I alone persist: Blissful: Absolute.

All this is, indeed, Brahman

There is nothing here apart from it

Surely Health is the primary requisite of spiritual life.
HRV AS A RESEARCH TOOL IN YOGA

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Abstract

A wide range of studies have reported HRV analyses of immediate, short and long term effects of Yoga and its different techniques. A Pubmed, Medline and Google Scholar search with regard to HRV and the terms Yoga / Prāṇāyāma / relaxation / meditation revealed 33 eligible studies published in indexed, peer reviewed journals. Of these, 21 were on acute / immediate effects of different techniques (Āsana, Prāṇāyāma and Meditation) while 11 reported the effects of training programmes ranging from 2 days to 4 months. The subject population of most studies was primarily normal, healthy volunteers of either/ both gender in 29 of them while 4 dealt with HRV studies in pregnant women, smokers on a cessation programme, patients of unipolar depression and post traumatic stress syndrome. While the majority gives evidence of enhanced parasympathetic activity and decreased sympathetic activity with improved SVB; a few strike a discordant note. Individual techniques are seen to have different effects as evidenced in acute studies on forced uninostril breathing and Kapālabhāṭī / high frequency Yogic breathing. The tools of HRV analysis are highly sensitive to various factors such as the frequency of breathing, vocalization, mental activities and physical posture and hence have limitations with regard to Yoga studies. Innovative thoughts and novel methods need to be developed and applied if we are to understand the intrinsic effects of this ancient art and science that is as relevant today as it was millennia ago.

Key Words: HRV, Yoga, Prāṇāyāma, Relaxation, Kapālabhāṭī, Google.

INTRODUCTION

In the past few decades, many researchers have investigated the effects of Yoga on markers of sympathetic / parasympathetic activation and cardiovagal function. A review by Innes et al identified 42 such studies with over 85% of them offering some evidence that Yoga promotes a reduction in sympathetic activation, enhancement of cardiovagal function, and a shift in autonomic nervous system (ANS) balance from primarily sympathetic to parasympathetic. The key changes they reviewed included significant reductions in respiratory and heart rate, in cortisol concentrations, catecholamine levels, and renin activity, in skin conductance, and in cardiovascular response to stress, as well as significant increases in heart rate variability (HRV) and baroreflex sensitivity.

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HRV, the beat-to-beat alterations in heart rate, is a simple noninvasive measurement for investigating autonomic influence on the cardiovascular system and may be evaluated by time domain and frequency domain methods. Time domain analysis is a simple method to quantify overall HRV whereas power spectral analysis provides a means of studying different mechanisms responsible for variability in instantaneous heart rates. A reduced HRV can be used as a predictor of hypertension, development of diabetic neuropathy, cerebrovascular disease, congestive heart failure, and lethal arrhythmic complications after an acute myocardial infarction. Low HRV and baroreflex sensitivity reflect impaired cardiovagal adaptability and suggest excessive sympathetic and/or insufficient parasympathetic tone that are, in turn, strong independent predictors of cardiovascular morbidity and mortality. In contrast, high HRV and baroreflex sensitivity are generally considered to indicate good cardiovagal adaptability and SVB, permitting greater responsivity and sensitivity to changing environmental demands.

Streeter et al., (2012) recently proposed a theory to explain the benefits of Yoga practices in diverse, frequently comorbid medical conditions based on the concept that Yoga practices reduce allostatic load in stress response systems such that optimal homeostasis is restored.

They hypothesized that stress induces an:
1. Imbalance of the ANS with decreased parasympathetic and increased sympathetic activity,
2. Under activity of the gamma amino-butyric acid (GABA) system, the primary inhibitory neurotransmitter system, and
3. Increased allostatic load.

They further hypothesized that Yoga-based practices
1. Correct underactivity of the parasympathetic nervous system and GABA systems in part through stimulation of the vagus nerves, the main peripheral pathway of the parasympathetic nervous system, and
2. Reduce allostatic load.

According to the theory proposed by Streeter et al, the decreased parasympathetic nervous system and GABAergic activity that underlies stress-related disorders can be corrected by Yoga practices resulting in amelioration of disease symptoms. HRV testing has a great role to play in our understanding intrinsic mechanisms behind such potential effects of Yoga.

