Research Article

Randomized controlled trial of 12-week yoga therapy as lifestyle intervention in patients of essential hypertension and cardiac autonomic function tests

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Abstract

Background: In the Indian subcontinent, 118 million people are with hypertension, and this figure is anticipated to double by 2025. Yoga has been widely claimed to play a role in the prevention and management of psychosomatic, stress-induced, and lifestyle disorders such as hypertension. **Aims and Objective:** To study the effect of 12 weeks of yoga therapy as a lifestyle intervention on cardiac autonomic functions in patients of essential hypertension. **Materials and Methods:** Subjects with hypertension from the Medicine Outpatient Department of the Jawaharlal Institute of Postgraduate Medical Education and Research were randomized into control and yoga groups. The control group was treated only with the allopathic medicines. The yoga group was given 12 weeks of yoga therapy module designed by JIPMER Institute Advanced Center for Yoga Therapy Education and Research along with the routine medical treatment. The participants' blood pressure and cardiac autonomic function were recorded before and after the 12 weeks of the study period. **Result:** No significant change was observed in the body weight (BW), body mass index (BMI), abdominal circumference, and waist–hip ratio (WHR) in both the control and yoga groups at the end of the 12 week-study period. There was a significant decrease in the resting systolic pressure (SP), diastolic pressure (DP), rate pressure product (RPP), and mean arterial pressure (MAP) in the yoga group. In contrast, there was no significant change in the SP, DP, RPP, and MAP of the control group. High frequency (HF) power, total spectral power, and HF normalized units (nu) showed a significant increase in the yoga group. Low frequency (LF) power, HF power, and LF (nu) showed a significant ($p < 0.05$) decrease in the yoga group at the end of the 12-week yoga therapy. **Conclusion:** Twelve weeks of yoga therapy reduced both the SP and DP in the yoga group. Furthermore, yoga therapy increased the heart rate variability and vagal tone and decreased the sympathetic tone in the subjects with hypertension. At the same time, it increased both the parasympathetic and sympathetic reactivity.

KEY WORDS: Autonomic Function Tests; Hypertension; Yoga; HRV

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Introduction

In the Indian subcontinent, hypertension (HT) has a prevalence of 20%–40% among the urban population and 12%–17% among the rural population. Studies have shown that about 118 million people in India are with HT, and this figure is anticipated to double by 2025.[1–3] In general, medical treatment of hypertension requires a long-term and, sometimes, lifelong use of drugs. It has been seen that HT being a disease involving both the genetic and environmental factors can be modifiable to some extent. It can also be prevented and can be treated effectively by appropriate lifestyle modifications.[4,5] Therefore, the magnitude of the burden of HT not only needs an increase in awareness and treatment but also efforts should be targeted on lifestyle modification in general population.[3]

In India, from ancient times, yoga has been widely claimed to possess a role in the prevention, management, and rehabilitation in psychosomatic and stress-induced and lifestyle disorders such as HT.[6–8] Now, in the modern era, different scientific communities are taking interests to evaluate its validity and role in all these modifiable diseases. Earlier studies have shown that autonomic imbalance occurs in patients with HT,[9] and yoga training helps in restoring the sympathovagal balance. Yoga training has been reported to result in a significant decrease in basal heart rate (HR) and blood pressure (BP) in patients with HT.[7,10]

Therefore, this study was planned to evaluate the role of yoga as a lifestyle modality and its effectiveness on cardiac autonomic functions in patients' of essential HT.

Materials and Methods

Before the commencement of the study, approval of the Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER) Scientific Advisory Committee and Ethics Committee was obtained.

Selection of Subjects

The subjects with HT in the age group of 35–55 years were recruited from the Medicine Outpatient Department (OPD) of JIPMER. Subjects with secondary HT, diabetes, ischemic heart disease, nephropathy, retinopathy, and any other chronic illness were also excluded by medical history. Subjects with any physical conditions hindering the performance of yoga practices were excluded. The sitting BP was recorded to see whether BP is under control with their current treatment regimen. Block randomization was used to generate allocation sequence, and serially numbered opaque sealed envelope technique (SNOSE) was applied to allot the subjects either to the control group or to the yoga group after obtaining their written informed consent.

Experimental Design

All the parameters were recorded in autonomic function testing lab, Department of Physiology, JIPMER between 9 a.m. and 11 a. m. The laboratory environment was quiet; the temperature was maintained between 25°C and 27°C and the lighting subdued. The subjects were advised to come at least 1 h after a light breakfast with an empty bowel and bladder. All the subjects were advised to refrain from smoking and alcohol on the day of test and during the entire study period. The subjects were asked to take the morning dosage of antihypertensive agent after the procedure, as it may interfere with the cardiac autonomic functions.

