

Measurement of the effect of Isha Yoga on cardiac autonomic nervous system using short-term heart rate variability

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ABSTRACT

Background: Beneficial effects of Yoga have been postulated to be due to modulation of the autonomic nervous system. **Objective:** To assess the effect of Isha Yoga practices on cardiovascular autonomic nervous system through short-term heart rate variability (HRV). **Design of the Study:** Short-term HRV of long-term regular healthy 14 (12 males and 2 females) Isha Yoga practitioners was compared with that of age- and gender-matched 14 (12 males and 2 females) non-Yoga practitioners. **Methods and Materials:** ECG Lead II and respiratory movements were recorded in both groups using Polyrite during supine rest for 5 min and controlled deep breathing for 1 minute. Frequency domain analysis [RR interval is the mean of distance between subsequent R wave peaks in ECG], low frequency (LF) power, high frequency (HF) power, LF normalized units (nu), HF nu, LF/HF ratio] and time domain analysis [Standard Deviation of normal to normal interval (SDNN), square of mean squared difference of successive normal to normal intervals (RMSSD), normal to normal intervals which are differing by 50 ms (NN50), and percentage of NN50 (pNN50)] of HRV variables were analyzed for supine rest. Time domain analysis was recorded for deep breathing. **Results:** Results showed statistically significant differences between Isha Yoga practitioners and controls in both frequency and time domain analyses of HRV indices, with no difference in resting heart rate between the groups. **Conclusions:** Practitioners of Isha Yoga showed well-balanced beneficial activity of vagal efferents, an overall increased HRV, and sympathovagal balance, compared to non-Yoga practitioners during supine rest and deep breathing.

Key words: Cardiovascular ANS, heart rate variability, Isha Yoga

INTRODUCTION

Cardiovascular functions are controlled by neural factors as well as others like temperature, hormones, etc. Of these, neural factors primarily concern the Autonomic Nervous System (ANS), which plays a major role in maintaining and regulating cardiac functions, e.g. systolic and diastolic blood

pressure (SBP and DBP) and heart rate (HR). Imbalances in these lead to cardiovascular disorders such as hypertension, ischemia, infarction, etc.^[1]

Numerous studies indicate a strong association between compromised ANS (e.g. decreased vagal activity or increased sympathetic activity) and sudden and non-sudden cardiac death.^[2,3] Lifestyle modifications are also increasingly recognized as important factors in the treatment, prevention, and rehabilitation of cardiovascular disorders.^[4] One highly popular and currently researched lifestyle modification is Yoga.

Yoga is considered a holistic practice generating a sense of well-being through its various actions on physiological systems in a seemingly complex, yet integrated manner. Regular Yoga practice has been postulated to help in prevention of disease,^[5] in particular, to streamline autonomic functions, specifically by modulating vagal efferents.^[6] Preliminary support for this hypothesis comes from a study demonstrating voluntary control over HR after a 30-day Yoga intervention.^[7]

Isha Yoga consists of a set of yogic practices such as

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Surya Namaskar, 16 types of *Asanas*, *Sakthi chhalana Kriya*, *Shambhavi Maha Mudra*, *Shoonya*, and *Samyama* meditations. Changes in cardiac ANS have been observed during the practice of *Shambhavi Maha Mudra*.^[8]

Several methods are available to measure cardiac ANS, of which heart rate variability (HRV) has been established as a non-invasive tool. HRV includes both variations in instantaneous HR and RR intervals. Beat-to-beat (R-R intervals) fluctuations reflect the ability of cardiovascular control systems to respond efficiently to a multitude of physiological changes. HRV is traditionally analyzed by frequency domain, time domain, and nonlinear methods, to investigate autonomic influences on the cardiovascular system. Classical spectral analysis of HRV signals distinguishes sympathetic from parasympathetic activity: sympathetic activity manifests in low frequency (LF) band power, while parasympathetic activity manifests in high frequency (HF) band power. LF/HF ratio and LF, HF normalized units (nu) are good indicators to assess alterations in cardiac autonomic nervous system behavior.^[9] Reduced HRV has been identified as a predictor of increased risk of cardiac mortality and sudden cardiac death.^[10]

Studies conducted so far on Yoga practices have by and large measured HRV just before, during, or immediately after Yoga sessions. Few studies have measured HRV in long-term regular practitioners.^[6] No studies have been conducted using HRV comparing Yoga practitioners and non-Yoga practitioners.

