (n=40) with an average age of 31.08 ± 7.31 and 29.93 ± 7.57 yr, respectively. The analysis of heart rate variability, blood pressure variability (BPV) and BRS during spontaneous and slow breathing was compared between the two groups.**

***Results*: During slow breathing, the heart rate (*P*<0.01) was lower, respiratory rate interval (*P*<0.05) and pNN50 per cent (*P*=0.01) were higher, mean systolic BP (SBP) (*P*<0.05) and SDSD (Standard deviation of successive beat to beat systolic blood pressure differences) (*P*<0.01) of SBP variability were lower with sequence BRS (*P*<0.001) and α low frequency (*P*<0.01) and α high frequency (*P*<0.001) of spectral BRS were higher in yoga practitioners.**

***Interpretation & conclusions*: The present study indicated higher parasympathetic activity and BRS with lower SBP variability at rest and during slow breathing in yoga practitioners compared to naive group. Findings indicate that the short-term practice of slow breathing complements the augmented parasympathetic activity and BRS in the yoga group.**

Key words Autonomic regulation - baroreflex sensitivity - blood pressure variability - cardiovascular - heart rate variability - slow breathing - Yoga

The physiological interactions of respiration and cardiovascular system are well documented[1]. The heart rate and blood pressure (BP) show phasic and rhythmic oscillations both at activity and at rest due to various physiological interactions for the maintenance of homeostasis and the arterial baroreflex represents a negative feedback system that limits extreme BP fluctuations into physiologically normal ranges.

The ratio of low and high frequency (LF & HF) of heart rate variability (HRV) is correlated positively with total power and very low-frequency and LF components of systolic and diastolic BP variability (BPV). Conversely, the ratio of LF and HF of HRV is inversely correlated with HF components of systolic and diastolic BPV. Similarly, baroreflex sensitivity (BRS) is correlated inversely with BPV[2]. The intervention of yoga in a randomized control trial has shown yoga to be as effective as medical treatment in controlling BP, and the major causative factor for essential hypertension was pointed towards impaired BRS[3]. Although the yoga is considered for spiritual enlightenment, the physical practices of *asanas, pranayama* and meditation are believed to impart beneficial effects on physical and emotional health. *Yogasanas* are performed with awareness where there is a voluntary synchronization of breathing with the body movements. *Pranayama* involves voluntary regulation of breathing. The pace of breathing in *pranayama* is modulated by the adjustment of the airflow through the nostrils and retention of breath[4-9].

The various methods of *pranayama* modulate the rate and depth of breathing that reflects in the oscillations of heart rate and BP that help in characterizing the autonomic activity of the cardiovascular system. Although the conclusive intrinsic mechanism of interactions between cardiovascular and respiration still remains to be deciphered, the studies on slow breathing intervention (6 cycles/min) are shown to be associated with potentiation of both the depressor and the cardioinhibitory components of the arterial baroreflex in healthy individuals[10] and reduction of sympatho-excitation in diseases such as chronic heart failure[11], hypertension[12] and chronic obstructive pulmonary disease[13]. One of our earlier studies has shown an increase in cardiovascular oscillations and also in the recruitment of baroreflex sequences and reported that the respiratory and cardiovascular oscillations during slow alternate nostril yogic breathing are coupled through multiple regulatory mechanisms such as mechanical coupling, baroreflex and central cardiovascular control[14]. BRS was shown to be increased by the intervention of yoga compared to aerobic training[15]. Breathing is an integral part of yoga not only as *pranayama* but also during the performance of *asanas.* The intervention of different types of *pranayama,* namely *Nadi Shodhana* (Inhalation: Breath hold:exhalation – 4:2:4), *Chandra Bhedi*, from initial 2-10 min practice per day, *Bhramari* (10 cycles per day) and *Omkar chanting* (a: o; ma as 1:4:2 10 cycles per day) for six weeks, has reported to reduce heart rate, systolic BP (SBP), diastolic BP and rate pressure product which are correlated to myocardial oxygen demand in hypertension[16]. Slow breathing at 0.1 Hz was reported to elicit heart rate oscillations at higher amplitudes when compared to other breathing frequencies[17] and enhance BRS in healthy individuals[18]. In yoga, slow breathing practiced during *pranayama* is at a respiratory frequency of around 0.1 Hz (6 breaths/min). An augmented respiratory sinus arrhythmia has been exhibited by the yoga practitioners compared to controls (naïve to yoga) during spontaneous breathing[19]. Therefore, considering the previous practice of yoga (*asanas, pranayama* and meditation) by the trained yoga practitioners, it was hypothesized that the cardiac autonomic tone and BRS would be augmented in trained yoga practitioners. Hence, the present study was undertaken to compare trained yoga practitioners to naïve-to-yoga group individuals with an aim to decipher the role of yoga in the modulation of HRV, BPV and BRS in response to slow breathing (6 cycles/min at 0.1 Hz).