Innes et al., had earlier (2005) also postulated two interconnected pathways (given below) by which Yoga reduces the risk of cardiovascular diseases through the mechanisms of parasympathetic activation coupled with decreased reactivity of sympathoadrenal system and HPA axis.
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STUDIES USING HRV TO EVALUATE EFFECTS OF YOGA

A Pubmed, Medline and Google Scholar search with regard to HRV and the terms Yoga / Pranayama / relaxation / meditation revealed 33 eligible studies published in indexed, peer reviewed journals. Of these, 21 were on acute / immediate effects of different techniques (Āsana, Prāṇāyāma and Meditation) while 11 reported the effects of training programmes ranging from 2 days to 4 months. The subject population of most studies was primarily normal, healthy volunteers of either/ both gender in 29 of them while 4 dealt with HRV studies in pregnant women, smokers on a cessation programme, patients of unipolar depression and post traumatic stress syndrome. Although evidence for a beneficial influence on sympathovagal (SVB) balance due to Yoga is quite consistent overall across the diverse array of studies, there are many limitations that hinder conclusive interpretation of findings.

In 1991 Stancšk et al., reported a decreased cardiac vagal modulation during high frequency Yogic breathing in 17 advanced Yoga practitioners by a spectral analysis of the time series of beat to beat series of the R-R intervals as well as systolic and diastolic blood pressure. This may very well be the earliest study in Yoga using concepts of HRV analysis. The next published report on Yoga using HRV was in 1997 by Bowman et al., who reported on baroreflex sensitivity in healthy elderly persons concluding that alpha HF (reflecting para-sympathetic activity) increased following 6 weeks of Yoga training but not after aerobic exercise. 

Raghuraj et al., (1998) reported the comparative effects of Kapālabhāti and Nāḍī Šuddhi thus...
becoming the first ones to use HRV analysis to differentiate effects of slow and fast Prāṇāyāmas and their effects on the ANS. They concluded that Kapālabhāti modifies autonomic status by increasing sympathetic activity with reduced vagal activity. Bernardi et al., (2001) studied breathing patterns and cardiovascular autonomic modulation during hypoxia induced by simulated altitude in 10 western Yoga trained subjects giving evidence that sympathetic activation following simulated altitude was blunted in Yoga trainees. Three more studies followed soon from SVYASA University, Bangalore with Vempati and Telles reporting on Yogi relaxation and Manjunath and Telles on Sirsasana. The first report on HRV from JIPMER was a report on Shavasan training in students by Madanmohan et al., in 2004. This was soon followed by another study discussing the correlation between short-term HRV indices and heart rate, blood pressure indices, pressor reactivity to isometric handgrip in healthy young male subjects. Recently researchers at JIPMER presented papers on the immediate effects of uninostril breathing techniques as well as on the cardiac autonomic effects of Shavasan in patients of heart failure. Other short term and long term studies on Yoga and its techniques in diabetic and hypertensive patient populations are in progress.

Dhyāna or meditation is an integral part of Patanjali’s Aṣṭāṅga Yoga though in modern times it has been highlighted individually with many newer techniques becoming popular worldwide. There are at least 13 acute / immediate studies on different forms of meditation such as Cyclic meditation, Zen meditation, Kuṇḍalinī meditation, Chi meditation, loving-kindness meditation, non-directive meditation and the contemplative chanting of the rosary or the Mantra ‘Om Maṇi Padme Om’. of these studies, 12 reported improvement of HRV power / SVB / increased para-sympathetic / decreased sympathetic while one reported increase in stochastic nature and decrease in nonlinear nature of the signal during Chi meditation with significant decrease in degree of nonlinearity and stochastic nature occurs during Kuṇḍalinī meditation. One of the interesting reports was that that individuals exhibiting acute increases in HF-HRV from resting baseline to meditation smoked fewer cigarettes at follow-up than those who exhibited acute decreases in HF-HRV.

Chaya et al., reported that subjects who had practiced Yoga for a year had higher resting sympathetic activity compared with controls as evidenced by significantly higher LF power, lower HF power and higher LF/HF ratio. This was attributed to the stress of a novel experimental setting, since in contrast to the Yoga group many of the subjects in the control group had undergone other experimental procedures such as protein kinetic studies in the experimental laboratory. In contrast, Khattab et al., have reported that relaxation by yoga after 5 weeks of training is associated
with a significant increase of cardiac vagal modulation.\(^{(29)}\) Another randomized control trial in Brazil reported significant decreases in LF as well as LF/HF ratio following 4 months of respiratory yoga training and concluded that it may be beneficial for the elderly healthy population by improving respiratory function and SVB.\(^{(31)}\)

A large scale study in the USA of 239 employee volunteers reported that the mind-body interventions showed significantly greater improvements on perceived stress, sleep quality, and the heart rhythm coherence ratio of HRV.\(^{(36)}\) They concluded that both mindfulness-based and therapeutic yoga programs may provide viable and effective interventions to target high stress levels, sleep quality, and autonomic balance in employees.

