Original Article

Autonomic Tone and Baroreflex Sensitivity during 70° Head-up Tilt in Yoga Practitioners

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Abstract

Introduction: The intervention of yoga was shown to improve the autonomic conditioning in humans evident from the enhancement of parasympathetic activity and baroreflex sensitivity (BRS). From the documented health benefits of yoga, we hypothesized that the experience of yoga may result in adaptation to the orthostatic stress due to enhanced BRS. **Aim:** To decipher the effects of yoga in the modulation of autonomic function during orthostatic challenge. **Materials and Methods:** This was a comparative study design conducted in autonomic function test lab, of the Department of Physiology, All India Institute of Medical Sciences, New Delhi, India. Heart rate variability (HRV), blood pressure variability, and BRS were analyzed on forty naïve to yoga (NY) subjects and forty yoga practitioners with an average age of 31.08 ± 7.31 years and 29.93 ± 7.57 years, respectively. All participants were healthy. Seventy degrees head up tilt (HUT) was used as an intervention to evaluate the cardiovascular variability during orthostatic challenge. **Results:** During HUT, the R-R interval ($P = 0.042$), root mean square of succesive R-R interval differences (RMSSD) ($P = 0.039$), standard deviation of instantaneous beat-to-beat R-R interval variability (SD1) ($P = 0.039$) of HRV, and sequence BRS ($P = 0.017$) and α low frequency of spectral BRS ($P = 0.002$) were higher in the yoga group. The delta decrease in RRI ($P = 0.033$) and BRS ($P < 0.01$) was higher in the yoga group than the NY group. **Conclusion:** The efferent vagal activity and BRS were higher in yoga practitioners. The delta change (decrease) in parasympathetic activity and BRS was higher, with relatively stable systolic blood pressure indicating an adaptive response to orthostatic challenge by the yoga practitioners compared to the NY group.

Keywords: *Baroreflex sensitivity, blood pressure variability, cardiovascular variability, heart rate variability, yoga*

Introduction

Yoga is one of the six Indian philosophies that have been used over the centuries to maintain health. Various facets of yoga such as Yama (moral commandments), niyamas (disciplines), postures (asanas), internal cleansing procedures (kriyas), breath regulation (pranayama), concentration (dharana), and meditation (dhyana) are often used. The intervention of yoga was shown to improve the autonomic conditioning in humans evident from the enhancement of parasympathetic activity[1-8] and baroreflex sensitivity (BRS).[9] Different types of Pranayama have reported reducing heart rate, systolic blood pressure, diastolic blood pressure, and rate pressure product correlated with myocardial oxygen demand in hypertension.[10] A significant reduction in resting heart rate and left ventricular end-diastolic volume was reported with 2 weeks of sarvangasana practice in healthy male subjects[11] and shown to be as effective as medical treatment in controlling blood pressure.[12] A significant reduction in blood pressure was observed with the intervention of 70° head up tilt (HUT) or yogic exercises in subjects of essential hypertension, highlighting the similarity of the physiological mechanism in autonomic readjustments underlying the effects of selected yogic exercises and 70° HUT. A close link between the etiology of essential hypertension and baroreflex was also suggested.[13] From the documented health benefits of yoga, we hypothesized that the intervention of yoga may improve the cardiovascular variability and enhance the BRS. The arterial baroreflex represents a negative feedback system that limits extreme blood pressure fluctuations into physiologically normal ranges. The

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heart rate variability (HRV) and BRS are widely used to estimate the autonomic modulation of cardiovascular function.[14,15] In the present study, 70° HUT is used to evaluate the cardiovascular variability to orthostatic challenge.[16] The yoga practitioners in this study were those who practiced asanas, pranayama, and meditation, altogether reflecting the comprehensive effect of yoga on the cardiovascular variability. The yoga practitioners were compared to naïve to yoga (NY) subjects with an aim to decipher the effects of yoga in the modulation of autonomic function during orthostatic challenge. To the best of our knowledge, the present study is the first to characterize the heart rate variability (HRV), blood pressure variability (BPV), and baroreflex sensitivity (BRS) simultaneously in yoga practitioners and NY group during 70° HUT.