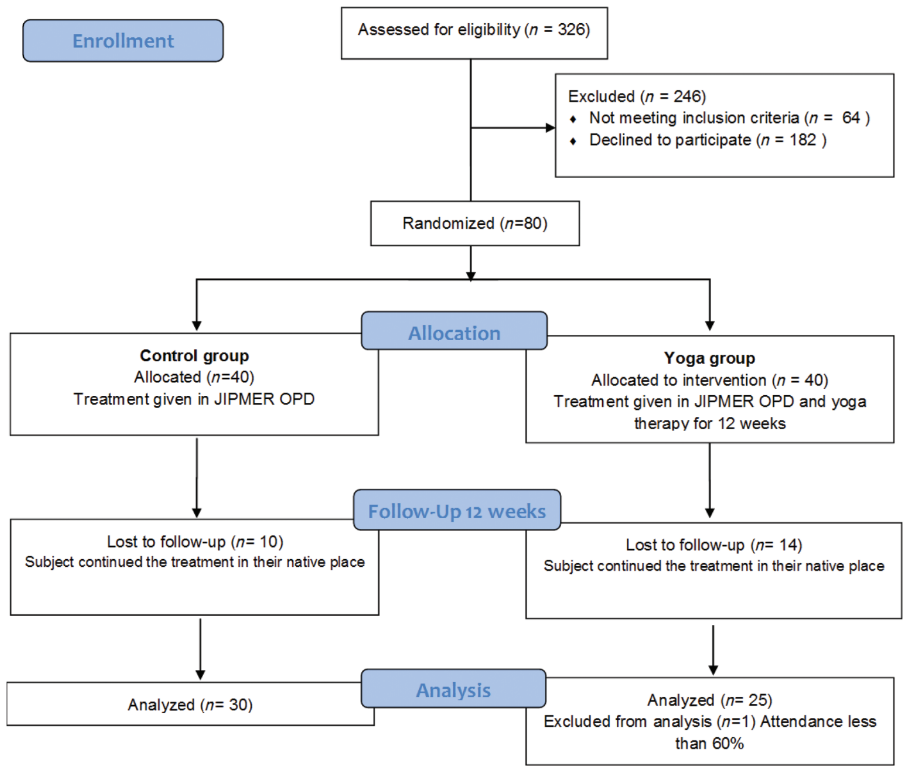

Figure 1: Project flow diagram.

Parameters Recorded

Anthropometric parameters. Height was measured by a wall-mounted stadiometer and weight with a spring balance. Waist circumference was measured at the narrowest point seen anteriorly between the subcostal margin and iliac crest. The hip circumference was measured at the level of gluteal region with maximum girth, and the waist–hip ratio (WHR) was calculated.

Short-term heart rate variability. The subjects were asked to lie comfortably in the couch and relax. After 5 min of supine rest, lead II ECG and respirations were recorded at 500 samples per s using BIOPAC MP100 data acquisition system with AcqKnowledge 3.8.2. software for the next 300 s in resting condition. The RR interval variation trend was analyzed using HRV software (version 1.1.; Biomedical Signal Analysis Group, University of Kuopio, Kuopio, Northern Savonia, Finland) for frequency and time domain parameters. Frequency domain parameters include: very low frequency [(VLF); 0.003 Hz–0.04 Hz], low frequency [(LF); 0.04 Hz to 0.15 Hz], high frequency [(HF); 0.15 Hz–0.4 Hz], total spectral power [(TP) = VLF + LF + HF), and LF/HF ratio; the ratio of LF power to HF power, low frequency power in normalized units (LF nu) = LF/(TP–VLF) × 100, and similarly HF nu was calculated. The time domain components include: mean and standard deviation of RR intervals (SDNN), square root of the mean of the sum of the squares of differences between adjacent RR intervals (RMSSD), adjacent RR interval differing more than 50 ms (NN50), and NN50 counts divided by all the RR intervals (pNN50). HF, HF nu, SDNN, RMSSD, NN50, and pNN50 reflect cardiovagal tone; LF reflects both the sympathetic and parasympathetic tones; VLF component's interpretation is not clear, and it cannot be interpreted using short-term HRV recordings; LF nu and HF nu represent a relative tone of sympathetic and parasympathetic nervous system (PSNS), and LF/HF ratio indicates sympathovagal balance. The BPs (SP, DP) and HR were measured at the end of ECG recording (OMRON MX3, USA).

