Open Journal of Medical Psychology, 2022, 11, 158-169
https://www.scirp.org/journal/ojmp
ISSN Online: 2165-9389
ISSN Print: 2165-9370

Effects of Yoga Exercises on Heart Rate Variability Parameters and Perceived Stress in Adolescent Students with High Score in Perceived Stress

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How to cite this paper: Sancinelli, S. (2022) Effects of Yoga Exercises on Heart Rate Variability Parameters and Perceived Stress in Adolescent Students with High Score in Perceived Stress. *Open Journal of Medical Psychology*, **11**, 158-169.
https://doi.org/10.4236/ojmp.2022.113012

Received: May 3, 2022
Accepted: July 11, 2022
Published: July 14, 2022

Abstract

Introduction: Hatha Yoga is a widely used form of holistic mind-body therapy for promoting health, and disease prevention like cardiovascular risks and part of treatment for neurological disorders. **Objective:** The aim of this study was to evaluate the effect of Hatha yoga on the autonomic nervous system by tracking acute changes in the time-domain and frequency-domain metrics of heart rate variability (HRV) in healthy International Baccalaureate students arranged in 3 different groups. **Methods:** The prospective interventional study was conducted among adolescent students in China. Thirty-six adolescent students were divided in three groups: 12 Hatha yoga experimental group participants; a control group of 12 students without participation in any activity and a recreational sport group of 12 other students. Outcomes measured were HRV parameters such as SDNN, RMSSD LF, HF, and LF/HF. Also, a Competitive State Anxiety Inventory-2 was used to measure stress and anxiety score in terms of Cognitive stress, Somatic Stress and Self Confidence. **Results:** Compared to baseline values, the Hatha yoga experiment group demonstrated a significant increase in HRV indices: SDNN 87.62 ± 13.89 (>0.0001) and RMSDD 86.61 ± 7.78 (>0.0001) respectively. In contrast it was documented after the 3 weeks of exposure to yoga training a statistically significant decrease in the frequency domain of LF 1911.53 ± 882.15 (0.0464) compared to baseline values. After completion of intervention the yoga experiment group HF (ms^2) values were increased 3430.40 ± 858.38 (>0.0001). Decrease and increase in the HF (ms^2) in the control and Hatha yoga group were statistically significant after following Hatha yoga. Cognitive anxiety 18.08 ± 6.30 (>0.0001) and Somatic anxiety 17.50 ± 6.33 (>0.0001) decreased after intervention with yoga and self-confidence increased significantly 32.50

± 1.17 (>0.0001). **Conclusions:** The investigation showed a significant increase of HRV parameters and cardiac autonomic function as a result of exposure to Yoga practice. Also, there was significant evidence of decrease in cognitive stress and somatic stress; increased values of self-confidence at the end of three weeks yoga exposure in comparison to the baseline values.

Keywords

Autonomic Nervous System, Heart Rate Variability, Yoga

1. Introduction

Hatha Yoga consists of a sequence of specific postures. A set of physical postures arranged to flow together, sequentially through an active range of motion of an appreciable joint angle, requiring a certain degree of skeletal muscles activation. The combination of postures, performed at slow pace, requires a lengthy voluntary muscles contraction of all major muscle groups to maintain and held the posture. In addiction the focus is placed on postures proper alignment and pairs with controlled breathing from one pose to the other. Yoga obviously requires static and dynamic body balance, stimulating the function of the vestibular, visual, and somatosensory systems. A growing body of evidence supports the claims that yoga improves physiological and psychosocial functions. The benefits are physical and mental via the downregulation of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system (SNS). Yoga postures are beneficial for strengthening muscles, augmenting balance and mind-body coordination, improvement in the blood flow, oxygenation and tissue perfusion, and enhancement of activities at the cellular levels [1]. Pranayama and dhyana are beneficial in calming down the mind, enhancing concentration and promoting vibrant thinking, improved judgement and operative decision making. It also promotes autonomic balance to enhance healthy life [2].

Cardiovascular diseases are one of the most prominent reasons for morbidity and mortality in both developed and developing countries. Most of the cardiovascular diseases like hypertension, arrhythmias and metabolic dysfunction are caused due to autonomic imbalance. Cardiac autonomic status could be effectively assessed through heart rate variability (HRV) which is a non-invasive tool [3]. Cardiac autonomic control is the balance between the sympathetic and parasympathetic regulators of the heart, and it is assessed using normal-to-normal (NN) intervals. Decrease in the parasympathetic activity is responsible for the decline in the HRV. Reduced HRV is considered as important clinical interpreter for cardiac diseases such as hypertension and coronary artery diseases mediated through thermogenesis [4] [5]. HRV is an estimate of temporal variation in the consecutive heart beats recorded through standard electrocardiogram (ECG). In QRS complex, R wave designates as peak and the difference between the two consecutive R wave peaks which are labelled as relative risk interval. Relative risk interval is also termed as NN interval when the heart beats at sinus rhythm.