Table 1: Demographic and anthropometric characteristics of naïve group and yoga group

Parameters	Value	
	Naïve group (*n*=40)	Yoga group (*n*=40)
Age (years)	31.08±7.31	29.93±7.57
Gender (male/female)	27/13	25/15
BMI (kg/m^2)	23.47±1.65	22.82±1.42
Yoga experience (years)	-	2.31±1.18

Data expressed as mean±SD. SD, standard deviation; BMI, body mass index

Materials and Methods

This was a comparative study design conducted in autonomic function test lab of the Department of Physiology, All India Institute of Medical Sciences, New Delhi, India. The study was approved by the institutional ethics committee (IESC/T-464/28.10.2015) and registered in Clinical Trial Registry, India (CTRI/2020/06/025730). The study was conducted on 80 healthy subjects between the age group of 20 and 50 years of both genders. Out of them, forty subjects (n = 40) were NY also called as naïve group and forty subjects (n = 40) were trained yoga practitioners also called as yoga group. Written informed consent was obtained from all subjects who were enrolled. All the participants were healthy, normotensive with normal resting electrocardiogram (ECG). Subjects with cardiovascular and respiratory illness or any other systemic illness, smokers, alcoholics, trained athletes, and varicose veins were excluded from the study. Individuals who did not have prior experience of yoga were recruited for the naïve group. The yoga practitioners who were trained in different yoga institutions in India were recruited for the yoga group. The yoga practitioners in this study were those who practiced asanas, pranayama, and meditation, altogether reflecting

Table 2: Heart rate variability during 70° head-up tilt

Parameter	Naïve group		Yoga group		*P*			
	Supine (a)	70° HUT (b)	Supine (c)	70° HUT (d)	Paired *t*-test/Wilcoxon signed-rank test		Independent sample *t*-test/Mann-Whitney U-test	
					a versus b	c versus d	a versus c	b versus d
Heart rate (bpm)	66.54 (62.07-75.22)	86.07 (78.05-91.44)	62.51 (56.61-70.50)	78.96 (73.77-90.40)	<0.0001*	<0.0001*	0.005**	0.075
Mean RRI (ms)	902.21 (828.6-960.49)	721.50 (660.22-782.64)	947.81 (849.81-1069.15)	791.47 (684.01-827.84)	<0.0001*	<0.0001*	0.024*	0.042*
SDNN (ms)	53.59 (42.44-83.62)	49.74 (44.10-62.63)	55.84 (47.40-73.79)	55.89 (42.25-72.98)	0.147	0.989	0.840	0.16
RMSSD (ms)	40.51 (31.79-67.59)	22.17 (18.63-27.29)	56.26 (36.65-67.90)	29.40 (20.62-44.32)	0.001*	<0.0001*	0.157	0.039*
pNN50%	8.91 (4.58-18.75)	1.95 (0.93-4.05)	15.38 (7.71-21.50)	5.56 (1.21-8.97)	< 0.0001*	< 0.0001*	0.08	0.094
LF (nu)	50.55 (36.17-68.42)	73.43 (62.77-82.33)	40.97 (22.52-62.57)	78.41 (53.60-87.91)	<0.0001*	<0.0001*	0.234	0.686
HF (nu)	45.16 (26.15-56.61)	21.94 (15.60-32.95)	50.25 (33.28-70.38)	17.86 (9.83-38.52)	<0.0001*	<0.0001*	0.312	0.570
LF/HF	1.07 (0.6-2.61)	3.34 (1.85-5.28)	0.77 (0.31-1.88)	4.45 (1.28-8.61)	<0.0001*	<0.0001*	0.306	0.57
SD1	28.69 (22.51-47.85)	15.69 (13.18-19.32)	39.86 (28.95-48.09)	20.81 (14.59-31.37)	<0.0001*	<0.0001*	0.619	0.039*
SD2	68.53 (53.86-104.51)	68.44 (60.5-90.95)	69.07 (55.95-88.40)	74.75 (59.50-95.09)	0.967	0.180	0.927	0.57
SD1/SD2	0.43 (0.3-0.57)	0.22 (0.18-0.27)	0.56 (0.39-0.71)	0.23 (0.20-0.38)	0.001*	<0.0001*	0.159	0.059

