Original Article

Comparative Analysis of Heart Rate Variability Parameters between Surya Namaskar and Stationary Bike Exercise Groups

Abstract

Background: Yoga practice has multiple health benefits. Surya Namaskar (SN) also known as sun salutation presents mental and physical health benefits equivalent to physical exercise. It consists of a sequence of 12 Hatha yoga postures with coordinated breathing. **Aims:** This study evaluated the effect of SN against mild intensity stationary cycling exercise (SCE) on parameters of heart rate variability (HRV). Methodology: This study was conducted in the department of physiology of a nationally important institute after obtaining ethics approval. A total of 40 healthy participants (males aged 46 ± 2.3 years) were enrolled in the study and divided into two groups, namely SN group and exercise group (SG and EG). The allocation on the group was based on subjects' choice and interest in performing SN or SCE. Baseline HRV, anthropometric measurement, and blood pressure were assessed. SG was subjected to 14 rounds of SN in about 20 min and EG to a 20-min mild-intensity stationary cycling session (30%–50% maximal heart rate). Assessments were conducted preexercise and postexercise recovery. HRV was assessed with the NeuralChek device. **Results:** SN led to increased SDNN, pNN50, RMSSD, and total power, indicating improved autonomic balance, cardiovascular health, and parasympathetic dominance. Conversely, SCE decreased SDNN, pNN50, and RMSSD, suggesting immediate postexercise sympathetic dominance. Spectral analysis of HRV highlighted autonomic balance differences, with SN increasing low frequency (LF%) reflecting both sympathetic and parasympathetic dominance, whereas exercise reduced LF% due to sympathetic activation. Minimal changes were observed in high-frequency percentage. SN combines flexibility, strength, and balance, providing a balanced physical activity. This balance results in a mixed autonomic response, with sympathetic activity for the physical effort and parasympathetic activity for the relaxation components. **Conclusions:** SN positively impacted HRV, promoting parasympathetic dominance and cardiovascular health, whereas exercise induced sympathetic activation with potential recovery benefits. Monitoring HRV offers insights into cardiovascular fitness and well-being. The study underscores the merits of incorporating yoga such as SN into daily activity routines.

Keywords: *Hatha yoga's sun salutations, heart rate variability, stationary cycling exercise, Surya Namaskar*

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Introduction

Physical activity has multiple health benefits, such as decreased rates of coronary artery disease, hypertension, diabetes, and obesity, among other conditions, thereby decreasing overall mortality.[1] However, the lack of physical inactivity is a major concern in the current world scenario and has led to a significant increase in lifestyle and metabolic disorders.[2] The American College of Sports Medicine (ACSM) and the American Heart Association recommended that all healthy adults aged 18–65 years engage in moderate-intensity aerobic (endurance) activity for at least 30 min 5 days a week or vigorous-intensity activity for at least 20 min 3 days a week to maintain good health.[3]

The ACSM also suggests that exercise leads to improvements in cardiorespiratory health, which then enhances the maximal oxygen consumption, decreases heart rate and blood pressure at a given workload, makes capillaries dense, also increases the threshold for lactate accumulation, and decreases the overall workload on the heart muscles, which in turn delays the onset of cardiovascular diseases.[4]

Exercise intensity and duration are inversely related. For instance, improvements in health-related fitness can be achieved with

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high-duration, low-intensity exercise, or with low-duration, high-intensity exercise. Conventionally, activities such as walking, jogging, biking, or swimming are done to elevate physical fitness; however, these activities may not be feasible for every individual.[5]

With increasing scientific evidence of its beneficiary effects, yoga can serve as an attractive alternative to traditional aerobic and strength training. It requires little space and no equipment. It focuses on relaxation, body awareness, and meditation, providing a qualitatively different exercise experience which may be perceived as less strenuous and more pleasurable.[6,7] Surya Namaskar (SN) or sun salutation is a common yogic practice with proven mental and physical health benefits equivalent to physical exercises. It consists of 12 postures with coordinated rhythmic breathing. During SN, muscles of the entire body experience stretch and pressure alternately, and therefore, it is said to give more benefits with less expenditure of time.[2]