Variability of this interval is assessed in terms of time (SDNN and RMSSD) and frequency (LF and HF) domain [6] [7].

Evidence based studies showed that students enrolled in the International Baccalaureate (IB) program, perceive greater amount of stress compared to traditional coursework of education [8].

The primary source of stress experienced by IB students is related to academic requirements [9].

Students enrolled in college preparatory programs like IB are more likely to experience elevated stress in relation to academic demands as opposed to typical adolescent concerns, and manifest worse outcomes in the face of stress [10].

Stress represents a prominent aspect of modern life and is associated with numerous negative health consequences. According to the Job Demand-Control-Support (JDCS) model [11] [12], stress increases when the demand is high, self-control is low and social support is poor. A strong culture of academic achievement characterizes China and drives Chinese students' behavior to achieve high results and experience high levels of stress.

Stress during the academic carrier can lead to diminished psychological health which can trigger mental distress and adverse impact on the cognitive functioning and learning [13]. Variation in the sympathovagal balance is accountable for unwanted adverse effects of stress such as psychosomatic disorders [14]. Neurobiological evidence supports the role of stress in the alteration of HRV variables. Alteration in the sympathovagal balance gives rise to decreased parasympathetic alteration, shifting towards sympathetic predominance. Changes in the autonomic functions without treatment for the considerable time duration can trigger irreversible alterations in the cardiovascular functions [15] [16]. HRV can be used to assess the psychological health of an individual including assessment of the autonomic nervous system.

A growing body of evidence suggests that Hatha yoga as a mind-body activity might be an effective strategy for decreasing allostatic load in stress response systems, and for restoring optimal homeostasis. Therefore, yoga can be a practice to reduce anxiety.

Yoga practice promotes balance in the autonomic nervous system activity denoted as sympathovagal-balance which indicates improvement in the HRV [17]. Yoga facilitates relaxation response which is physiologically opposite to the stress or fight-or-flight response. This triggers a decrease in the sympathetic nervous activity and stimulates parasympathetic activity. In a study, Isha yoga practitioners demonstrated improved vagal activity balance in comparison to a control group of participants. Also, Yoga practitioners demonstrated improved parasympathetic modulation [18]. HRV increases through shifting autonomic activity towards parasympathetic [19].

Hence, this study was undertaken to evaluate the effect of Hatha Yoga on HRV and stress parameters.

2. Objectives

Assessing cognitive stress, somatic stress, and self-confidence through CSAI-2 questionnaire.

To study the effect of Hatha Yoga on cardiac autonomic activity, among adolescent students in China, using heart rate variability as an indicator of autonomic nervous system activity.

To study the effect of Hatha Yoga on levels of stress and anxiety, among adolescent students in China.

2.1. Materials and Methods

This prospective interventional study was conducted in the department of Sport Science. The Clinical protocol for the conduct of the study was approved by the Institutional Scientific and Ethics Committee. The author has not conflict of interest to declare.

2.2. Participants

Thirty-six adolescent students were enrolled in the IB program of a bilingual school in China mandarin-English language of instruction. These students were randomized upon the completion of baseline testing (normal BMI) to an experimental (Hatha Yoga) and control group (No activity and recreational sports). Sample size calculation was performed depending on the hypothesis testing in the interventional studies. Keeping drop-out in the mind, sample size was kept at 10 % extra as compared to the required. Participants were instructed not to be involved in any other physical exercises during the conduct of the study.

Participants were categorized in the following groups:

Experiment group (12 students exposed to yoga training) Control group 1 (12 students did not participate to yoga).

Control (recreational) group 2 (12 students exposed to recreational sport activities like table tennis and badminton).

3. Inclusion Criteria and Exclusion Criteria

Inclusion criteria:

- Age 15 - 18 years old adolescents who are willing to do Hatha yoga for the duration of three weeks.
- Participants giving consent to participate in the study.
- Participants with no previous experience of Yoga.

Exclusion criteria:

- Participants addicted to smoking or alcohol or stimulants.
- Participants with major surgery in the recent past and treatment with the medications with potential alteration of the autonomic functions.

3.1. Intervention

Participants were trained under the guidance of certified Hatha Yoga trainer.