Values expressed as median (interquartile range). *P<0.05 considered statistically significant compared to naïve to yoga group. HRV, heart rate variability; SDNN, standard deviations of normal to normal R-R interval; RMSSD, root Mean Square of the successive R-R interval differences; pNN50, the percentage of adjacent NN intervals that differ from each other by more than 50 ms; LF, low frequency; HF, high frequency; nu, normalised unit; SD1, standard deviation of instantaneous beat-to-beat R-R interval variability; SD2 standard deviation of long term R-R interval variability ; Br, breathing; HUT, head up tilt

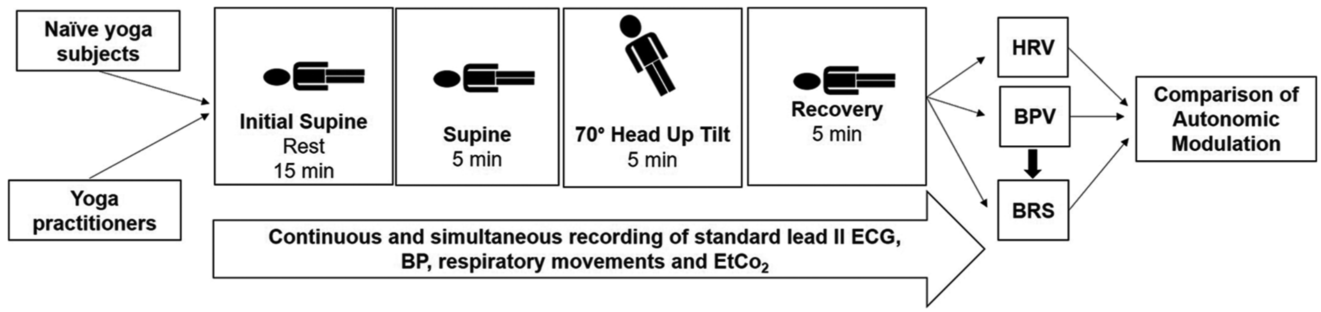

Figure 1: Work plan of the study

Table 3: Systolic blood pressure variability and baroreflex sensitivity during 70° head-up tilt

Parameter	Naïve group		Yoga group		*P*			
	Supine (a)	70° HUT (b)	Supine (c)	70° HUT (d)	Paired *t*-test or Wilcoxon signed-rank test		Independent sample *t*-test/ Mann-Whitney U-test	
					a versus b	c versus d	a versus c	b versus d
SBP (mm Hg)	121.51 (111.49-134.74)	122.97 (114.13-135.79)	115.18 (105.54-120.50)	115.27 (107.10-125.41)	0.027*	0.648	0.028*	0.003*
SDNN (mm Hg)	6.43 (3.97-7.31)	7.15 (4.96-8.89)	4.94 (3.77-6.57)	5.59 (5.03-7.80)	0.008*	0.016	0.045*	0.098
SDSD (mm Hg)	2.59 (2.03-3.15)	3.42 (2.72-4.28)	2.05 (1.69-2.74)	2.97 (2.43-3.69)	<0.0001*	<0.0001*	0.033*	0.136
LF (nu)	74.07 (56.06-82.21)	74.86 (63.33-82.30)	77.09 (59.79-84.69)	65.68 (53.67-82.41)	0.313	0.211	0.719	0.319
HF (nu)	18.33 (14.53-35.89)	20.03 (15.02-30.71)	14.75 (9.60-36.94)	31.42 (16.24-43.70)	0.657	0.119	0.870	0.183
TP (nu)	278.71 (188.52-411.43)	136.83 (119.27-187.14)	303.57 (208.84-467.81)	143.94 (124.4-191.30)	<0.0001*	<0.0001*	0.548	0.620
Number of all sequences	23.5012-32.75)	48.50 (27-59)	18.50 (7.25-36.75)	38 (18-51.75)	<0.0001*	<0.0001*	0.704	0.032*
BRS (ms/mm Hg)	14.68 (12.44-20.78)	7.27 (5.06-8.86)	24.01 (16.60-32.72)	8.90 (6.89-13.04)	<0.0001*	<0.0001*	0.001*	0.017*
α LF (ms/mmHg)	3.75 (2.82-5.55)	1.99 (1.58-2.55)	4.37 (2.70-7.25)	2.67 (2.13-3.06)	<0.0001*	<0.0001*	0.096	0.002*
α HF (ms/mmHg)	5.95 (3.93-7.20)	1.87 (1.18-2.71)	9.79 (6.01-12.83)	2.21 (1.19-3.11)	<0.0001*	<0.0001*	0.001*	0.419