Orthostatic stress test. After recording ECG in supine position for 15 s, the subject was asked to stand as quickly as possible, preferably within 3 s with minimal effort so that artefacts can be minimized. HR response to standing was calculated as the ratio between the longest RR interval around the 30th beat and the shortest around the 15th beat. The 30/15 ratio indicates both the sympathetic and parasympathetic functions.

Heart rate response to deep breathing. The subjects were trained to breath at the rate of six cycles per minute guided with a metronome. Deep breathing was done for a complete1 min and during this period (the period of deep breathing), ECG was recorded. The ratio between the maximum RR interval during expiration and the minimum RR interval during inspiration were calculated for each breath cycle. The average of six such measurements was taken as the expiratory to inspiratory (EI) ratio of the subject. This quantitates respiratory sinus arrhythmia, which is predominantly a manifestation of vagal tone.

Isometric handgrip test. After familiarizing the subjects with the procedure, they were asked to perform a maximum voluntary contraction (MVC) in the handgrip dynamometer (Inco, Ambala). Following it, they were instructed to maintain 30% of MVC for up to 3 min, while BP and HR were monitored in the nonexercising arm every minute for the next 3 min after starting a sustained handgrip. Increase in DP above the resting stage with 30% MVC at the end of 3 min of contraction was taken as a measure of sympathetic reactivity (ΔDP).

Intervention (12 weeks)

The subjects of both the groups received antihypertensive drugs provided in JIPMER OPD. The yoga group received a validated yoga therapy in addition to the drug therapy. The yoga therapy delivered to the subjects was validated by the Advanced Center for Yoga Therapy Education and Research (ACYTER) and JIPMER in accordance with Morarji Desai National Institute of Yoga (MDNIY) Guidelines and given by a trained ACYTER yoga teacher. Each session of yoga therapy was for about 45 min. Yoga therapy was given 3 days a week under our direct supervision for 12 weeks. Patients were motivated to practice the same daily at home. Only highly motivated patients were included in the study. Attendance register was maintained for yoga therapy sessions, and the data were obtained only from those patients whose attendance was at least 70%.

Components of Therapy

Yoga classes started with a brief prayer. Preparatory practices such as breath–body coordination and joint loosening exercises were undertaken for 10 min. This was followed by 10 min asan, 10 min pranayam, and 15 min Shavasan practice [Table 1]. At the end of the class, attendance was taken, and the subjects were motivated to practice at home on other days. Some of the classes were preceded by talk on diet and lifestyle modification in controlling chronic lifestyle disorders.

Data Analysis

The pre- to postintervention change of all the parameters and their percentage change were calculated. SPSS software (version 19.0) was used for data analysis. Pre-post intervention comparisons were made using Student's paired *t*-test within the group. In between the

Table 1: Yoga therapy module

1. Yogic counseling	
2. Preparatory practices:	Breath–body coordination practices and joint loosening practices
3. Asans or static postures:	Talasan
	Ardhakati chakrasan
	Ardha chakrasan
	Uttanpadasan
	Ardha halasan
	Pavanmuktasan
	Makarasan
	Bhujangasan
	Vajrasan
4. Pranayam or breathing techniques:	Chandra nadi
	Pranav
	Nadi shuddhi
5. Relaxation techniques:	Kayakriya in shavasan
	Shavasan with savitri pranayam

study and control groups, comparison was made using Student's unpaired *t*-test for continuous data and χ^2-test for categorical data.

RESULT

There was no significant difference in age, gender, smoking history, alcohol intake, diet pattern, drug intake, and anthropometric parameters between the control and the study groups before the start of the study; hence, the groups were comparable [Table 2].

Anthropometric Parameters

We observed no significant change in BW, BMI, abdominal circumference, and WHR in both the control and yoga groups at the end of 12 week-study period [Table 3].

Resting Cardiovascular Parameters

In our control group, there was no change in the resting HR. In the yoga group, there was an insignificant decrease in HR. Moreover, there was a significant decrease in the resting SP, DP, rate pressure product (RPP), and mean arterial pressure (MAP) in the yoga group. In contrast, there was no significant change in the SP, DP, RPP, and MAP of the control group [Table 4].

Table 2: Baseline characteristics in the control and yoga groups

Parameters, *n* (%)	Control group (*n* = 30)	Yoga group (*n* = 25)
Age (years; mean ± SD)	43.63 ± 6.79	43.08 ± 8.53
Male	25 (83)	19 (76)
Female	5 (17)	6 (24)
Smoker	3 (10)	2 (8)
Alcoholic	10 (33)	7 (28)
Nonvegetarian	23 (77)	19 (76)
CCB	12 (40)	13 (52)
ACEI	16 (53)	11 (40)
CCB + ACEI	2 (7)	1 (4)

CCB, subjects on calcium channel blockers; ACEI, subjects on angiotensin-converting enzyme inhibitors.
Analysis done with Student's unpaired *t*-test for continuous data and χ^2-test for categorical data.
$p > 0.05$ for all the above-mentioned parameters.