Yoga sessions were comprised of asanas (postures) and vinyasa (exercises). The experimental group completed a 3week yoga program which prescribed three sessions per week after school as a co-curricular activity (50 min per session).

3.2. Outcome Measures

The primary outcome was the high frequency (HF) power and included most of HRV parameters (LF, SDNN, RMSDD), and psychological Competitive State Anxiety Inventory-2 (CSAI-2).

CSAI-2 is a sport-specific state anxiety scale developed by Martens, Vealey, and Burton (1990).

4. Data Collection

All participants prior to the experiment signed an informed consent form, and they were given precise instructions on the entire procedure. Data collection happened in the sport science lab where students were equipped with Photoplethysmography technology. HRV pulse wave sensor finger wearables (Elite-Core sense) connected to an app downloaded previously on their smartphone app (Elite HRV). Measurements were taken in the morning at 7 am before breakfast, empty stomach (3 times a week for a total 9 recording per subject). The questionnaire (Competitive State Anxiety Inventory-2) was taken by each student at the end of each week (total of 3 times).

Participants used Photoplethysmography technology-HRV pulse wave sensor finger wearables (Elite-Core sense) connected to consumer-available smartphone app (Elite HRV), assessment smartphone app to collect HRV time domain data (SDNN, RMSDD) and frequency domain data (LF and HF).

HRV measurement took place in the supine position trough eyes open during data collection to ensure participants did not sleep during data collection.

Same protocol was followed for the data collection for baseline data and on week 1, 2 and 3.

4.1. Statistical Analysis

Statistical analysis was performed using Graph pad prism 9.0.0.0. Vales were expressed as Mean ± SD. For control, Hatha Yoga and recreational group, HRV variable values after intervention at week 3 were compared with baseline values. Parameters of the CSAI-2 at the baseline were compared with the parameters at the week 3.

4.2. Results

Thirty-six participants satisfying inclusion and exclusion criteria were included in the study. All the participants successfully completed the Hatha Yoga protocol. The age of the participants was 16 ± 2 years. Baseline HR, SDNN, RMSSD, LF, and HF values among control and intervention group were not statistically significant. Baseline heart rate (HR) in control, experimental and recreational groups was 80.48 ± 5.30, 80.49 ± 5.31 and 80.25 ± 3.87 beats/min. respectively. HR at the end of three weeks in the control, experimental and recreational groups were 83.47 ± 5.57, 74.17 ± 4.20 (0.0002) and 78.65 ± 5.84 beats per min. respectively (Table 1). After completion of intervention, heart rate was increased in the control group; however, heart rate was decreased in the experimental Hatha Yoga group and recreational group. Nevertheless, this difference in the heart rate after practicing Hatha Yoga was statistically significant in the Hatha yoga group; however, it was not statistically significant in recreational sports group.

In the time domain SDNN and RMSSD values were expressed as milliseconds (ms). Baseline SDNN (ms) in control, experimental and recreational groups were 55.06 ± 9.93, 56.90 ± 10.00 and 57.52 ± 8.88 (ms) respectively. SDNN values at the end of study in the control, experimental and recreational groups were 50.48 ± 6.62, 87.62 ± 13.89 (<0.0001) and 67.05 ± 8.91 (ms) (0.0152) respectively. At the end of three weeks SDNN (ms) value was decreased in the control group; however, SDNN (ms) value was increased in the experimental Hatha Yoga group and recreational group. This difference in the SDNN (ms) after intervention was statistically significant in the Hatha Yoga group and recreational group as compared to the baseline data. Baseline RMSSD (ms) in control, experimental and recreational groups were 61.05 ± 17.04, 59.26 ± 16.03 and 72.07 ± 8.43 (ms) respectively and after following Hatha Yoga were 42.85 ± 5.91 (0.0042), 86.61 ± 7.78 (<0.0001) and 71.02 ± 10.06 (ms) (0.7848) respectively. At the end point RMSSD value was decreased in the control group and recreational group; A statistically significant increase in the experimental Hatha Yoga group was recorded.