Values expressed as median (interquartile range). *P<0.05 considered statistically significant compared to naïve to yoga group. SDNN, standard deviations of beat to beat systolic blood pressure; SDSD, standard deviation of successive beat to beat systolic blood pressure differences; RMSSD, root mean square of the successive beat to beat systolic blood pressure differences; LF, low frequency; HF, high frequency; nu, normalised unit; SD, standard deviation; Br, breathing; HUT, head up tilt

the comprehensive effect of yoga. 70° HUT was used as an intervention to induce hemodynamic changes in lab settings. Electrically motorized tilt table (Huntleigh Akron Health care, UK) was used for HUT test. Participants lay on the table and the table is tilted from a supine position to an angle of 70° at a speed of ~2.3°/s. Each subject was held at 70° HUT position for 5 min.

Study design

All the recordings were performed in a controlled ambient temperature of 24° ± 1°C in the autonomic function testing lab in the department of physiology. All the subjects were abstained from caffeine-containing beverages for 24 h and had light breakfast before 3 h of the testing. Yoga practitioners avoided the practice of yoga on the day of data recording. Data recording of each participant was completed within a single session. All the participants were made to relax in supine for 15 min before data recording. After 5 min of baseline recording, the participants were exposed to HUT, for a duration of 5 min followed by recovery. Lead II ECG, beat-to-beat blood pressure, respiratory movements, and end-tidal carbon dioxide were recorded simultaneously and continuously for the entire duration of the experiment.

Data collection and analysis

Lead II ECG was recorded simultaneously along with the beat-to-beat blood pressure using a Human NIBP system (Model ML 283, Finapres Medical Systems Australia). Respiratory movements were recorded using a respiratory belt transducer (Model MLT-1132 AD Instruments Australia) connected to the analog to digital converter (Power lab model 15T AD Instruments, Australia). End-tidal carbon dioxide is a noninvasive measurement of partial pressure of carbon dioxide (mm Hg) during expiration, measured using CapnoTrue (Blue point Technologies, Germany). A nasal cannula was placed in the nostrils and connected to the CapnoTrue. It gives values in every 8 s in mm Hg. Lead II ECG was recorded at a sampling frequency of 1 kHz. The digital band pass filter had a low cutoff frequency of 0.5 Hz and a high cutoff frequency of 35 Hz. Blood pressure and respiratory movements were recorded at a sampling frequency of 200 Hz. All the signals were recorded in Lab chart 8 (AD Instruments) and saved for offline analysis of HRV and BPV in time domain and frequency domain methods. 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 blood pressure from the same time period were selected for the analysis.[14,15,17]

Table 4: Respiratory rate and end-tidal carbon dioxide during supine and 70° head-up tilt

Posture	Naïve group	Yoga group	*P*
Resp Rate (cycles/min)			
Supine	16.12±3.07	14.70±2.70	0.034*
70° HUT	15.19±2.64	14.25±2.65	0.147
$Etco_2$ (mm Hg)			
Supine	33.93±4.99	38.55±3.27	<0.0001*
70° HUT	32.89±5.65	36.67±2.99	0.002*