Heart rate variability (HRV) is a key indicator of cardiovascular and overall health. Studies have suggested the beneficiary effects of SN on various HRV parameters.[5] The respiratory alterations that occur during SN may have an impact on brain function as well. The variations in respiratory parameters may cause variations in oxygen and carbon dioxide levels, which may be directly accountable for electroencephalogram changes.[8]

The novelty of the study is that it offers a unique perspective on how traditional and modern exercise methods affect HRV which has not been extensively explored in existing literature. This can be of great interest to individuals seeking exercise routines tailored to heart health. The findings of this study could contribute to tailoring exercise recommendations for individuals based on their specific health goals and preferences, potentially paving the way for personalized exercise prescriptions. Exercise choice is largely dependent on the subject's motivation and physical abilities. A flexible individual may choose an athletic type of exercise while a less flexible one may choose a simpler one. The novelty of this study is a comparison of both dynamic isometric and static isotonic exercise components in yoga SN with that of bicycle ergometer which isotonic type of exercise and their respective HRV changes that can be elaborately highlighted. The comparative study could help us understand the right choice of exercises.

Methodology

Study design

This study was an observational study with crossover design [Figure 1a] conducted in the Department of Physiology and AYUSH, All India Institute of Medical Sciences (AIIMS), Bhopal, India. Approval was granted by the Institute Ethics Committee for Student Research at AIIMS, Bhopal, under the registration numbers (IEC nos. IM079 and IM0427). The data were pooled from two different studies. Both intervention groups had similar participant characteristics to ensure comparability, and they were selected from the yoga unit of AIIMS, Bhopal, Department of AYUSH. There was a gap of 3 months between the two interventions. The 20 subjects of Surya Namaskar were same as that of stationary bike exercise.

Sample size

A purposive sample of 20 healthy male subjects were included in the study. They choose to do SN. They were recruited from AYUSH Department, AIIMS, Bhopal, from September 2021 to December 2021.

The subjects for exercise group (EG) were healthy volunteers from the AYUSH Department. The purpose and the objective of the study were explained to the participants. Informed and written consent was obtained before the initiation of the study. The preexercise resting and postexercise recovery HRV was assessed in the autonomic function test laboratory in the physiology department.

The G*Power software (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) was used to estimate the sample size for this study. Our goal was to examine variations in the HRV parameters before activity, during mild-intensity cycle exercise and SN, and during the recovery phase following exercise and SN. We projected a medium effect size of 0.252 for sample variance based on prior literature. To compute the sample size, a type 1 error of 5%, a power of 80%, and a medium effect size of 0.252 were used. The initially calculated sample size was 18. After accounting for non-responses and factoring in a 10% attrition rate, the final sample size was adjusted to 20. Consequently, 20 healthy volunteers within the 20–50-year age range were enrolled for the study.

Inclusion criteria

Participants included were the male volunteers in the age range of 20–50 years, with no history of medical illness, such as chronic obstructive pulmonary disease, asthma, or heart disease that limits exercise performance and willing to give consent for the study participation.

Exclusion criteria

Patients with backache, sciatic nerve entrapments, lumbar spondylosis, spine malformations, and lower leg pain were excluded from SN group (SG). High-performance athletes, individuals with diabetes, hypertension, any physical condition, major chronic diseases, or other health issues that could prohibit the participants in the workout challenge, taking prescription drugs that might have an impact on how well they would exercise, alcoholics and smokers, as well as those who chew tobacco, were excluded from the study of EG.

Procedure

There were 20 participants in each group – SG and EG. Depending on subjects' choice and interest, they were divided into two groups.