Material & Methods

The study was conducted from May 2016 to September 2018 in autonomic function test laboratory of the department of Physiology, All India Institute of Medical Sciences, New Delhi, India. Ethical clearance was obtained from the Institute Ethical Committee (Ref. No. IESC/T-464/30.09.2015, RT-23/28.10.2015) and was registered in the Clinical Trials Registry India (CTRI/2020/06/025730). A cross-sectional study was undertaken to compare the immediate effects of slow breathing on cardiovascular variability between naïve-to-yoga individuals and yoga practitioners. The differences between these two groups during spontaneous breathing showed the long-term effect of yoga on cardiovascular variability while the differences between groups during slow breathing showed the long-term effect of yoga on modulation of cardiovascular variability in response to slow breathing. The sample size was calculated by considering the change in BRS (outcome variable) after the intervention of slow breathing as 5±3 ms/mm Hg in healthy individuals[18] and the anticipated change in yoga practitioners as 3±1.5 ms/mm Hg from the baseline values of BRS[20] with the power at 90 per cent and the level of significance of five per cent with consideration of 20 per cent loss to follow up. Forty naïve-to-yoga individuals (also called naïve group) and 40 yoga practitioners (also called yoga group) were included in the study. All the participants were healthy, normotensive with normal resting ECG. None of our naïve group participants had prior experience of yoga nor did they exercise regularly. Written informed consent was obtained from all the participants. An appeal with details of the experimental procedure of the study was put on the notice board of the department, along with the circulation of the message to yoga practitioners to join the study. Those who satisfied the selection criteria and willing to participate were recruited in the study. The initial information was collected over the telephone. On interview, the ability and ease of performance of *yogasanas* (*Halasana, Sarvangasana, Ushtrasana, Chakrasana, Sirshasana* and *Padahastasana, Paschimottanasana*), *pranayama* namely *Anulom-Vilom* (inhalation, retention, exhalation in the ratio of 1:2:2) and *Bhastrika* (rapid inhalations and exhalations – HF breathings)[21] have been ascertained before calling for data collection. These *asanas* were selected based on a group of postures involving forward, backward and head down and upright postures. These *asanas* require a great degree of steadiness, concentration and coordination with the breath and also require extensive control of muscles with great flexibility. The recruited yoga practitioners were trained in yoga institutes, namely Morarji Desai National Institute of Yoga, Delhi, Swami Vivekananda Yoga Anusandhana Samsthana, Bangaluru, and Kaivalyadhama Yoga Institute and Research Center, Lonavla. All of these yoga practitioners had an average practice period of 2.31 ± 1.18 yr. Forty age-matched healthy individuals were selected under naïve group. None of our naïve group participants had prior experience of yoga nor did they exercise regularly. All the participants were healthy, normotensive with normal resting ECG. Patients with cardiovascular and respiratory illness, with any other systemic illness, smokers, alcoholics and trained athletes were excluded. All the recordings were performed in controlled ambient temperature. Data recording for each participant was completed in a single session. All the participants were requested to abstain from caffeine-containing beverages for 24 h, and they had light breakfast before 3 h of the testing. Yoga practitioners avoided the practice of yoga on the day of data recording.

Slow breathing protocol: The individuals performed slow breathing with five-second inhalation and five-second exhalation at a frequency of 0.1 Hz in sync with the continuous repetitive instructions for slow breathing by a brief training of slow breathing in a sitting position. The participants were briefly trained to inhale and exhale for five seconds each in synchrony with the instructions from the audiotape with simultaneous visualization of the colour-filled image. During data recording, participants followed audio instructions and breathed comfortably without rapid and forceful inhalation and exhalation. The data recording was done in supine with eyes closed to avoid visual distractions and concentrate on the audio instructions. The instructions were uniform to all the participants. Supine rest for 15 min was ensured before each recording. The initial recording was obtained during spontaneous breathing with subsequent recording obtained during slow breathing. In this sequence, three sets of recordings of spontaneous breathing and slow breathing were obtained. Each recording was for five minute duration. The average values of the three recordings of spontaneous breathing and slow breathing, respectively, were applied for statistical analysis. All the participants were supine during the data recording.