This study measured the effects of Isha Yoga on cardiac ANS in healthy regular practitioners who had been practicing for over 6 months, comparing them with healthy, age- and gender-matched controls at rest and in respiratory sinus arrhythmias using short-term HRV. It was hypothesized that these measures would help understand how the cardiovascular ANS responds to Isha Yoga practices.

MATERIALS AND METHODS

The study was conducted at the Neurophysiology Lab, Isha Institute of Inner Sciences and Research, Coimbatore, India, after obtaining Ethics Committee approval from Stanley Medical College, Chennai, India.

Study protocol

Subjects

Fourteen healthy Isha Yoga practitioners and 14 healthy, age- and gender-matched, non-Yoga practitioners (mean age 31.57 ± 5.83 years, 12 males and 2 females) were recruited by the Isha Institute of Inner Sciences and Research.

Inclusion criteria

Age between 18 and 40 years; in addition, for the Yoga group: doing Isha Yoga practices for 1½ h per day, 5 times a week, minimum for over 6 months.

Exclusion criteria

Medical illness or on medication or exercise regime; obese; smoking; taking recreational drugs or alcohol. For non-Yoga control group: previous exposure to Yoga or exercise practice.

About Isha Yoga practices

Isha Yoga consists of a set of yogic practices such as *Surya Namaskar*, 16 types of *Asanas*, *Sakthi chhalana Kriya*, *Shambhavi Maha Mudra*, and *Shoonya* meditation designed by *Sadhguru*, a Yogi, mystic, and a humanitarian. Practitioners practiced all Isha Yoga practices described below regularly during a stipulated, protected time period for a minimum of 2½ h every day. All practitioners had learnt them following initiation when attending Isha Yoga programs conducted by Isha Foundation.

Surya Namaskar: 12 cycles of *Surya Namaskar* were done in medium pace in a span of 15 min.

Hatha Yoga (practiced daily) consists of a set of balanced, scientifically structured, simple, but powerful *Asanas* (Yoga postures) that were done in a period of 45 min in medium pace (*Nadivibhajan*, *Padabastasana*, *Konasana*, *Trikonasana*, *Vrikshasana*, *Ekapadda Uttamapadasana*, *Dwipadantamapadasana*, *Shalabasana*, *Naukasana*, *Bujangasana*, *Dhanurasana*, *Paschimothasana*, *Janur Sirasasana*, *Arda Matsyendrasana*, *Sarvangasana*, and *Mayurasana*).

They were not performed merely as physical exercise or body bending, but slowly, with eyes closed and complete awareness aligning the mind with coordinated movements of body and breath.

Sakthi chhalana Kriya consists of a powerful set of purifying techniques employing the breath to gain control over one's vital energies, practiced at least once daily. Practitioners sit on their heels with knees bent (*vajrasana*), eyes closed, inhaling and exhaling in cycles of different rates and volume, with the attention focused on breath and body. Depending on breath rate and number of cycles, 45–75 min may be required to complete it.

Shambhavi Maha Mudra (practiced at least once daily for 21 min) is usually done in cross-legged posture (*arthasiddhasana*) with eyes closed and hands in *Yoga Mudra*. Practitioners consciously focus and apply body, breath, and mind to balance their inner energy systems in a relaxed manner.

Shoonya Meditation (practiced twice a day for 15 min): This is a refined and intensive, advanced meditation technique. Practitioners sit cross-legged (*sukhasana*) with eyes closed, in an effortless process of conscious non-doing, aiming to bring about a state of no activity to body and mind.

Procedure

The study was a cross-sectional design comparing Isha Yoga practitioners with individuals not practicing Yoga. The study was explained to the subjects both orally and in writing, and formal written consent was obtained.