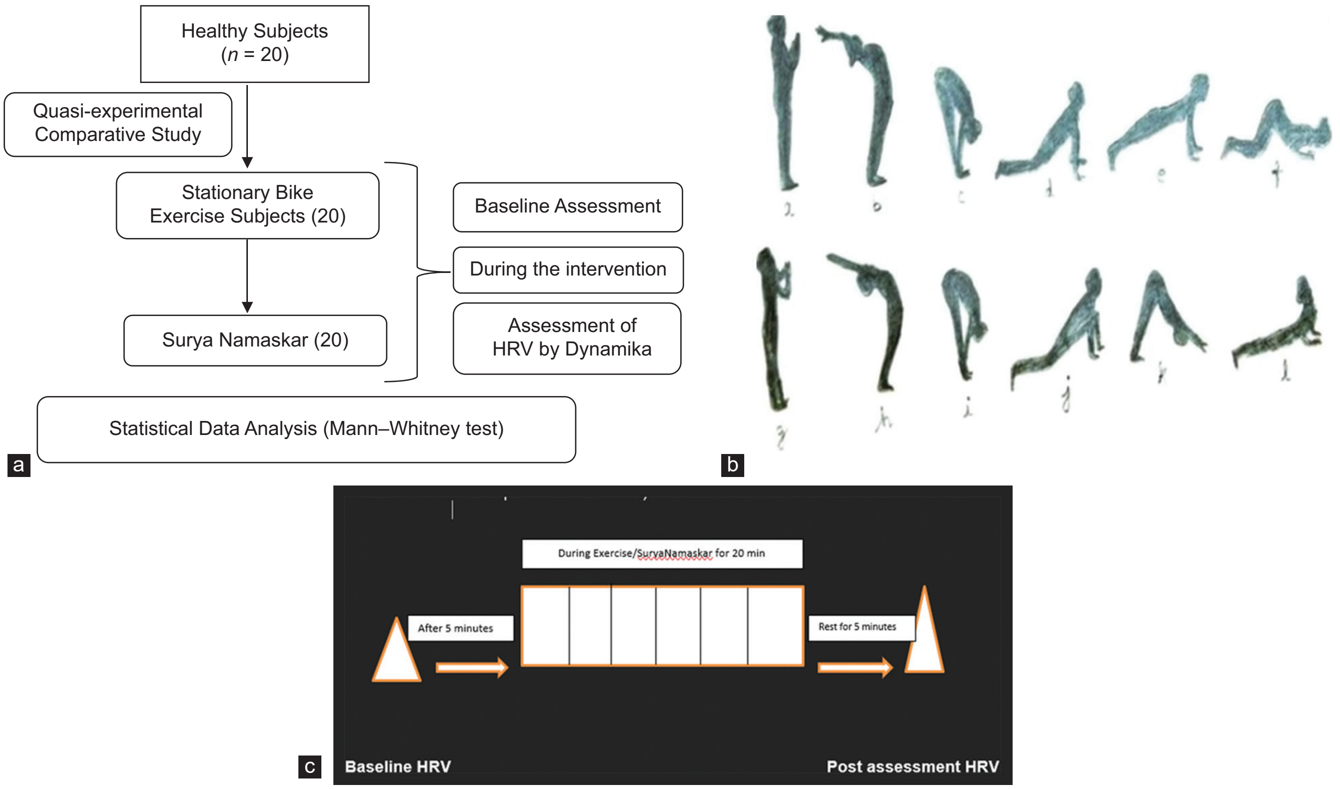

Figure 1: (a) Participant flowchart. Both intervention groups had similar participant characteristics to ensure comparability, and they were selected from the yoga unit of AIIMS Bhopal, Department of AYUSH. There was a gap of 3 months between the two interventions. The 20 subjects of Suryanamaskar were same as that of stationary bike exercise. HRV: Heart rate variability, (b)The sun salutation or Surya Namaskar poses (c) Schematic Diagram showing HRV Assessment with NeuralChek, Methodology, and Standards Compliance

Table 1: The Sun Salutation or *Surya Namaskar poses*

Sanskrit names	English names
Namaskarasana	Salutation position/Prayer pose
Hastauttanasana	Raised arm position
Padahastasana	Hand to foot position/standing forward bend pose
Ekapadaprasaritasana/ Ashwasanchalanasana	Equestrian position
Dwipadapeasaritasana/ Dandasana	Plank pose/Stick pose
Ashtanganamaskarasana	Salutations using eight parts
Urdhwamukhaswanasana	Upward facing dog position
Adhomukhaswanasana	Downward facing dog position
Ekapadaprasaritasana/ Ashwasanchalanasana	Equestrian pose
Padahastasana	Hand to food position
Hastauttanasana	Raised arm position
Namaskarasana	Prayer pose