Data collection: Lead II ECG was recorded simultaneously along with the beat-to-beat BP using Human NIBP System (Model ML 283, AD Instruments, Australia). Respiratory movements were recorded using respiratory belt transducer (Model MLT-1132 ADInstruments, Australia) connected to the analogue to digital converter (Model 15T ADInstruments, Australia) during spontaneous breathing and slow breathing at 0.1 Hz. Lead II ECG was recorded at a sampling frequency of 1 kHz. BP and respiratory movements were recorded at a sampling frequency of 200 Hz. All the signals were recorded in LabChart 8 (ADInstruments, Australia) and saved for offline analysis of HRV and BPV in time-domain and frequency-domain methods[22]. The BRS was computed by sequence method and spectral method using Nevrokard software analysis/version 6.2.0 (Nevrokard Kiauta, Izola, Slovenia). Segments of ECG and BP from the same time period were selected for the analysis of HRV, BPV and BRS. Time-domain analysis of HRV is a statistical analysis of the respiratory rate (RR) interval data. The time-domain indices of HRV computed were standard deviation of all normal to normal intervals (SDNN), root mean square of successive NN interval differences (RMSSD) and pNN50 (NN50 count divided by the total number of all NN intervals). Frequency-domain analysis of HRV is the spectral analysis of the tachogram plot. The power spectrum displays the power of the frequencies present in RR interval variations. The power spectral density (PSD) was calculated using Fast Fourier transform (FFT) in the LF at 0.04-0.15 Hz and HF at 0.15-0.40 Hz bands. The BPV was analyzed in the time domain to calculate SDNN and RMSSD. For spectral analysis, the PSD of the BPV was calculated using FFT in the LF and HF bands, along with the total power. The sequence and the spectral methods were used for quantification of BRS. The criteria for the detection of baroreflex sequences were as follows: (*i*) R-R variation >5 ms, (*ii*) BP changes >0.5 mm Hg, (*iii*) sequences >3 beats, and (*iv*) sequences correlation coefficient >0.85. The slope of the regression line between the RRI and SBP provides spontaneous BRS. The spontaneous BRS by the spectral technique was assessed using FFT of the RR interval and SBP spectral powers in the frequency regions around 0.1 Hz and at around 0.2 and 0.3 Hz. At these frequencies, RRI and SBP display high coherence (>0.5) and the squared root of the ratio of RR interval and SBP powers is the α-coefficient in the above frequency regions. The baroreflex gain was computed in the α-LF and the α-HF band[23-25].

Statistical analysis: Each parameter was tested for distribution of data based on standard normality test, Shapiro–Wilk test. Independent t test or Mann–Whitney U test was applied for Gaussian and non-Gaussian data, respectively. Statistical analysis was performed using SPSS, version 20.0 (IBM Corp. Armonk, NY, USA: IBM Corp Released 2011).

Results

The demographic and clinical profiles of the study groups are listed in Table I. All baseline characteristics were matched between groups.

Heart rate variability (HRV): During spontaneous breathing, the RR interval, RMSSD, pNN50 and SD1 were significantly higher with heart rate and Total Power (normalized unit) [TP(nu)] significantly lower in yoga practitioners compared to the naïve group. During slow breathing, the RR interval and pNN50 were significantly higher with heart rate and total power significantly lower in yoga practitioners compared to the naïve group (Table II).

Table I. Demographic and clinical profile of study groups

Parameters	Naïve-to-yoga group	Yoga practitioners
Age (yr)	31.08±7.31	29.93±7.57
Male:female	27:13	25:15
BMI (kg/m^2)	23.47±1.65	22.82±1.42
Yoga experience (yr)	-	2.31±1.18
HR (bpm)	68.77±7.31	65.53±8.49
SBP (mm Hg)	117.95±13.63	115.75±13.14
MBP (mm Hg)	79.76±11.06	77.73±8.69
DBP (mm Hg)	62.13±9.62	61.08±8.20

Data expressed as mean±SD; n=40 in each group. SD, standard deviation; SBP, systolic blood pressure; DBP, diastolic blood pressure; MBP, mean blood pressure; HR, heart rate; BMI, body mass index

Blood pressure variability (BPV): During spontaneous breathing, SDSD of SBP variability and SDNN, SDSD and HF(nu) of mean BPV were significantly lower in yoga practitioners compared to the naïve group. During slow breathing, the mean of SBP, SDSD of SBP variability and SDNN of mean BPV was significantly lower in yoga practitioners than naïve to the yoga group (Table III).