HRV recordings were performed as per Task Force 1996 recommendations in the morning, 2 h after a light breakfast. All subjects were asked to void urine before testing and made to sit in a relaxed atmosphere in the lab for 20 min prior to the start of recordings. The lab was maintained at 26–28°C, light was subdued, and noise levels were kept to minimum.

Participant's height in meters and weight in kilogram were measured to calculate their body mass index (BMI).

Ten minutes electrocardiogram (ECG Lead II) recording was made with the eyes closed at supine rest, with normal respiratory frequency of 12–18/min, using *RMS Polyrite D Hardware*, India at a rate of 200 Hz.

Resting Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) were measured using a sphygmomanometer on the left arm after 10 min supine rest. Following this, subjects were asked to open their eyes and follow the researcher's verbal commands to breathe slowly and deeply at 6 breaths per minute, monitored and recorded by a respiratory transducer.^[11]

HRV analysis

Task Force recommendations for HRV were followed for analysis.^[9] A stationary 256-second RR series was chosen and data transferred from RMS Polyrite to a window-based PC. RR series was extracted using a rate detector algorithm after artifact and ectopic exclusion.

HRV analysis was done using HRV analysis software version 1.1 (Biosignal Analysis group, Finland). Calculated time domain indices included mean RR, Standard Deviation of normal to normal interval (SDNN), square of mean squared difference of successive normal to normal intervals (RMSSD), normal to normal intervals which are differing by 50 ms (NN50), and percentage of NN50 (pNN50).

The RR series was resampled at 4 Hz for frequency analysis, its mean and trend removed, a Hanning window applied and the 1024 data point series transformed by Fast Fourier transformation.

LF and HF spectral powers were determined by integrating the power spectrum between 0.04 and 0.15 Hz and between 0.15 and 0.4 Hz, respectively. The ratio of LF and HF powers was also calculated. Spectral powers were expressed in absolute units of milliseconds square. LF and HF powers were expressed in normalized units.

Statistical analysis

SPSS-11 was used for all statistical analyses. Student's independent *t*-test was performed to study the statistical significance of differences in all basic parameters: age, BMI, resting heart rate (RHR), SBP and DBP, mean arterial pressure (MAP) and Pulse Pressure (PP) and HRV indices for supine rest and deep breathing. Data were expressed as mean \pm Standard Deviation. *P* value equal to or less than 0.05 was taken as significant. All statistical tests were two-tailed tests.

RESULTS

Both time domain and frequency domain parameters were obtained for all subjects during supine rest. Time domain parameters alone were measured for deep breathing.

General parameters

Tests for normality of distribution consistently found normal distributions for all parameters. There was no significant age and BMI difference between the two groups. RHR was not statistically significant. There was a decrease in SBP, DBP, PP and MAP with statistically significant differences SBP ($P = 0.00$), DBP ($P = 0.01$), PP ($P = 0.01$), and MAP ($P < 0.00$) during supine rest in the Yoga practitioners. [Table 1]

HRV during supine rest

Mean RR did not differ significantly between the two groups ($P=0.3$). SDNN increased and was significant ($P=0.02$) in Yoga practitioners. Yoga group's LF in powers decreased and was significant ($P = 0.00$), LF in normalized units also decreased and was just significant ($P=0.05$). HF in powers increased and was just significant ($P = 0.05$), HF in normalized units also increased and was just significant ($P = 0.05$), LF/HF decreased but was not significant ($P = 0.43$)[Table 2] [Figure 1].

HRV analysis during 1 min deep breathing

During deep breathing, HRV components such as mean RR ($P = 0.04$), SDNN ($P = 0.03$), NN50 ($P = 0.00$), and pNN50 ($P = 0.05$) increased in the Yoga Practitioners' group and showed statistically significant differences [Table 3] [Figure 2].