Values expressed as mean±SD. *P<0.05 considered statistically significant compared to naïve to yoga group using Independent sample *t*-test or Mann-Whitney U-test. SD=Standard deviation, HUT=Head-up tilt

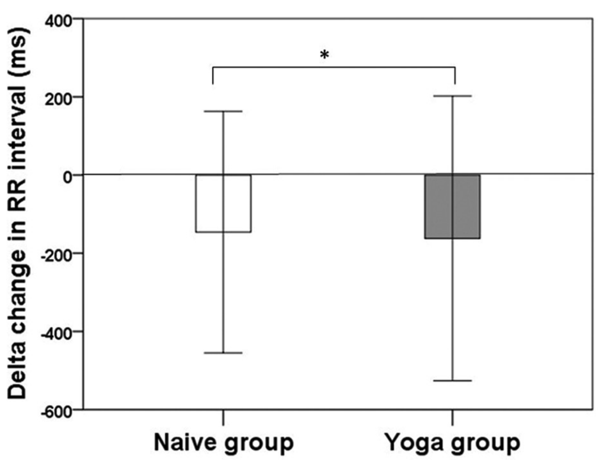

Figure 2: The delta change in RR interval from supine to 70° head-up tilt

Statistical analysis

The distribution of the data was tested using the standard normality test Shapiro–Wilk test. Paired sample *t*-test or Wilcoxon signed-rank test and Independent sample *t*-test or Mann–Whitney U-test were applied for normally distributed data and nonnormally distributed data, respectively, for within-group and between-group comparisons. The $P < 0.05$ was considered statistically significant. Statistical analysis was performed using SPSS (IBM Corp. version 20.0. IBM Corp Released 2011, Armonk, NY, USA).

Results

The study participants were age matched. The average yoga experience in yoga practitioners was 2.31 ± 1.18 years. The body mass index was comparable between groups.

Heart rate variability

Heart rate, low frequency (LF), were significantly increased and RR interval, RMSSD, pNN50, HF, SD1, and SD1/SD2 were significantly decreased in both the groups (within-group comparison) during 70° HUT compared to supine. However, RR interval, RMSSD, and SD1 were observed to be significantly higher in the yoga group than the naïve group. The delta decrease in RR interval from supine to HUT was higher in the yoga group than the naïve group (between-group comparison).

Blood pressure variability and baroreflex sensitivity

The SDSD of systolic blood pressure variability and the number of baroreflex sequences were observed to be

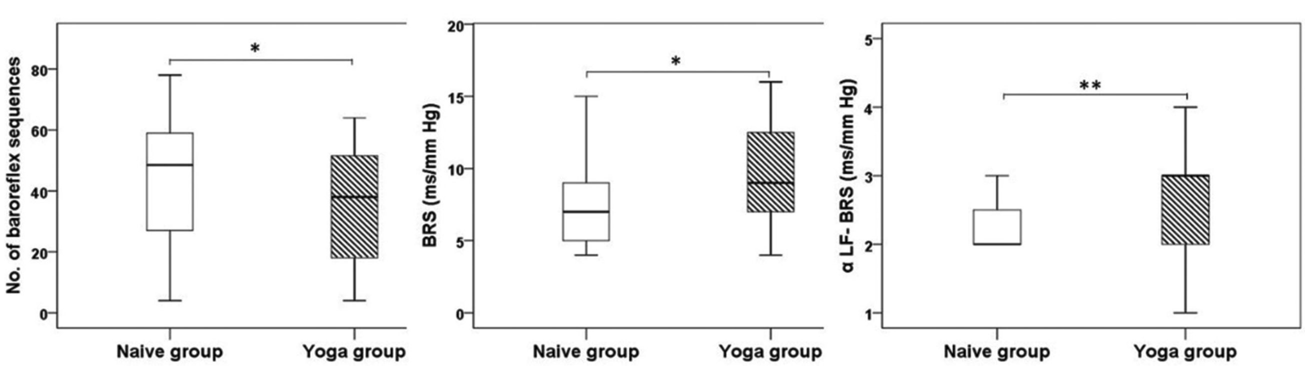

Figure 3: Comparison of baroreflex sequences and baroreflex sensitivity in naïve group and yoga group