Baroreflex sensitivity (BRS): During both spontaneous breathing and slow breathing, up BRS, down BRS, all BRS, α-LF and α-HF of BRS were observed to be higher in yoga practitioners compared to the naïve group (Table IV). The delta change of variables from spontaneous breathing to slow breathing within groups was comparable between the groups (Table V).

Discussion

The HRV, BPV and BRS were compared between naïve group and yoga practitioners to decipher the long-term effect of yoga at rest and in response to slow breathing (6 cycles/min at 0.1 Hz). The findings of the study showed higher parasympathetic activity, lowered SBP variability, mean BPV and augmented BRS in yoga practitioners during spontaneous breathing. Our findings were in confirmation with the previous studies[26,27]. During rest in supine position, the cardiac sympathetic tone is lower with a predominance of parasympathetic activity. Repeated sympathovagal modulations with corresponding responses on heart rate during the practice of yoga might have resulted in long-lasting enhancement of vagal tone in yoga practitioners compared to naïve-to-yoga individuals[27].

Table II. Heart rate variability during spontaneous breathing and slow breathing between groups

Parameters	Breathing	Naïve-to-yoga group (n=40)	Yoga practitioners (n=40)
Respiratory rate (bpm)	Spontaneous breathing	15.80 (13.99-17.63)	15.73 (12.33-17.71)
HR (bpm)	Spontaneous breathing	67.83 (64.39-75.71)	62.85 (56.58-70.85)**
	Slow breathing	68.67 (64.60-75.03)	63.19 (58.50-72.16)**
RRI (ms)	Spontaneous breathing	902.73 (837.21-951.88)	962.73 (837.89-1052.45)**
	Slow breathing	882.41 (812.05-937.40)	954.98 (840.14-1035.39)*
SDNN (ms)	Spontaneous breathing	54.96 (42.13-74.24)	60.15 (51.60-81.05)
	Slow breathing	75.08 (62.52-106.45)	93.24 (71.11-111.58)
RMSSD (ms)	Spontaneous breathing	41.14 (33.61-57.54)	53.43 (39.86-75.62)**
	Slow breathing	49.55 (39.80-71.93)	66.97 (46.11-89.61)
pNN50 (%)	Spontaneous breathing	9.74 (4.77-15.63)	13.94 (9.93-21.60)**
	Slow breathing	12.31 (7.49-16.28)	16.43 (11.01-19.77)**
LF (nu)	Spontaneous breathing	47.63 (41.38-61.14)	46.32 (28.33-60.66)
	Slow breathing	85.19 (78.99-91.04)	85.14 (77.78-91.70)
HF (nu)	Spontaneous breathing	45.54 (35.20-53.63)	43.05 (35.48-64.28)
	Slow breathing	12.90 (7.94-18.80)	13.40 (7.42-20.06)
TP (nu)	Spontaneous breathing	143.97 (129.73-196.68)	132.15 (119.99-162.22)*
	Slow breathing	111.05 (106.85-118.17)	107 (104.41-114.81)
LF/HF ratio	Spontaneous breathing	1.22 (0.90-2.0)	1.36 (0.45-2.11)
	Slow breathing	8.12 (4.88-13.66)	7.80 (4.27-14.05)
SD1	Spontaneous breathing	30.41 (23.80-41.02)	38.08 (28.69-55.96)*
	Slow breathing	36.25 (28.18-54.74)	51.91 (33.32-64.63)
SD2	Spontaneous breathing	70.17 (54.18-94.10)	78.33 (20.22)
	Slow breathing	102.42 (85.12-139.91)	116.42 (91.90-131.56)
SD1/SD2	Spontaneous breathing	0.45 (0.35-0.52)	0.53 (0.41-0.7)
	Slow breathing	0.36 (0.3-0.39)	0.38 (0.33-0.47)

P^*<0.05, *<0.01 compared to naïve-to-yoga group; Values expressed as median (IQR). SDNN, standard deviations of normal to normal; RRI, R-R intervals; RMSSD, the square root of the mean of the sum of the squares of differences between adjacent NN intervals, pNN50, NN50 count divided by the total number of all NN intervals; LF, low frequency; HF, high frequency; nu, normalized units; HR, heart rate; IQR, interquartile range; TP, total power

This was viewed to be possible as yoga corollary to regular exercise training could modify the autonomic balance by parasympathetic reactivation during post-exercise, correlating with athletic fitness. Our results also confirmed the augmentation of BRS in yoga practitioners. Similar findings were reported only in α-HF of BRS[15]. This might be due to the difference in the duration of the intervention period which was for six weeks much lesser than our yoga practitioners.