DISCUSSION

Basic parameters at supine rest

The Isha Yoga practitioners and non-practitioners did

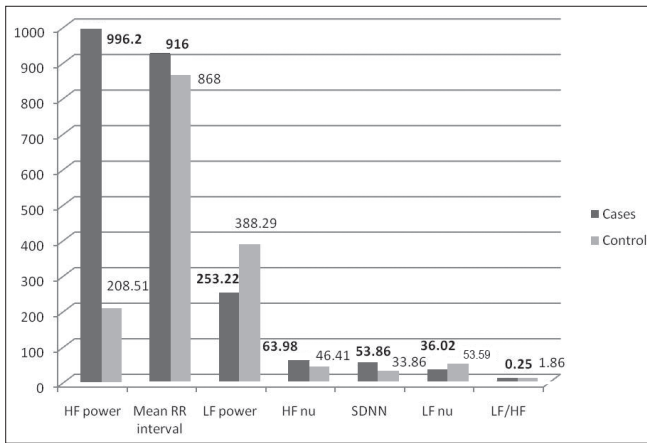


Figure 1: HRV Analysis During Supine Rest. RR interval: distance between subsequent R wave peaks in ECG, LF: Low Frequency, HF: High Frequency, nu: normalized units, SDNN: Standard Deviation of Normal to Normal RR interval

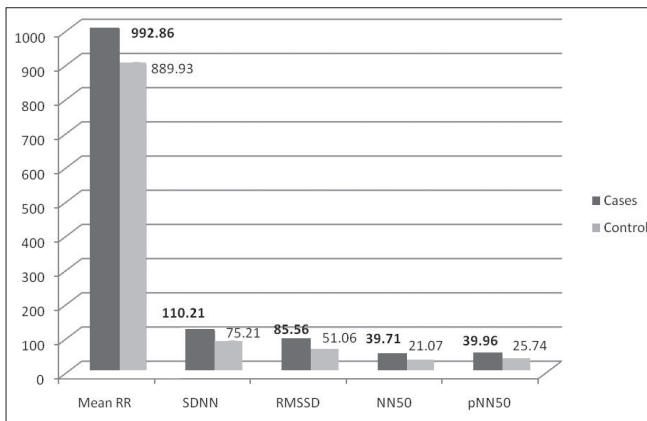


Figure 2: HRV Analysis During 1 minute Deep Breathing. RMSSD: square of mean squared difference of successive normal to normal intervals, NN50: normal to normal intervals which are differing by 50 ms, pNN50: percentage of NN50

not differ in RHR in a supine resting state. Statistically significant differences were observed between the two groups in SBP, which mainly depends on the cardiac output and is controlled by several mechanisms. Originally the baroreflex receptor mechanism was only thought to be for its short-term control and not to have a long-term influence, but recent studies suggest involvement of both baroreceptors and renal sympathetic nerve activity (RSNA) in its long-term control.^[12]

Since RHR was normal in both the groups, reasons for lower SBP in Isha Yoga practitioners could be: better end diastolic volume, strengthening of the baroreceptor mechanism, or more responsive norepinephrine transporter inhibition.^[13] Decreased SBP was due to effects on baroreceptor reflex and RSNA and their control on long-term functioning of blood pressure regulation.^[14] $SBP = cardiac\ output\ (CO) \times peripheral\ resistance$, wherein $CO = HR \times stroke\ volume$. The HR forms one of the determinants of SBP, since

Table 1: General parameters, basal heart rate, blood pressure during supine rest

Parameters	Cases	Controls	P value
Age (years)	31.57 ± 5.83	33.29 ± 7.3	0.50
Resting HR (bpm)	68.36 ± 6.49	71.03 ± 10.79	0.43
SBP (mm Hg)	105.57 ± 8.27	117.00 ± 7.22	0.00*
DBP (mm Hg)	70.29 ± 5.25	76.00 ± 5.14	0.01*
PP (mm Hg)	35.29 ± 6.87	41.00 ± 4.13	0.01*
MAP (mm Hg)	82.05 ± 5.54	90.57 ± 7.51	0.00*

HR = Heart rate, bpm = Beats per minute, SBP = Systolic BP, DBP = Diastolic BP, PP = Pulse pressure, *P ≤ 0.05 was considered significant