**DIFFICULTIES IN HRV ANALYSIS OF YOGA TECHNIQUES**

It is difficult to analyse frequency domain studies of HRV during any yogic manoeuvre especially Prāṇāyāma, as respiratory frequency, tidal volume and minute ventilation influences both low frequency and respiratory frequency RR interval power spectra. Respiration must be controlled if RR interval power spectra are to be interpretable.\(^{(40)}\) When performing HRV it is essential that there is a simultaneous recording of respiration alongside ECG and BP measurements. Since Prāṇāyāma involves altering breathing frequency, ratio and depth - as such the HRV spectra cannot be interpreted as they often are routinely and spectral analysis may not give useful information beyond that contained in the time domain.

For short manoeuvres the mean RR interval and simple time domain measures of RR interval variability: SDNN; and pNN50 if possible are useful. Spectral analysis of HRV may not yield any further useful information because each manoeuvre may be associated with a distinct pattern of breathing (depth, ratio and frequency). Being able to quantify both depth and frequency of breathing will be ideal but the minimum that needs to be known for correct interpretation is respiratory frequency as the association of respiratory frequency, tidal volume and minute ventilation with short-term autonomic control is well established.\(^{(40)}\) Simple mental and verbal activities markedly affect HRV through changes in respiratory frequency. This possibility should be taken into account when analyzing HRV without simultaneous acquisition and analysis of respiration.\(^{(41)}\) Autonomic rhythms measured during different breathing protocols have much in common but it has been reported that a stepwise protocol without stringent control of inspired volume may allow for the most efficient assessment of short-term respiratory-mediated autonomic oscillations.\(^{(42)}\)

To mitigate these difficulties, the simplest way to analyse acute/immediate effects of different
Yoga techniques seem to be to do the HRV recordings only before and after the selected manoeuvres and earlier works on HRV and Prāṇāyāma have done so\(^7,27,28\). Two recent studies\(^30,34\) tried to analyse HRV during Prāṇāyāma and finally concluded that such an analysis couldn't be done due to the changes in breathing frequency and patterns.

Another difficulty in doing acute / immediate studies on Yoga techniques such as Āsanas is that there are postural changes involved in most of them. This is relevant as Kotani et al., have concluded that the postural change associated with an altered autonomic balance affects not only the amplitude of RSA, but also the phases of RSA and BP variations in a complicated manner.\(^{43}\) They noted note that the phase of the DBP waveform in the sitting position largely differs from that in the standing position, which is caused by the factor that RSA changes the diastolic duration that is sufficiently large to alter the cardiovascular regulation. This seems to be a major difficulty in acute/immediate studies on inverted techniques such as Sarvangasana\(^{44}\) or Sirsasana\(^{11}\). It is also important to remember that any of these dramatic changes in body position can influence the SVB and that a short period of rest may be required in between repeat assessments after such dramatic position changes. Dantas et al., have reported modifications in all parameters in time and frequency domains due to increased sympathetic activity and decreased parasympathetic activity when their subjects changed from supine to orthostatic position.\(^{45}\)

Many of the breathing practices as well as concentrative-contemplative-meditative and relaxation techniques of Yoga, involve mental imagery and visualization with conscious awareness as well as the intonation of audible sounds as part of Nāda Yoga. This may interfere with HRV analysis as it has been reported that simple free talking, reading aloud and mental arithmetic result in marked LF predominance that may mistakenly be interpreted as due to sympathetic activation.\(^{41}\) The slowing of breathing per se generates a confounding effect on the RR spectrum, by bringing respiratory sinus arrhythmia (a predominantly vagal effect) into the non-respiratory LF, thought (simplistically) to reflect sympathetic activity. These results have practical relevance in the analysis and interpretation of Holter electrocardiograms using HRV techniques as, in the absence of simultaneous analysis of respiration, changes in LF/HF ratio should not be taken as clear evidence of changes in autonomic tone.\(^{41}\) Despite these observations it is interesting to note that exactly a year later, Bernardi et al., studied the recitation of the rosary, and also of Yoga mantras, reporting that they both slowed respiration to almost exactly 6/min, and enhanced HRV and baroreflex sensitivity by synchronizing inherent cardiovascular rhythms.\(^{15}\)