In the frequency domain, LF and HF values were expressed in terms of ms^2. Baseline LF (ms^2) in control, experimental and recreational groups were 2654.56 ± 1170.48, 2559.90 ± 1244.25 and 2227.73 ± 1180.78 (ms^2) respectively which were not statistically significant, and the end of three weeks these values were 3666.02 ± 1571.14 (0.0028), 1911.53 ± 882.15 (0.0464) and 2819.85 ± 1118.90 (ms^2) respectively. After intervention, LF (ms^2) values were increased in the control group and recreational group; however, LF (ms^2) values were statistically significant decreased in the experimental Hatha Yoga group. Baseline HF (ms^2) in control, experimental and recreational groups were 1670.62 ± 689.96, 1830.13 ± 859.29 and 1350.62 ± 756.59 (ms^2) respectively which were not statistically significant and after completion of intervention, these values were 1098.73 ± 610.15 (0.0044), 3430.40 ± 858.38 (<0.0001) and 2813.31 ± 5132.19 (ms^2)

Table 1. Hear rate (beats/min.) for the participants.

Parameter	Control group		Experimental group		Recreational group	
	Baseline	Week 3	Baseline	Week 3	Baseline	Week 3
HR	80.48 ± 5.30	83.47 ± 5.57	80.49 ± 5.31	74.17 ± 4.20	80.25 ± 3.87	78.65 ± 5.84
P value	0.1522		0.0002		0.4583	

respectively. After completion of intervention HF (ms^2) values were decreased in the control group; however, HF (ms^2) value was increased in the experimental Hatha Yoga group and recreational group. Decrease and increase in the HF (ms^2) in the control and Hatha yoga group were statistically significant after following Hatha Yoga (**Tables 2-4**).

Competitive State Anxiety Inventory-2 (CSAI-2) was used to measure cognitive anxiety (Stress C), somatic anxiety (Stress S) and Self-confidence (S. Conf). Baseline Stress C, Stress S and S. Conf values among control and intervention group were not statistically significant. Cognitive anxiety score for control group, experimental group and recreational group at baseline were 33.00 ± 1.34, 34.50 ± 1.31 and 33.00 ± 1.34 respectively and these values at the end point were 33.00 ± 1.34, 18.08 ± 6.30 (<0.0001) and 32.5 ± 1.38 (0.0527) respectively. Somatic anxiety score for control group, experimental group and recreational group at baseline were 32.66 ± 1.87, 33.75 ± 1.36 and 32.5 ± 1.56 respectively and these values at the end of the study were 32.66 ± 1.87, 17.50 ± 6.33 (<0.0001) and 32.5 ± 1.73 (>0.9999) respectively. Baseline, Self-confidence score for control group, experimental group and recreational group at baseline were 19.83 ± 2.48, 19.75 ± 2.42 and 19.91 ± 2.19 respectively and at the end of the intervention these values were 19.75 ± 2.49 (0.5863), 32.50 ± 1.17 (<0.0001) and 19.75 ± 2.49 (0.5035) respectively (**Table 5**). Cognitive anxiety and Somatic anxiety were statistically decreased, and Self-confidence score was statistically increased in the Hatha yoga group at the end point of intervention in comparison to the baseline score.

Table 2. HRV indices for control group participants.

Parameter		Control group		
		Baseline	Week 3	*P* value
Time domain	SDNN (ms)	55.06 ± 9.93	50.48 ± 6.62	0.2065
	RMSSD (ms)	61.05 ± 17.04	42.85 ± 5.91	0.0042
Frequency domain	LF (ms^2)	2654.56 ± 1170.48	3666.02 ± 1571.14	0.0028
	HF (ms^2)	1670.62 ± 689.96	1098.73 ± 610.15	0.0044
	LF/HF	2.79 ± 1.91	2.95 ± 1.29	0.7710

Table 3. HRV indices for experimental group participants.

Parameter		Experimental group		
		Baseline	Week 3	*P* value
Time domain	SDNN (ms)	56.90 ± 10.00	87.62 ± 13.89	<0.0001
	RMSSD (ms)	59.26 ± 16.03	86.61 ± 7.78	<0.0001
Frequency domain	LF (ms^2)	2559.90 ± 1244.25	1911.53 ± 882.15	0.0464
	HF (ms^2)	1830.13 ± 859.29	3430.40 ± 858.38	<0.0001
	LF/HF	2.80 ± 1.91	2.96 ± 1.29	0.7710

Table 4. HRV indices for recreational group participants.

Parameter		Recreational group		
		Baseline	Week 3	*P* value
Time domain	SDNN (ms)	57.52 ± 8.88	67.05 ± 8.91	0.0152
	RMSSD (ms)	72.07 ± 8.43	71.02 ± 10.06	0.7848
Frequency domain	LF (ms^2)	2227.73 ± 1180.78	2819.85 ± 1118.90	0.0893
	HF (ms^2)	1350.62 ± 756.59	2813.31 ± 5132.19	0.3534
	LF/HF	3.04 ± 1.89	2.90 ± 1.26	0.8155

Table 5. Competitive state anxiety inventory-2 (CSAI-2) score.