Table 2: Heart rate variability during supine rest

Parameters	Cases (n = 14)	Controls (n = 14)	P value
Mean RR interval	916 ± 94.3	868 ± 142.33	0.3
SDNN	53.86 ± 21.35	33.86 ± 22.66	0.02*
LF power (= sympathetic > parasympathetic)	253.22 ± 40.43	388.29 ± 60.55	0.00*
HF power (= parasympathetic)	996.2 ± 045.31	208.51 ± 1005.1	0.05*
LF/HF	0.25 ± 4.05	1.86 ± 6.35	0.43
LF nu	36.02 ± 21.73	53.59 ± 22.63	0.05*
HF nu	63.98 ± 22.63	46.41 ± 17.93	0.03*

*P ≤ 0.05 was considered significant, RR interval: the distance between subsequent R wave peaks in ECG, SDNN: Standard Deviation of normal to normal RR interval, LF: Low Frequency, HF: High Frequency, nu: normalized units

Table 3: Heart rate variability during 1-min deep breathing

Parameters	Cases (n = 14)	Controls (n = 14)	P value
Mean RR interval	992.86 ± 00.31	889.93 ± 142.33	0.04*
SDNN	110.21 ± 41.86	75.21 ± 37.41	0.03*
RMSSD	85.56 ± 33.71	51.06 ± 40.0	0.02*
NN50	39.71 ± 11.29	21.07 ± 10.91	0.00*
pNN50	39.96 ± 18.31	25.74 ± 17.90	0.05*

*P ≤ 0.05 was considered significant, RMSSD: root mean square Standard Deviation, NN50: normal to normal RR interval differing more than 50 ms, pNN50: percentage of NN50

the change in the HR is profoundly affecting the SBP by indirectly decreasing the cardiac output. The resting HR was low in the study group, but not significant.

There was also a decrease in the DBP in Isha Yoga practitioners, which could have been due to reduction in centrally mediated peripheral resistance. In the case of vasodilatation, local mechanisms like Nitric Oxide (NO), etc. could cause it peripherally, and hence lower DBP. Another mechanism in long-term regulation is the rennin angiogenesis system, investigation of which is beyond the scope of this study and should be considered for further studies. Investigating mechanisms will require further studies, including measures of biochemical markers of

rennin angiotensin, peripheral resistance, and cardiac output.

MAP, a determinant of organ perfusion, was significantly lower in Isha Yoga practitioners, indicating better autoregulation of their vital organs.

Resting HRV

Frequency domain analysis

The two groups did not differ in mean resting RR in a supine resting state. The LF in powers, quantifying the ratio of sympathetic to parasympathetic activity, indicates low sympathetic activity in Isha Yoga practitioners.

LF, the quantitative marker of sympathetic activity expressed in normalized units, decreased in Isha Yoga practitioners, indicating low sympathetic activity.^[15] Blood pressure is sensed by arterial baroreceptors, which adjust HR through the central nervous system via both the slower sympathetic and the faster vagal action. At the same time, baroreceptors induce a slow sympathetic withdrawal in the vessels. The delay in the sympathetic branch of the baroreflex in turn determines a new oscillation, which is sensed by the baroreflex and induces a new oscillation in HR. LF oscillation arises from the interaction of slow sympathetic and fast vagal responses. We have observed that the respiratory pattern in the study group was low rate. Respiration-induced blood pressure oscillations result in resonant LF oscillations due to the delay in the slow conducting sympathetic loop of the baroreflex.

Decreased LF component in HRV indicates increase in baroreflex gain and decrease in sympathetic outflow. Change in the LF component has a profound effect in modulating chemoreception, thermoregulation, and the vasomotor activity. The secretion of catecholamine and response to these neurotransmitters by target organs are also decreased. Low level of sympathetic activity increases the renal blood flow and also decreases the renin angiotensin activity. Long-term blood pressure regulatory mechanisms such as of kidney and other endocrine organs are very well conditioned to have low sympathetic activity.

Long-term Isha Yoga practitioners show overall decreased sympathetic activity that tends to reduce both SBP and DBP and HR. Reduction of LF in normalized units is a clear marker of reduced sympathetic activity. This effect is beneficial for cardiovascular and other systems.