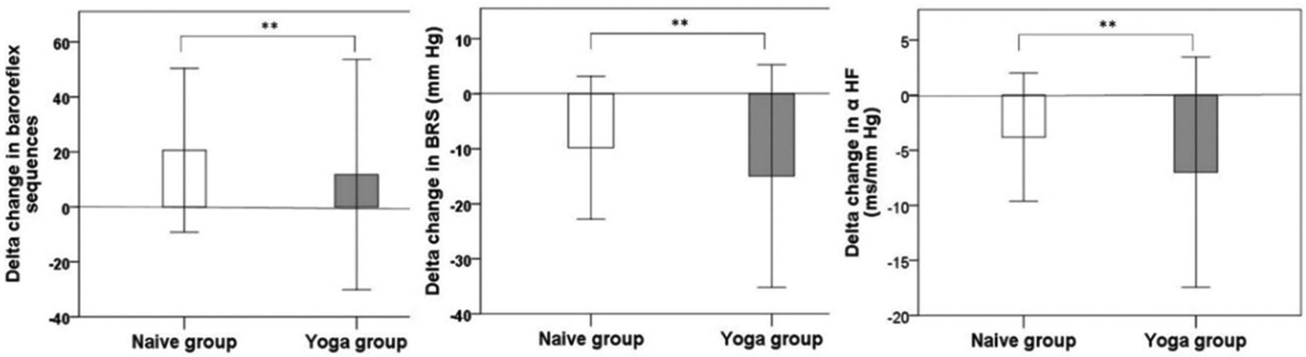

Figure 4: The delta change in the indices of baroreflex sensitivity from supine to 70° HUT

significantly increased and sequence and spectral BRS were significantly decreased in both the groups (within-group comparison) during HUT compared to supine. A significant increase in systolic blood pressure with significant decrease in SDNN of systolic BPV was observed within naïve group only. The mean of systolic blood pressure and the number of baroreflex sequences were significantly lower and sequence and α LF of spectral BRS was significantly higher in the yoga group than the naïve group during HUT (between-group comparison) [Table 3].

Delta change in variables from supine to 70° head-up tilt between naïve group versus yoga group

The delta change in systolic blood pressure (2.95 ± 8.73 vs. 0.42 ± 7.74; P = 0.175), heart rate (16.18 ± 8.16 vs. 17.62 ± 7.90; P = 0.431), and R-R interval (−166.84 ± 82.22 vs. −183.67 ± 121.46; P = 0.476) were comparable. However, down baroreflex sequences (11.65 ± 10.10 vs. 6.25 ± 12.82; P = 0.04), total baroreflex sequences (20.58 ± 14.89 vs. 11.78 ± 20.94; P = 0.03), total BRS (−9.8 ± 6.48 vs. −14.94 ± 10.11; P = 0.008), and α-HF-brs (−3.80 ± 2.90 vs. −6.98 ± 5.22; P = 0.001) were significantly lower in yoga practitioners compared to NY individuals [Figures 3 and 4].

The respiratory rate was significantly lower in the yoga group than the naïve group in supine rest, while during HUT, there was no significant difference in respiratory rate between groups. End-tidal carbon dioxide was significantly higher in the yoga group than the naïve group during supine and 70° HUT [Table 4].