Parameter	Control group		Experimental group		Recreational group	
	Baseline	Week 3	Baseline	Week 3	Baseline	Week 3
Cognitive anxiety (Stress C)	33.00 ± 1.34	33.00 ± 1.34	34.50 ± 1.31	18.08 ± 6.30	33.00 ± 1.34	32.5 ± 1.38
P value	NA		<0.0001		0.0527	
Somatic anxiety (Stress S)	32.66 ± 1.87	32.66 ± 1.87	33.75 ± 1.36	17.50 ± 6.33	32.5 ± 1.56	32.5 ± 1.73
P value	NA		<0.0001		>0.9999	
Self-confidence (S. Conf)	19.83 ± 2.48	19.75 ± 2.49	19.75 ± 2.42	32.50 ± 1.17	19.91 ± 2.19	19.75 ± 2.49
P value	0.5863		<0.0001		0.5035	

5. Discussion

The outcome of this study highlights that there is significant increase in cardiac oscillations after practicing Hatha Yoga. Time and frequency domain of HRV augmented significantly after practicing Hatha Yoga in comparison to the control group and the recreational exercise group.

Time domain parameters such as SDNN and RMSSD exhibited significant increase following Hatha Yoga which demonstrates augmented parasympathetic profile. SDNN is considered as the median value for HRV. It is defined as the inclusive variability or total power. Higher values of mean for RMSSD are regarded as the augmented parasympathetic activity [20]. Hence, increase in the RMSSD after Hatha Yoga can predict improvement in the parasympathetic activity [21].

Results demonstrated that HF component increased significantly; however, LF and LF/HF reduced significantly after practicing Hatha Yoga. Sympathetic and vagal outflows interplay demonstrate major role in the neural regulation of the circulatory function [22]. Sympathetic activation and efferent vagal activity are associated with the LF band and HF band of the HRV [23]. LF/HF is considered as the predictor of sympathovagal balance. LF and HF values demonstrate extent of control exerted by the sympathetic and parasympathetic system of autonomic nervous system (ANS) [24]. Also, it reflects control exerted by the sympathetic and parasympathetic nervous system. From the results, it can be inferred that there is decrease in the sympathetic activity, decrease in the parasympathetic activity and augmented sympathovagal balance following Hatha Yoga.

Competitive State Anxiety Inventory-2 (CSAI-2) which comprises of 27 items was developed to examine intensity of cognitive anxiety, somatic anxiety, and self-confidence in sports. Cognitive anxiety denotes athlete's negative expectations and concerns about their performance. Somatic anxiety reflects physiological alterations of anxiety. Self-confidence symbolizes athlete's confidence for successfully completing the task. CSAI-2 score delivers outcome in the range of 9 to 36 points. Results closer to number 9 indicate low anxiety and closer to 36 indicate high anxiety. Overall, findings from the current study support the supposition that Practicing Yoga including Hatha Yoga could be helpful in psycho-physiological relaxation. Results demonstrated that decreased HR rate and increased HRV following Hatha Yoga indicate physiologically relaxed state and improved mental alertness. Based on the dominance of left or right cerebral hemispherical, there could be augmentation in the spatial or verbal skills [25]. Increase in the parasympathetic activity and decrease in the sympathetic activity indicate psychological conditions such as distress, anxiety, and depression at the young age individuals [26].In this study, reduction in the stress could be due to increase in the HRV [27].

Hence, it can be interpreted that Yoga not only impact autonomic balance at the subconscious levels but also through regulation of emotional alterations.

In this study, there was noticeable augmentation in the cardiac autonomic function which reflects Yoga exhibit positive impact on the general health status of the individual. Noticeably, these effects were observed after short term of Yoga practice. It is realistic to accept that long term practice of Yoga could reduce risk of physiological and psychological diseases and improve quality of life. Hence, practicing Yoga could be believed as the non-pharmacological treatment strategy for the population under stress. To further validate effect of short-term Yoga on the autonomic balance, it is necessary to repeat the study on larger and more diverse population.

6. Conclusion

Outcome of this study demonstrated that Hatha yoga practice could improve parasympathetic activity as opposed to the control and recreational participants, as evident from the time and frequency domains of the HRV. Based on the results of this study Hatha yoga can be incorporated in the conventional cardiovascular prevention and stress management strategies. However, it can be argued that long term practice of Hatha yoga needs to be explored in a diverse population of healthy individuals and individuals under different stress conditions.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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