During spontaneous breathing, the HF power represents the influence of respiration on the HRV and BPV and the location of the respiratory peak depends on the frequency of the respiration[1]. The LF power of HRV reflects both sympathetic and parasympathetic activities while HF power predominantly reflects parasympathetic modulation which depends on the frequency of the respiration. The LF power of BPV reflects the sympathetic modulation of the vascular tone while HF power reflects the parasympathetic activity influenced by respiration. In the present study, the frequency of slow breathing at 6 cycles per min was at 0.1 Hz and accordingly the respiratory peak was observed to be shifted to LF frequency of the spectrum (Fig.1). The spectral analysis has shown a sharp decline in HF power and the rise of LF power, respectively, during slow breathing. By documenting the findings of the previous studies[28,29], our study confirms the lowered heart rate indicating an enhancement of efferent vagal activity during spontaneous breathing and slow breathing at 0.1 Hz in the supine position

Table III. Blood pressure variability during spontaneous breathing and slow breathing between groups

Parameter	Spontaneous breathing		Slow breathing	
	Naïve-to-yoga group (n=40)	Yoga practitioners (n=40)	Naïve-to-yoga group (n=40)	Yoga practitioners (n=40)
Mean BP (mm Hg)				
SBP	120.63 (111.78-129.72)	115.27 (107.10-125.41)	118.52 (113.07-128.37)	115.05 (100.34-121.75)*
MBP	80.65 (74.07-87.26)	78.64 (74-81.68)	78.42 (71.87-85.31)	77.25 (72.25-81.57)
DBP	63.15 (57.21-70.05)	61.10 (59.26-64.95)	61.13 (55.59-70.30)	60.53 (55.67-63.98)
SDNN (mm Hg)				
SBP	5.77 (4.34-7.48)	5.28 (4.14-6.40)	5.97 (4.81-7.02)	5.62 (4.65-6.63)
MBP	3.52 (3.07-4.55)	3.22 (2.73-4.08)*	4.07 (3.58-4.59)	3.79 (2.87-4.41)*
DBP	3.20 (2.55-3.95)	2.95 (2.56-3.51)	3.46 (3.18-4.30)	3.54 (2.67-3.92)
SDSD (mm Hg)				
SBP	2.64 (2.08-3.06)	2.11 (1.76-2.67)**	2.58 (2.25-3.15)	2.21 (1.95-2.85)**
MBP	1.74 (1.26-1.86)	1.41 (1.19-1.59)*	1.82 (1.62-2.32)	1.71 (1.49-2.13)
DBP	1.58 (1.27-1.93)	1.45 (1.26-2.04)	1.59 (1.43-2.31)	1.79 (1.37-2.27)
LF (nu)				
SBP	67.57 (58.31-76.57)	74.05 (61.64-81.36)	89 (83.54-92.76)	90.41 (87.12-94.10)
MBP	79.23 (70.76-83.50)	81.72 (73.89-89.52)	89.03 (84.31-91.57)	87.69 (83.90-92.04)
DBP	73.96 (69.75-82.74)	75.22 (60.68-83.85)	86.37 (81.02-90.61)	87.57 (80.98-92.24)
HF (nu)				
SBP	26.04 (18.26-39.30)	13.39 (13.02-13.56)	8.28 (5.11-13.62)	7.10 (4.85-11.12)
MBP	15.94 (11.61-21.62)	12.93 (5.86-20.76)*	8.93 (5.72-13.01)	9.44 (6.10-14.62)
DBP	18.78 (13.29-25.52)	19.88 (11.10-31.58)	9.65 (6.82-15.27)	9.72 (6.20-16.50)
TP (nu)				
SBP	299.01 (246.01-391.57)	321.14 (253.05-387.31)	178.27 (149.51-215.06)	198.83 (144.80-271.57)
MBP	250.91 (211.11-353.32)	258.34 (215.07-305.47)	167.29 (144.52-199.16)	164.60 (134.96-230.49)
DBP	240.49 (192.42-287.78)	223.36 (186.07-254.50)	166.52 (136.47-204.90)	161.78 (125.61-188)

P^*<0.05, **<0.01 compared to naïve-to-yoga group during spontaneous breathing and slow breathing, respectively. Values expressed as median (IQR). SBP, systolic blood pressure; SDNN, standard deviation of beat-to-beat SBP; SDSD, standard deviation of successive beat-to-beat SBP differences; RMSSD, root mean square of successive beat-to-beat differences in blood pressure; DBP, diastolic blood pressure; MBP, mean blood pressure; IQR, interquartile range; LF, low frequency; HF, high frequency; nu, normalized units; TP, total power