The above limitations take on a new dimension when we realize that most of the acute and immediate studies on various types of meditation have been actually done during meditation.\(^{12}\)
However Hamada et al., have suggested that specific correlated relationships exist between changes in autonomic nervous activity and EEG power depending on the difference in mental task, whether meditation or mental arithmetic. They have also pointed out that autonomic nervous activity during meditation is characterized by decreased sympathetic activity and increased parasympathetic activity while mental arithmetic tasks induce an enhanced sympathetic activity.

**CONCLUSION**

A wide range of studies have reported HRV analyses of immediate, short and long term effects of Yoga and its different techniques. While the majority gives evidence of enhanced parasympathetic activity and decreased sympathetic activity with improved SVB; a few strike a discordant note. Individual techniques are seen to have different effects as evidenced in acute studies on forced uninostril breathing and Kapālabhāṭī / high frequency Yogic breathing. The tools of HRV analysis are highly sensitive to various factors such as the frequency of breathing, vocalization, mental activities and physical posture and hence have limitations with regard to Yoga studies. Innovative thoughts and novel methods need to be developed and applied if we are to understand the intrinsic effects of this ancient art and science that is as relevant today as it was millennia ago.

<table>
<thead>
<tr>
<th>Total studies</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Retrieved from a Pubmed search of the terms HRV and Yoga, HRV and Prāṇāyāma, HRV and breathing, HRV and meditation, HRV and relaxation)</td>
<td></td>
</tr>
<tr>
<td>Duration of study</td>
<td>Acute / immediate studies</td>
</tr>
<tr>
<td>Effect of training</td>
<td>Ranging from 2, 5, 10 and 30 minutes of different techniques to overnight sleep studies</td>
</tr>
<tr>
<td>Technique studied</td>
<td>Āsana 1</td>
</tr>
<tr>
<td>Prāṇāyāma</td>
<td>Śīrṣāsana</td>
</tr>
<tr>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Kapālabhāṭī, Nāḍī Śuddhi, right and left uninostril and alternate nostril breathing techniques.</td>
<td></td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Relaxation</th>
<th>3</th>
<th>DRT, Āsavasana, others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Various types of meditation / chanting/ Nāda Yoga</td>
<td>13</td>
<td>Cyclic, Zen, Kuṇḍalini, Chi meditation, loving-kindness meditation, nondirective meditation and rosary/ Mantra chanting</td>
</tr>
<tr>
<td>Combination practices</td>
<td>7</td>
<td>Āsana, Prāṇāyāma, relaxation, meditation</td>
</tr>
<tr>
<td>Others techniques</td>
<td>1</td>
<td>Integrative body-mind training</td>
</tr>
<tr>
<td>Subject population</td>
<td>Normal/healthy volunteers</td>
<td>29</td>
</tr>
<tr>
<td>Special populations</td>
<td>4</td>
<td>One each in pregnancy, smokers on cessation programme, depression and post traumatic stress syndrome</td>
</tr>
<tr>
<td>Major conclusions Improvement of HRV/ SVB / increased parasympathetic/ decreased sympathetic</td>
<td>23</td>
<td>Eight studies of combination practices, 12 of meditation/chanting, 2 with relaxation techniques and 1 each of slow Prāṇāyāma and integrative body-mind training</td>
</tr>
<tr>
<td>Sympathetic enhancement</td>
<td>5</td>
<td>One of Śīrṣāsana and 3 of Kapālabhāti / high frequency yogic breathing. The other one was a comparison between subjects who had a year of Yoga and controls</td>
</tr>
<tr>
<td>Blunting of sympathetic response</td>
<td>1</td>
<td>Subjects trained in combination practices</td>
</tr>
<tr>
<td>No significant changes as compared to controls or between techniques</td>
<td>3</td>
<td>One in Āsavasana relaxation and 2 in comparative study of uninostril and alternate nostril prāṇāyāma techniques</td>
</tr>
<tr>
<td>Other reported findings</td>
<td>1</td>
<td>Increase in stochastic nature and decrease in nonlinear nature of signal during Chi meditation with decrease in degree of nonlinearity and stochastic nature during Kuṇḍalinī meditation.</td>
</tr>
</tbody>
</table>
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REFERENCES


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