Short-term HRV

Frequency domain measures. The short-term spectral components namely VLF power, LF power, HF power, total power (TP), LF: HF, LF (nu), and HF (nu) showed no significant change in the control group. In the yoga group, there was no significant change in VLF power and LF power. But, HF power, TP, and HF (nu) showed a significant increase in the yoga group. LF: HF and LF (nu) showed a significant ($p < 0.05$) decrease in the yoga group at the end of the 12 week-yoga therapy [Table 5].

Time domain statistical measures. In the control group, no significant change was observed in the mean RR interval, SD of RR (SDNN), mean HR, RMSSD, NN50, and pNN50 at the end of the 12 week-period. In the yoga group, the mean RR interval, mean HR, RMSSD, NN50, and pNN50 showed no significant difference at the end of the study period. SDNN showed a significant ($p < 0.01$) increase in the yoga group after 12 weeks of yoga therapy [Table 6].

Reactivity tests. In our study, the HR response to standing did not show a significant change in both the control and yoga groups. EI ratio did not show a significant change in the control group at the end of the study period. In the yoga group, the EI ratio showed an insignificant increase at the end of the 12-week study period. In isometric handgrip test, the yoga group showed a significant increase in ΔDP. The control group did not show a significant difference in ΔDP [Table 7].

DISCUSSION

Anthropometric Parameters

We observed no significant change in BW, BMI, abdominal circumference, and WHR in both the control and yoga groups at the end of the 12 week-study period. Our finding is supported by Cohen et al.,[11] who reported no change in BW and BMI after 12 weeks of Iyengar yoga therapy in pre-HT and stage 1-HT patients. In contrast, Bera and Rajapurkar[12] have reported a significant decrease in the abdominal circumference of young practitioners of yoga after a period of 1 year in their study. Studies by Murugesan et al.[5] and Yogendra et al.[13] showed a significant decrease in BW in patients with hypertension and ischemic heart disease, respectively. The findings of these studies can be attributed to the duration of yoga therapy, as it was for a longer period and to other measures followed by them, which include strict low fat, high fiber diet, and aerobic exercise. Our

Table 3: Anthropometric parameters in control and yoga groups before and after the 12 week-study period

Parameters	Control group (*n* = 30)		Yoga group (*n* = 25)	
	Before	After	Before	After
Height (m)	1.64 ± 0.08	1.65 ± 0.09		
Body weight (kg)	73.53 ± 12.2	74.28 ± 13	73.4 ± 13.37	73.1 ± 13.23
BMI (kg/m^2)	27.32 ± 4.17	27.59 ± 4.47	26.79 ± 4.07	26.68 ± 4
WHR	0.88 ± 0.05	0.879 ± 0.048	0.851 ± 0.051	0.85 ± 0.052

BMI, body mass index; WHR, waist–hip ratio.
Values are expressed as mean ± SD.

Table 4: Resting cardiovascular parameters in control and yoga groups before (B) and after (A) the 12 week-study period

Parameters	Control group (n = 30)				Yoga group (n = 25)			
	B	A	Change	% change	B	A	Change	% change
HR (bpm)	72.37 ± 11.88	71.83 ± 10.15	-0.53 ± 9.18	0.18 ± 11.59	72.88 ± 9.8	69.72 ± 8.73	-3.16 ± 9.3	-3.47 ± 12.9
SP (mm Hg)	126.47 ± 11.21	125.97 ± 10.95	-0.5 ± 11.64	0.02 ± 8.96	124.8 ± 8.1	118.56 ± 11.06***†	-6.24 ± 8.2	-4.98 ± 6.43
DP (mm Hg)	83.2 ± 7.11	81.87 ± 7.28	-1.33 ± 6.98	-1.27 ± 8.12	80.44 ± 7.02	76.84 ± 8.78**†	-3.6 ± 5.8	-4.47 ± 7.3
PP (mm Hg)	43.27 ± 7.8	44.1 ± 7.2	0.83 ± 7.86	3.5 ± 17.62	44.36 ± 5.9	41.72 ± 10.25	-2.64 ± 7.5	-6.39 ± 17.4
MAP (mm Hg)	97.62 ± 7.87	96.57 ± 7.99	-1.06 ± 7.99	-0.76 ± 7.94	95.23 ± 6.83	90.75 ± 8.29***†	-4.48 ± 5.7	-4.68 ± 5.9
RPP	91.83 ± 19.04	90.38 ± 15.15	-1.45 ± 16.2	0.4 ± 16.36	91.04 ± 13.97	82.71 ± 13.1**†	-8.3 ± 13.7	-8.16 ± 14.7

HR, heart rate; SP, systolic pressure; DP, diastolic pressure; PP, pulse pressure; RPP, rate pressure product; MAP, mean arterial pressure.
Values are expressed as mean ± SD.
*$p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$ comparison within group; $^{†}p < 0.05$ comparison between the yoga and control groups.