(Fig. 2). Slow yogic breathing increased the BRS at symmetrical breathing of five seconds of inspiration and expiration in yoga beginners[30]. The *asanas* that were selected for routine practice in our study involved forward, backward, head down and standing postures. These yogic practices have been shown to reduce heart rate (HR), left ventricular end-diastolic volume (LVEDV) and SBP[31]. *Anulom-Vilom* and *Bhastrika pranayama* were also practiced along with *asanas*. The higher resting BRS in yoga practitioners was due to the baseline firing of the baroreceptors with the recruitment of baroreflex sequences. There was also an increased coherence of RR interval and SBP at LF and HF at rest. This could be due to the effect of the yogic intervention on BRS in response to slow breathing. Significantly higher RR interval and lower heart rate confirmed higher vagal activity in yoga practitioners than the naïve group. At rest, besides significantly higher BRS (Fig. 3), the BPV was also significantly lower indicating better regulation of BP in yoga practitioners. The BRS which is predominantly a measure of cardiac vagal regulation, is correlated inversely with BPV[2]. Baroreflex is a negative feedback mechanism that limits extreme BP fluctuations into physiologically normal ranges. Therefore, higher resting BRS might have controlled the BPV even

Table IV. Baroreflex sensitivity during spontaneous breathing and slow breathing between groups

Parameters	Breathing	Naïve-to-yoga group (n=40)	Yoga practitioners (n=40)	Effect size |ρ|	Power (%)
Number of up sequences	Spontaneous breathing	12 (6.50-16.83)	9.83 (4.17-14.75)	0.241	25.89
	Slow breathing	20 (16.42-22.25)	18.17 (14.83-20.58)	0.398	58.20
Number of down sequences	Spontaneous breathing	9.58 (6.33-14.41)	12.33 (6.16-19.91)	0.282	33.64
	Slow breathing	24 (22.08-26)	23.83 (21-25.92)	0.181	16.65
Number of all sequences	Spontaneous breathing	21.75 (13.16-30.50)	23.16 (11.83-30.50)	0.025	51.78
	Slow breathing	42.83 (39.83-48.25)	41.50 (36-46.58)	0.321	41.56
All BRS (ms/mm Hg)	Spontaneous breathing	16.42 (12.35-22.70)	22.67 (17.55-30.71)***	0.883	99.77
	Slow breathing	18.57 (14.57-23.39)	23.51 (19.12-32.71)***	0.745	98.17
α-LF (ms/mm Hg)	Spontaneous breathing	3.98 (3-5.08)	5.07 (3.48-7.32)**	0.656	94.57
	Slow breathing	5.34 (4.02-6.94)	6.65 (5.40-9.25)**	0.637	93.36
α-HF (ms/mm Hg)	Spontaneous breathing	5.29 (3.87-7.16)	8.99 (6.12-13.13)***	0.960	99.94
	Slow breathing	6.09 (4.57-8.42)	9.46 (6.33-13.57)***	0.753	98.34

*P*** <0.01, *** <0.001 compared to naïve-to-yoga group, Data are expressed as median (IQR). LF, low frequency; HF, high frequency; BRS, baroreflex sensitivity; IQR, interquartile range

Table V. Comparison of the delta change in variables between study groups

Parameters	Naïve-to-yoga group (n=40)	Yoga practitioners (n=40)
ΔHR (bpm)	0.29±3.61	1.31±4.38
ΔRRI (ms)	−3.40±42.75	−13.01±59.81
ΔpNN50 (%)	1.19±4.73	0.54±4.96
ΔSBP (mm Hg)	−0.35±4.85	−1.43±3.89
ΔSDSD-SBP (mm Hg)	0.18±0.75	0.15±0.37
ΔUp sequences	7.20±6.72	6.92±6.68
ΔDown sequences	12.78±7.23	9.76±7.12
ΔAll sequences	19.96±12.96	16.68±12.20
ΔAll BRS (ms/mm Hg)	1.32±5.19	0.81±9.98
Δα-LF (ms/mm Hg)	1.45±2.05	1.81±2.87
Δα-HF (ms/mm Hg)	0.961±3.41	0.82±4.56

Values expressed as mean±SD. The delta change is measured from with-in group change in variables during slow breathing from spontaneous breathing. SD, Standard deviation; HR, Heart rate; SBP, systolic blood pressure; SDSD, standard deviation of successive beat-to-beat blood pressure differences; BRS, baroreflex sensitivity; LF, low frequency; HF, high frequency; RRI, R-R intervals; pNN50, NN50 count divided by the total number of all NN intervals

during slow breathing. This might have resulted in lesser stimulation of baroreceptors leading to lesser activation of the baroreflex in yoga practitioners compared to the naïve group.