Surya Namaskar protocol

Twenty fit volunteers who regularly practiced Hatha yoga performed 14 rounds of SN. Each round started with a sun salutation, went through trunk flexion, and finished with another sun salutation. This finished off one round. The sun salutation or SN positions [Figure 1b and Table 1] required roughly 20 min to complete all 14 cycles. The participants were told to breathe naturally. Under the guidance of a certified yoga instructor, the full rounds of SN were completed. The individuals underwent a 20-min intervention, followed by a 5-min Shavasana (laying on the back) relaxation session.

Exercise protocol

Following a 5-min period of rest, study participants' HRV was measured for 5 min, whereas they were at rest. For 20 min, they engaged in light stationary cycling activity at 30%-50% of their maximum heart rate. To calculate the maximum age-related heart rate, the formula subtracts the age in years from 220 (220 - age). The range of 30%-50% of the maximal age-related heart rate is employed to denote light-to-moderate exercise intensity levels. Beginners are advised to aim for 30%, while those seeking to improve fitness can target 50%.[9,10] The exercise was haled, if any discomfort or unexpected increase in HR was reported by the participants. HRV was recorded in the postexercise recovery phase after the 20-min workout for 5 min. The 1982 12-min bicycle test protocol was described in earlier work by Cooper.[11] The HRV values obtained before and after SN and exercise were compared. To accurately assess the effectiveness of the program, it is necessary to use a fitness test that simulates the duration and intensity of the workouts. By extending the Cooper's

12-min test to 20 min, we can obtain more relevant data on the participants' aerobic capacity and endurance.[12,13] Further, the pilot testing of 20-min bicycle exercise was well tolerated, safe, and convenient for the subjects.

The 20-min exercise challenge was performed on a Powermax Fitness stationary cycle.

Measurements

Using the NeuralChek device (BrainTap® INC, New Bern, NC, USA), HRV data were recorded, whereas the patient was relaxing for 5 min [Figure 1c]. A cutting-edge digital analyzer called the Dinamika HRV is used to evaluate HRV through neurodynamic analysis. It evaluates an ECG recording while simultaneously tracking functional state indices in real time. It examines the ECG signal in the wide frequency spectrum that contains the human heart rate. The North American Association of Electrophysiology and the European Society of Cardiology have set standards for the measurement, physiological interpretation, and clinical use of cardiac intervalometry indices, and Dinamika software and hardware comply with these standards.[14,15] Within 5 min, the HRV was evaluated. With jelly, the electrodes were applied to the wrist. Five minutes were spent collecting the subject's baseline data. The HRV was recorded in both the groups after SN and after stationary cycling exercise (SCE) [Figure 2].

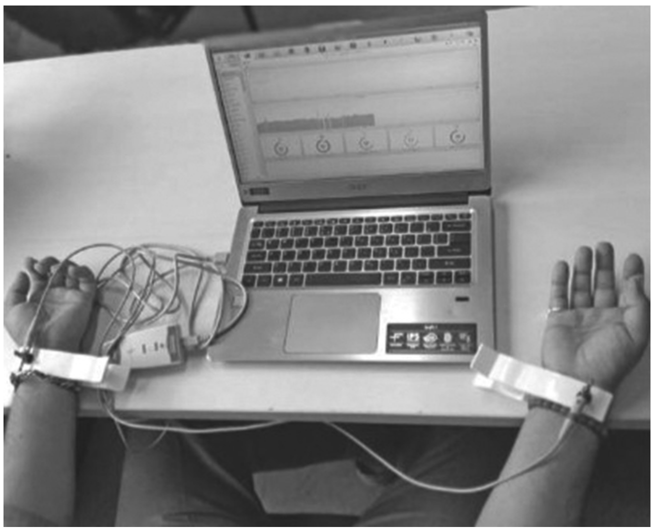

Figure 2: Dinamika mobile unit measuring heart rate variability

Statistical analysis

The analysis of the data for normality revealed that it was nonparametric. These are shown as mean ± standard deviation (SD). The GraphPad online software (GraphPad Software, 2023 Boston, MA , USA) was employed to compare and analyze Heart Rate Variability (HRV) measurements both at rest and post-intervention (exercise/SN). A significance level of $P < 0.05$ was utilized, indicating statistical significance. The between-group P value was determined using independent sample *t*-test/Mann–Whitney test. The within-group P value was assessed using Wilcoxon signed-rank test [Table 2].