Table 5: Frequency domain (nonparametric) measures in control and yoga groups before (B) and after (A) the 12 week-study period

Parameters	Control group (n = 30)				Yoga group (n = 25)			
	B	A	Change	% change	B	A	Change	% change
VLF power (ms^{2})	81.77 ± 75.03	77.7 ± 70.59	-4.07 ± 66.75	19.12 ± 79.38	69.32 ± 61.73	96.16 ± 81.73	26.84 ± 80.19	137.05 ± 260.3
LF power (ms^2)	99.67 ± 71.72	95.43 ± 74.64	-4.23 ± 71.82	29.33 ± 96.69	121.48 ± 90.26	139.24 ± 81.7†	17.76 ± 65.92	69.57 ± 141.05
HF power (ms^2)	76.73 ± 58.9	78.3 ± 56.71	1.57 ± 51.04	101.58 ± 340.87	111.96 ± 100.41	175.48 ± 142.8****†††	63.52 ± 88.4	220.42 ± 378.3
Total power (ms^2)	258.17 ± 156.24	251.43 ± 167.29	-6.73 ± 138.92	24.06 ± 91.27	302.76 ± 204.54	410.88 ± 241.7**††	108.12 ± 177.8	110.51 ± 214.1
LF:HF	1.95 ± 1.64	1.56 ± 1.18	-0.39 ± 1.72	3.64 ± 67.68	2.18 ± 2.8	1.12 ± 0.7*	-1.06 ± 2.3	-15.65 ± 74.37
LF (nu)	58.51 ± 15.8	54.36 ± 16.5	-4.15 ± 16.24	-4.11 ± 28.78	56.41 ± 19.28	47.78 ± 15.83*	-8.63 ± 15.34	-10.24 ± 34.4
HF (nu)	41.49 ± 15.8	45.64 ± 16.5	4.15 ± 16.24	26.44 ± 77.71	43.59 ± 19.28	52.22 ± 15.83*	8.63 ± 15.34	42.74 ± 71.78

VLF, very low frequency; LF, low frequency; HF, high frequency; nu, normalized units.
Values are expressed as mean ± SD.
*$p < 0.05$, $^{**}p < 0.01$ comparison within group; $^{†}p < 0.05$, $^{††}p < 0.01$, $^{†††}p < 0.001$ comparison between the yoga and control groups.

Table 6: Time domain statistical measures of HRV in control and yoga groups before (B) and after (A) the 12 week-study period

Parameters	Control group (n = 30)				Yoga group (n = 25)			
	B	A	Change	% change	B	A	Change	% change
SD of RR (ms)	26.87 ± 10.21	25.37 ± 9.55	-1.5 ± 9.19	4.37 ± 44.06	28.64 ± 11.14	33.88 ± 13.35**††	5.24 ± 9.7	31.07 ± 60.14
RMSSD (ms)	22.58 ± 9.77	22.31 ± 8.58	-0.27 ± 9.06	17.82 ± 83.03	25.07 ± 11.87	28.39 ± 14†	3.32 ± 12.25	35.62 ± 82.72
NN50 (count)	17.1 ± 19.47	15.9 ± 17.31	-1.2 ± 20.4	-	27.68 ± 29.56	34.36 ± 41.89†	6.68 ± 36.25	-
pNN50 (%)	4.99 ± 5.66	4.66 ± 5.01	-0.33 ± 5.9	-	8.26 ± 9.46	10.58 ± 13.27†	2.32 ± 11.59	-

HR, heart rate; SD of RR, Standard deviation of all NN intervals; RMSSD, Root mean of the sum of the squares of differences between adjacent NN intervals; NN50, number of NN intervals differing by more than 50 ms to their adjacent NN intervals; pNN50, NN50 count divided by the total number of NN intervals.
Values are expressed as mean ± SD. *p < 0.05, **p < 0.01 comparison within group; †p < 0.05, ††p < 0.01 comparison between the yoga and control groups.

study constituted breathing and relaxation techniques and only a few asans. Moreover, the duration of each asan was less, and the yoga sessions were conducted only thrice a week.