Discussion

We investigated the autonomic modulation of baroreflex sensitivity from the oscillations of heart rate and blood pressure during 70° HUT in yoga practitioners or yoga group and NY individuals or naïve group [Figure 1]. All study participants were age matched and had a normal body mass index [Table 1]. The respiratory rate of all the participants was within normal physiological limits and the respiratory rate was significantly lower in the yoga group than the naïve group [Table 4]. This may be either due to a better relaxed state achieved by yoga practitioners[18] or due to higher tidal volume than the naïve group.[19] At rest, the yoga group showed higher efferent vagal activity and lower heart rate than the naïve group [Table 2]. Repeated sympathovagal modulations with corresponding responses on heart rate during the practice of yoga might have resulted in long lasting enhancement of efferent vagal activity in yoga practitioners compared to naive group.[20] Yoga practitioners have also shown a significantly higher end-tidal carbon dioxide than the NY group both at baseline and HUT. This may be similar to the swimmers[21] where postinspiratory apnea is a part of swimming.[22] Similarly, the practice of apnea or breath holding which is an important component in pranayama might also have resulted in higher end-tidal carbon dioxide (within normal physiological limits) in the yoga group than the naïve group. This could be an adaptive response due to repetitive exposure to hypercapnia during breath holding pranayama practices by the yoga practitioners.[23,24] HUT is an experimental simulation of orthostatic stress. Pooling of blood to lower extremities triggers the compensatory mechanisms with an aim to maintain stable blood pressure. The data during HUT have confirmed sympathoexcitation with decrease in parasympathetic activity similar to earlier studies.[25,26] When compared between groups, the yoga group was shown to maintain higher parasympathetic activity than the naïve group during HUT. However, the delta decrease in RR interval from supine to HUT was higher in yoga practitioners confirming greater reduction in parasympathetic activity in yoga practitioners than the naïve group [Figure 2]. The BPV has also increased within both the groups during HUT [Table 3]. Even though a significant increase in heart rate was observed within both groups, systolic blood pressure significantly increased only in naïve group but not in yoga practitioners during HUT compared to supine. The rise in blood pressure and heart rate that reflects enhanced sympathetic activity in naïve group may also be due to the vestibulo-sympathetic reflex[27] which gets triggered with postural changes and the response was observed to be more remarkable in naïve group than in yoga practitioners. This may possibly be due to the proactive adjustment of the sympathetic activity in yoga practitioners. The practice of tilting the body in yogasanas may have resulted in adaptation to the vestibulo-sympathetic reflex by the yoga group. Moreover, the maintenance of a stable systolic blood pressure in yoga practitioners from supine to HUT may also indicate an efficient buffering of extreme fluctuations in blood pressure evident from higher BRS in the yoga group. Baroreceptors play a vital role in sensing the blood pressure changes and activate the baroreflex that limits extreme blood pressure fluctuations into physiologically normal ranges through negative feedback mechanism. At rest, the BRS was higher in yoga practitioners. This is in accordance with the study where the intervention of yoga was shown to augment BRS.[9] During HUT, the BRS has significantly decreased in both the groups, while, the yoga group has shown higher BRS than the naïve group (between group) [Table 3]. The delta decrease in BRS (sequence method) and α HF (spectral method) from supine to HUT was also significantly higher with the delta rise in baroreflex sequences significantly lower in the yoga group than the naïve group. The higher absolute BRS and RR interval indicates higher parasympathetic activity in the yoga group while the delta decrease in RR interval and BRS reflects that the amount of parasympathetic withdrawal to be higher in the yoga group during the sympathoexcitaion (HUT) [Figure 4]. The systolic blood pressure was observed to be maintained without any significant change during orthostatic stress suggesting a possibility of either efficient buffering of extreme BPV due to higher BRS at baseline in yoga practitioners or due to the possibility of maintenance of normal stroke volume by the yoga practitioners. The findings of the study may be viewed as a customized response by the yoga practitioners, due to their adaptation to the yogasanas or postural changes which are performed in synchrony with the breathing.

Conclusion

The efferent vagal activity and BRS were higher in yoga practitioners. During 70° HUT, higher delta change (decrease) in parasympathetic activity and BRS along with the maintenance of relatively stable systolic blood pressure in the yoga group indicates an adaptive response to orthostatic challenge by the yoga practitioners.

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Conflicts of interest

There are no conflicts of interest.

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