Results

Table 3 illustrates the baseline characteristics of the participants in both the groups (SG and SCE group).

There were 40 participants, 20 in each group. Based on the above P values provided, all the variables do not show

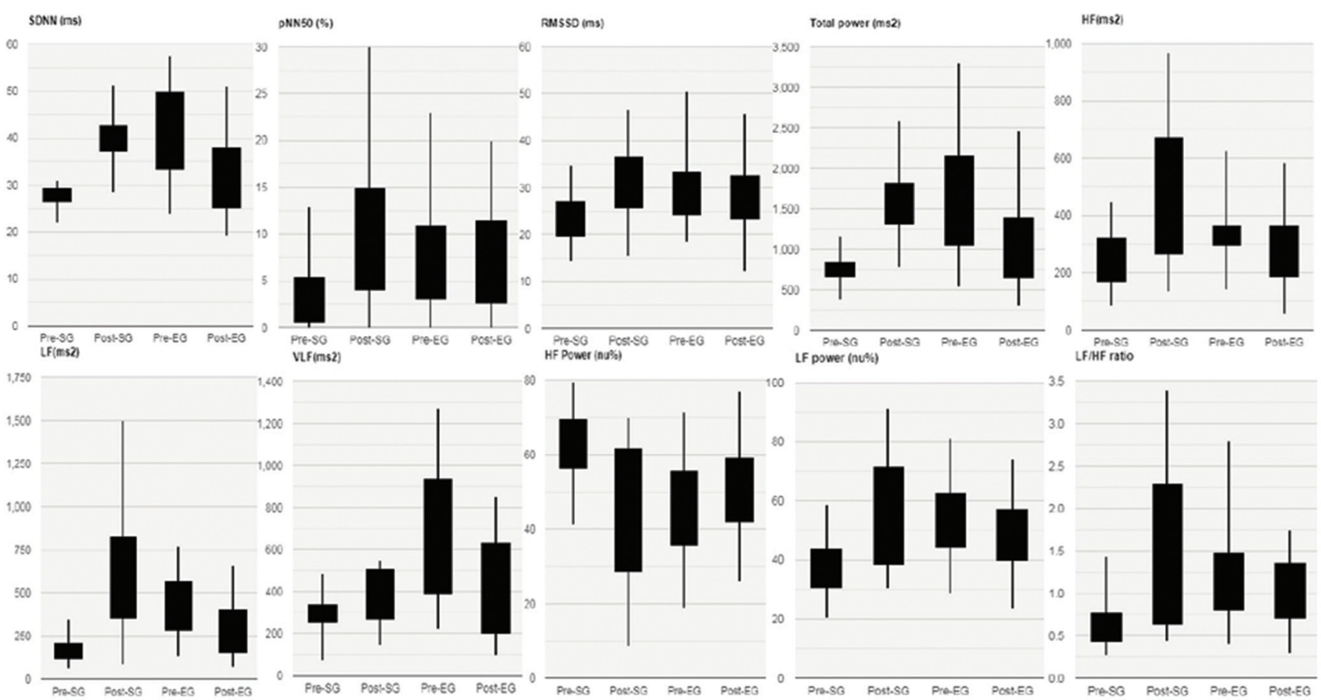

Figure 3: Box plots showing changes in heart rate variability in both the groups

Table 2: Comparison between heart rate variability parameters of both groups

Parameters	SG (*n*=20)	EG (*n*=20)	$P^{\#}$
Mean heart rate (bpm)			
Baseline	78.4 (5.9)	76.3 (4.9)	0.228
After intervention	79 (6.2)	78.5 (7.3)	0.816
$P^{\$}$	0.599	0.126	
SDNN (ms)			
Baseline	29 (8.3)	41.4 (10.4)	<0.001
After intervention	39.4 (8.7)	32.8 (9.4)	0.026
$P^{\$}$	<0.001	0.003	
pNN50 (%)			
Baseline	6.3 (13.1)	10.1 (9.5)	0.30
After intervention	10.3 (8.1)	7.6 (6.4)	0.484
$P^{\$}$	0.068	0.234	
RMSSD (ms)			
Baseline	25.6 (11.6)	31.2 (10.1)	0.206
After intervention	31 (7.8)	27.6 (8.6)	0.380
$P^{\$}$	0.010	0.132	
Total power (ms^2)			
Baseline	852.7 (634.9)	1641.4 (766.7)	<0.001
After intervention	1561.8 (658.9)	1088.2 (568)	0.019
$P^{\$}$	<0.001	0.008	
HF (ms^2)			
Baseline	352.6 (452.5)	410.4 (233)	0.614
After intervention	474.1 (250.4)	312.1 (191)	0.027
$P^{\$}$	0.150	0.098	
LF (ms^2)			
Baseline	186.6 (112.3)	453.6 (255.5)	<0.001
After intervention	646.8 (400.1)	294.2 (161.8)	<0.001
$P^{\$}$	<0.001	0.025	
VLF (ms^2)			
Baseline	313.4 (126.8)	753.5 (467.6)	<0.001
After intervention	441.1 (303.4)	468.5 (352.6)	0.793
$P^{\$}$	0.032	0.027	
LF/HF ratio			
Baseline	0.7 (0.5)	1.3 (1)	0.021
After intervention	1.9 (2.2)	1.1 (0.6)	0.124
$P^{\$}$	0.030	0.470	

$^{\#}$Between-group *P* value compared using independent sample *t*-test/Mann–Whitney test, $^{\$}$Within-group *P* value, compared using paired sample *t*-test/Wilcoxon signed-rank test. $P<0.05$ has been considered significant. Values have been represented as mean±SD. SG: Surya Namaskar group, SCE: Stationary cycling exercise, SD: Standard deviation, LF: Low frequency, VLF: Very LF, HF: High frequency, SDNN: The Standard deviation of NN intervals, RMSSD:The root mean square of successive differences between normal heartbeats