HF power, a measure of parasympathetic dominance, increased in the Isha Yoga group, indicating that vagal dominance increased during rest. Benefits of vagal dominance include reduction of HR, increased variations in HR and cardiac output, again reducing overall load on the heart and, indeed, the entire cardiovascular system (CVS).

During supine rest, Isha Yoga practitioners' LF/HF ratio did not decrease significantly. Often, LF/HF ratio is an indicator of sympathovagal balance (SVB), though precise ways to measure it are unknown. Although our study did not find significant LF/HF ratios, this does not predict nonexistence of SVB, about which differences in opinion exist among investigators in the field. On one hand, there are studies suggesting that SVB may be indicated by a reciprocal relationship between LF and HF^[16] or by LF/HF ratio.^[17] On the other hand, Eckberg states that "calculations of sympathovagal balance (ratio of LF to HF) may obscure rather than illuminate human physiology and pathophysiology," indicating fundamentally different approaches to the problem,^[18] on which we cannot comment. But lower LF/HF ratio indicates that the cardiac ANS has better autonomic tone than autonomic modulation, whereas its long-term control requires better autonomic modulation than autonomic tone.

Resting HRV

Time domain analysis

The time domain index, SDNN, the square root of variance, a measure of overall HRV, increased in Isha Yoga practitioners relative to non-practitioners. Increased HRV signifies the extent of the ability of the cardiac ANS to accommodate wide variations, but not the rate of response. In this study, only 5 min of supine rest was taken for analysis out of 10 min of recording. Long-term 24-h Holter monitoring would give better SDNN estimation.

Heart rate variability during deep breathing

HRV during deep breathing (HRVdb) is a major index of HRV, known as one of the most reliable and reproducible markers of parasympathetic modulation of cardiac autonomic function. Respiratory sinus arrhythmia is maximum at the breathing rate of 6/min. Maximum vagal fluctuation in both afferent and efferent limbs can be measured at SA node only at 6 breaths per minute.

All the above significantly increased in Isha Yoga practitioners: SDNN, RMSSD, NN50, pNN50 significantly increased, indicating long-term vagal modulation of cardiac function. This could be due to increase in tidal volume, which compensates for reduced breathing rate, which in turn maintains minute ventilation.^[19,20]

Benefits of decreased breath rate with adequate minute ventilation are better oxygen saturation, effective CO₂ elimination, better organ perfusion, and strengthening of baroreflex activity, all of which have a beneficial effect on the cardiac system, in particular, the cardiac ANS. Increased HRVdb in the Yoga group indicates that cardiac vagal effects (vagal modulation R-R intervals) are increased. These may be due to increased baroreflex sensitivity.^[21]

Limitations

Short-term HRV limits the ability of measurement of time domain analysis accurately. Measurement of HRV through 24-h Holter monitoring would help to understand this better. Direct measurement of sympathetic activity like measurement of peripheral arterial resistance, Galvanic Skin Resistance (GSR), and optical sensors would have given better understanding of the state of the sympathetic nervous system,^[22]. Other factors influencing cardiac ANS like measurement of baroreflex sensitivity through beat-to-beat BP measurement should also be investigated, as should cardiac stress markers like catecholamine assay and steroid and rennin levels, both of which influence HRV. None of these have yet been measured. Also, prospective studies under controlled conditions would better evaluate changes in cardiac ANS functioning resulting from Isha Yoga practices. If the sample size were bigger, it would probably have helped us understand the significance of LF:HF ratio better.

CONCLUSIONS

During both supine rest and deep breathing, Isha Yoga practitioners showed well-balanced activity of vagal efferents, overall increased HRV, and sympathovagal balance, compared to non-Yoga practitioners. Hence, it may be postulated that Isha Yoga practitioners

- have better exercise tolerance,
- their cardiac response to adverse conditions like day-to-day stress is improved following Isha Yoga practices
- the probability of them experiencing hypertension and other premature cardiac events like ischemia or infarction is decreased after the practice of Isha Yoga.

However more studies should be conducted to explore these areas further.

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