Resting Cardiovascular Parameters

Many workers have reported a decrease in HR after the yoga therapy.[5,7,14–16] In contrast, other studies have reported that yoga training increases HR.[17] This can be explained on the type of yoga training practiced by the subjects. We conclude that the intensity and duration of yoga training in our subjects was not sufficient to produce a decrease in the resting HR.

Yoga training produced a significant decrease in the resting SP, DP, and MAP. In contrast, there was no change in the SP, DP, and MAP of the control group. DP is mainly owing to the peripheral vascular resistance, which in turn is maintained by sympathetic tone. The significant decrease in DP can be explained on the basis of a decrease in sympathetic tone. Although Udupa et al.[18] and Khanam et al.[15] have concluded that yoga training does not result in a decrease in resting BP, many studies have reported a decrease in BP with yoga training.[5,14,19,20] This difference can be explained on the basis of the type of yoga training and duration. Furthermore, we observed no change in pulse pressure in the yoga group after intervention. Pulse pressure says about the tissue perfusion. So, even though the BP is reduced in the yoga group, maintenance of pulse pressure denotes that the tissue perfusion is maintained.

RPP is an index of myocardial oxygen consumption and load on the heart.[21] Decrease in RPP in the yoga group suggests that yoga training is instrumental in reducing the resting myocardial oxygen consumption and load on the heart. Our result is consistent with those of Madanmohan et al.[7] and Vijayalakshmi et al.[16] With the results of our resting cardiovascular parameters, it is concluded that 12 weeks of yoga therapy reduces BP in people with hypertension, while reducing the workload on the heart and retaining the tissue perfusion.

Short-term HRV

Frequency domain measures. Total power is the variance of NN intervals over the temporal segment. Increase in total power is an indicator of improved heart rate variability. Total power increased in the yoga group after the 12 weeks of intervention leaving us to hypothesize reduced cardiovascular complication in future.

High frequency (HF) power in the control group showed no significant change, while in the yoga group, there was a significant increase at the end of 12 weeks. In addition, a significant difference in HF power was noticed between the groups at the end of the study period. It is well documented in literature that HF component is predominantly modulated by parasympathetic system.[22] So, an increase in HF power shows parasympathetic predominance with yoga therapy. Telles et al.[23] showed a decrease in HF power with high frequency breathing and Raghuraj et al.[24] showed a decrease or no change in HF power.

At the end of the study period, there was a significant difference in LF power in the yoga group on comparison with the

Table 7: Reactivity test in control and yoga groups before and after the 12 week-study period

Parameters	Control group (n = 30)		Yoga group (n = 25)	
	Before	After	Before	After
HR_{max}/HR_{min} ratio	1.39 ± 0.17	1.44 ± 0.19	1.37 ± 0.18	1.36 ± 0.16
I–E	18.57 ± 5.97	18.65 ± 7.71	18.27 ± 8.36	21.23 ± 9.86*
EI ratio	1.29 ± 0.11	1.3 ± 0.15	1.33 ± 0.18	1.37 ± 0.17
ΔDP (mmHg)	26.37 ± 8.42	27.83 ± 9	22.60 ± 7.99	27.36 ± 12.36*

HR_{max}, immediate maximum rise in heart rate after standing; HR_{min}; minimum heart rate observed after standing; I–E, inspiration to expiration difference. ?DP, rise in diastolic pressure from supine rest.
Values are expressed as mean ± SD.
*$p < 0.05$ comparison within group.

control group. Even though both the sympathetic and parasympathetic limbs of autonomic nervous system govern LF power, it is predominantly by the sympathetic system. Hence, increase in LF power can lead to a false conclusion that resting sympathetic tone is increased. The result has to be interpreted along with the normalized values of LF and HF, which clearly gives the relative power each system. There is a decrease in LF nu and an increase in HF nu after the yoga intervention. With this result, we can safely conclude that relative sympathetic tone is reduced after yoga intervention even though LF power is increased. In addition, study by Rahman et al.[25] suggests that LF power is an indicator of baroreflex function independent of cardiac sympathetic innervations. Therefore, increase in LF power is an indicator of increase in BRS for which further studies are needed.

Our study suggests an increase in parasympathetic tone, which is evident from a significant decrease in LF:HF and LF nu and an increase in HF nu. Therefore, the yoga practices followed in our study is suitable for the patients to restore the sympathovagal balance in whom sympathetic drive is increased.[26,27] In contrast, studies by Raghuraj et al.[24] and Telles et al.[23] showed a significant increase in LF:HF immediately after pranayam practice (high frequency breathing), suggesting an increase in sympathetic tone.