The variables that were significantly different during slow breathing between groups were observed to be comparable in their delta change. This showed that the immediate effect of slow breathing was similar between the groups. In the naïve group, during slow breathing, the variables (post-test) were observed to increase/decrease and almost reach the values similar to baseline values of yoga practitioners. While in yoga practitioners, slow breathing further increased/decreased from their baseline values. In the yoga group, the variables of cardiovascular variability which were significantly different at baseline, were also observed to be significantly different during slow breathing in spite of similar delta change in variables.

Therefore, our findings indicate an immediate augmentation of parasympathetic activity and BRS with slow breathing, while higher resting parasympathetic activity and BRS can be acquired with long-term practice of slow breathing. This suggests that slow breathing complements parasympathetic activity, BRS and lower BPV.

Yogasanas constitute postures involving stretching and isometric exercises in synchrony with breathing. Muscle stretching which is a central component in the performance of *asanas* increases the flexibility of the body[32] and regular static muscle stretching induces a significant reduction in arterial stiffness[33]. The central arterial stiffness was shown to be significantly lesser with yoga practice compared to sedentary individuals[34].

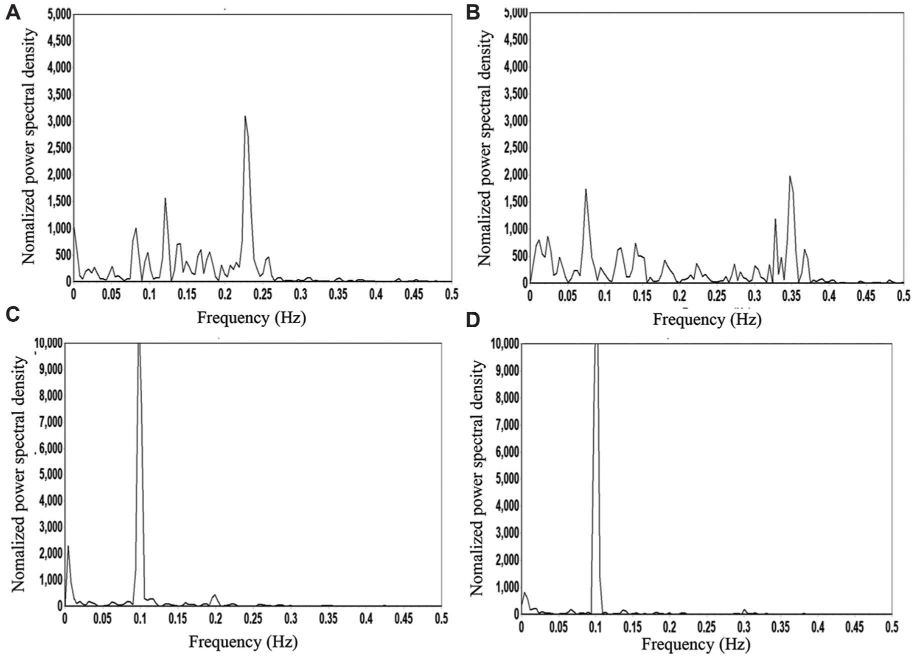

Fig. 1. Power spectral density indices of one representative participant from each group. Naïve-to-yoga group [(**A** and **C**) of left panel] and trained yoga practitioner [(**B** and **D**) of right panel] during spontaneous breathing [upper panel (**A** and **B**)] and slow Breathing [lower panel (**C** and **D**)]. During slow breathing at 0.1 Hz, the respiratory peak was observed to be shifted to LF frequency of the spectrum (**C** and **D**) while during spontaneous breathing, multiple peaks were distributed all over the spectrum (**A** and **B**).