Time domain statistical measures. There is evidence from literature that SDNN (the estimate of overall HRV) is significantly decreased in HT[9,28] and is an indicator of cardiovascular morbidity and mortality. So, increase in SDNN with 12 weeks of yoga therapy suggests that practice of yoga regularly can decrease cardiovascular risk factors owing to HT. Our results are consistent with the studies by Khattab et al.[28] and Pinheiro et al.[20] who showed a significant increase. RMSSD, NN50, and pNN50 measurements of short-term variation that estimates HF variations in HR, showed a significant increase in the yoga group when compared with control group at the end of the study period. This indicates that in yoga group, there is an increased parasympathetic tone after yoga therapy. Study by Khattab et al.[29] showed a significant increase in RMSSD and NN50, which is consistent with our study. Telles et al.,[23] in their study, showed a significant decrease in NN50 and pNN50 with high frequency breathing, which is associated with increased sympathetic tone. On analyzing time domain and frequency domain measures, it is clear that yoga decreases sympathetic tone and increases parasympathetic tone.

Reactivity tests. The results of reactivity tests indicate an increase in vagal activity, as the change in HR during breathing is mainly owing to the change in vagal activity. In the yoga group, there was a significant increase in ?DP as far as isometric handgrip test is concerned. Increase in ?DP in our study shows that with yoga therapy, there is an improvement in sympathetic response during pressor stimuli in subjects with hypertension. Grassi et al.[30] have reported that, although baseline muscle sympathetic nerve activity is higher in hypertensives, changes in sympathetic nerve activity during pressor stimuli are attenuated in people with hypertension. The significant increase in ?DP shows that there is improvement in reactivity to pressor stimuli. This is consistent with the findings of Mourya et al.[19] Our finding is consistent with the study done by Vijayalakshmi et al.,[16] who have concluded that yoga optimizes sympathetic response to isometric hand grip and restores autonomic regulatory reflex mechanism. In contrast, Khanam et al.,[15] in their study, have shown a decrease in DP with isometric hand grip at the end of 1-week yoga therapy and concluded that yoga training reduces sympathetic reactivity in asthmatic subjects.

CONCLUSION

Twelve weeks of yoga therapy reduced both SP and DP in subjects with hypertension. Furthermore, yoga therapy increases parasympathetic tone and decreases sympathetic tone in subjects with hypertension. At the same time, it increased both the parasympathetic and sympathetic reactivity.

Limitations

In this study, yoga therapy was given to the subjects only three times a week. In the rest of the days, the subjects' were asked to practice at home. This may have resulted to noncompliance by the subjects. Supervised yoga therapy for all the days of the week would be ideal. Beat-to-beat noninvasive BP recording was not done. Hence, BP variability and baroreflex sensitivity could not be determined in our subjects.

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References

1. Goyal A, Yusuf S. The burden of cardiovascular disease in the Indian subcontinent. Indian J Med Res. 2006;124(3):235–44.
2. Gupta R. Trends in hypertension epidemiology in India. J Hum Hypertens. 2004;18(2):73–8.
3. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: analysis of worldwide data. Lancet. 2005;365(9455):217–23.
4. Andrews G, MacMahon SW, Austin A, Byrne DG. Hypertension: comparison of drug and non-drug treatments. Br Med J (Clin Res Ed). 1982;284(6328):1523–6.
5. Murugesan R, Govindarajulu N, Bera TK. Effect of selected yogic practices on the management of hypertension. Indian J Physiol Pharmacol. 2000;44(2):207–10.
6. Innes KE, Bourguignon C, Taylor AG. Risk indices associated with the insulin resistance syndrome, cardiovascular disease, and possible protection with yoga: a systematic review. J Am Board Fam Pract. 2005;18(6):491–519.
7. Madanmohan Udupa K, Bhavanani AB, Shatapathy CC, Sahai A. Modulation of cardiovascular response to exercise by yoga training. Indian J Physiol Pharmacol. 2004;48(4):461–5.
8. Manchanda SC, Narang R, Reddy KS, Sachdeva U, Prabhakaran D, Dharmanand S, et al. Retardation of coronary atherosclerosis with yoga lifestyle intervention. J Assoc Physicians India. 2000;48(7):687–94.
9. Sevre K, Lefrandt JD, Nordby G, Os I, Mulder M, Gans RO, et al. Autonomic function in hypertensive and normotensive subjects: the importance of gender. Hypertension. 2001;37(6):1351–6.
10. Bernardi L, Sleight P, Bandinelli G, Cencetti S, Fattorini L, Wdowczyc-Szulc J, et al. Effect of rosary prayer and yoga mantras on autonomic cardiovascular rhythms: comparative study. BMJ. 2001;323(7327):1446–9.
11. Cohen DL, Bloedon LT, Rothman RL, Farrar JT, Galantino ML, Volger S, et al. Iyengar yoga versus enhanced usual care on blood pressure in patients with prehypertension to stage I hypertension: a randomized controlled trial. Evid Based Complement Alternat Med. 2011;2011:546428.
12. Bera TK, Rajapurkar MV. Body composition, cardiovascular endurance and anaerobic power of yogic practitioner. Indian J Physiol Pharmacol. 1993;37(3):225–8.
13. Yogendra J, Yogendra HJ, Ambardekar S, Lele RD, Shetty S, Dave M, et al. Beneficial effects of yoga lifestyle on reversibility of ischaemic heart disease: caring heart project of International Board of Yoga. J Assoc Physicians India. 2004;52:283–9.
14. Damodaran A, Malathi A, Patil N, Shah N, Suryavansihi, Marathe S. Therapeutic potential of yoga practices in modifying cardiovascular risk profile in middle aged men and women. J Assoc Physicians India. 2002;50(5):633–40.
15. Khanam AA, Sachdeva U, Guleria R, Deepak KK. Study of pulmonary and autonomic functions of asthma patients after yoga training. Indian J Physiol Pharmacol. 1996;40(4):318–24.
16. Vijayalakshmi P, Madanmohan, Bhavanani AB, Patil A, Babu K. Modulation of stress induced by isometric handgrip test in hypertensive patients following yogic relaxation training. Indian J Physiol Pharmacol. 2004;48(1):59–64.
17. Raghuraj P, Telles S. Immediate effect of specific nostril manipulating yoga breathing practices on autonomic and respiratory variables. Appl Psychophysiol Biofeedback. 2008;33(2):65–75.
18. Udupa K, Madanmohan, Bhavanani AB, Vijayalakshmi P, Krishnamurthy N. Effect of pranayam training on cardiac function in normal young volunteers. Indian J Physiol Pharmacol. 2003;47(1):27–33.
19. Mourya M, Mahajan AS, Singh NP, Jain AK. Effect of slow- and fast-breathing exercises on autonomic functions in patients with essential hypertension. J Altern Complement Med. 2009;15(7):711–7.
20. Pinheiro CH, Medeiros RA, Pinheiro DG, Marinho MJ. Spontaneous respiratory modulation improves cardiovascular control in essential hypertension. Arq Bras Cardiol. 2007;88(6):651–9.
21. Gobel FL, Norstrom LA, Nelson RR, Jorgensen CR, Wang Y. The rate-pressure product as an index of myocardial oxygen consumption during exercise in patients with angina pectoris. Circulation. 1978;57(3):549–56.
22. Mathias CJ, Bannister SR. Investigations of autonomic disorders In: Mathias CJ, Bannister SR (Eds.). *Autonomic Failure: A Textbook of Clinical Disorders of Autonomic Nervous System.* 4th edn. United States: Oxford university press, 1999. pp. 169–95.
23. Telles S, Singh N, Balkrishna A. Heart rate variability changes during high frequency yoga breathing and breath awareness. BiopsychosocMed. 2011;5:4.
24. Raghuraj P, Ramakrishnan AG, Nagendra HR, Telles S. Effect of two selected yogic breathing techniques of heart rate variability. Indian J Physiol Pharmacol. 1998;42(4):467–72.
25. Rahman F, Pechnik S, Gross D, Sewell L, Goldstein DS. Low frequency power of heart rate variability reflects baroreflex function, not cardiac sympathetic innervation. Clin Auton Res. 2011;21(3):133–41.
26. Ganong WF. The autonomic nervous system. *Review of Medical Physiology*, 22nd edn. New York: McGraw-Hill, 2005. pp. 223–31.
27. Julius S. Autonomic nervous system dysregulation in human hypertension. Am J Cardiol. 1991;67(10):3B–7B.
28. Radaelli A, Bernardi L, Valle F, Leuzzi S, Salvucci F, Pedrotti L, et al. Cardiovascular autonomic modulation in essential hypertension. Effect of tilting. Hypertension. 1994;24(5):556–63.
29. Khattab K, Khattab AA, Ortak J, Richardt G, Bonnemeier H. Iyengar yoga increases cardiac parasympathetic nervous modulation among healthy yoga practitioners. Evid Based Complement Alternat Med. 2007;4(4):511–7.
30. Grassi G, Cattaneo BM, Seravalle G, Lanfranchi A, Mancia G. Baroreflex control of sympathetic nerve activity in essential and secondary hypertension. Hypertension. 1998;31(1):68–72.

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