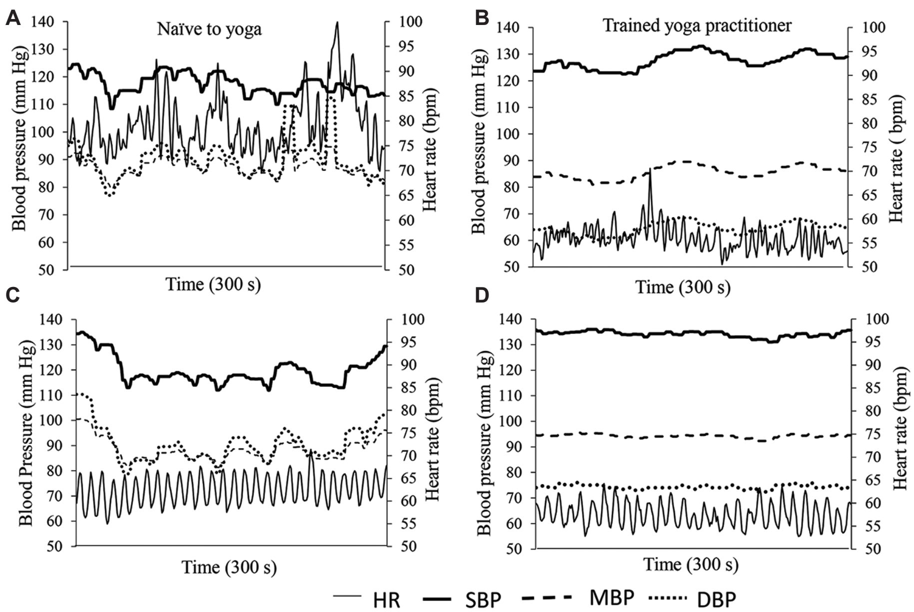

Fig. 2. Age-matched comparison (27 yr old male participants) of systolic, diastolic, mean blood pressure and heart rate of representative participants from naïve to yoga (left panel) and yoga practitioner (right panel) during spontaneous breathing (**A** and **B**) and slow breathing (**C** and **D**). The blood pressure fluctuations and heart rate were observed to be lower in yoga practitioners compared to naïve-to-yoga participants. During slow breathing, the heart rate was 72.40 and 57.50 bpm in naïve-to-yoga and yoga practitioners, respectively.

Yoga is also known to increase the parasympathetic activity, decrease the sympathetic activity[26] and reduce body mass index which is inversely related to HRV[35], BPV[36] and BRS[37]. Further, BPV is inversely related to aortic stiffness[38] and BRS[2]. These associations in yoga practitioners are multifaceted that reflect as the comprehensive effect of yoga. The yoga practice by the yoga group could not be monitored personally

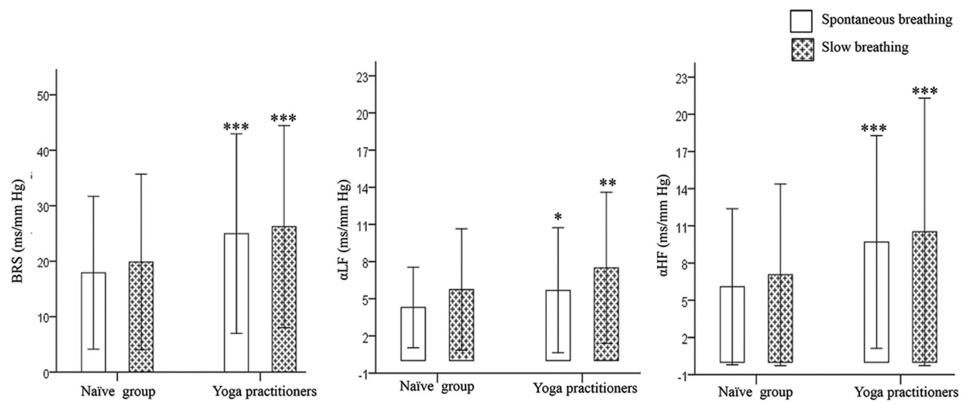

Fig. 3. Baroreflex sensitivity (BRS) in naïve group and yoga practitioners. The sequence and spectral BRS (αLF and αHF) is significantly higher in yoga practitioners compared to naïve group during spontaneous breathing and slow breathing, respectively. LF, low frequency; HF, high frequency. $P^{*}<0.05$, $^{**}<0.01$, $^{***}<0.001$ compared to naïve-to-yoga group.

which was a limitation in this study. Future studies with intervention of yoga may be recommended to ascertain the causal effect of yoga. Besides, the direct measure of muscle sympathetic nerve activity would have given a better understanding of the sympathetic and parasympathetic interactions during slow breathing. It is pertinent to mention that the *post hoc* analysis of power has revealed the estimates of BRS (outcome variable) greater than 90 per cent power at 5 per cent significance level.

In conclusion, the present study showed higher parasympathetic activity and BRS with lower SBP variability at rest and during slow breathing in yoga practitioners compare to naive group. Findings indicate that short-term practice of slow breathing complements the augmented parasympathetic activity and BRS in the yoga group.

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