significant differences between the two groups, indicating similar baseline characteristics of height (cm), body mass index (kg/m^2), systolic blood pressure (mmHg), diastolic blood pressure (mmHg), and pulse pressure (mmHg).

After the intervention, both groups exhibited varied patterns in HRV parameters [Figure 3], with an overall increase observed in all parameters for the SG and a reduction for the SB group. Statistically significant differences were noted between the groups in SDNN (ms) (p = 0.026), total power (ms2) (p = 0.019), HF (ms2) (p = 0.027), and LF (ms2) (p < 0.001) parameters.

The differences between HRV parameters of both the groups are illustrated in Table 2.

In relation to HRV baseline parameters detailed in Table 2, it is possible to observe that except for the mean heart rate, both the groups presented different results in all parameters; however, they were statistically significant for the SDNN (ms) (<0.001), total power (ms^2) (<0.001), low frequency (LF) (ms^2) (<0.001), very LF (VLF) (ms^2) (<0.001), and LF/high-frequency (HF) ratio (0.021).

Postintervention, we identified that there were no relevant changes on the mean Heart Rate (HR) for both the groups. Twenty minutes of mild-intensity exercise did not change the heart rate because the HR was recorded during recovery phase, and the exercise performed was only in mild intensity. However, there was an overall increase in all the other parameters for the SG, whereas there was a reduction for the SB group. Between the groups, there was a statistically significant difference in the SDNN (ms) (0.026), total power (ms^2) (0.019), HF (ms^2) (0.027), and LF (ms^2) (<0.001) parameters.

Both the groups noticed varied patterns in HRV parameters, as listed in Table 4.

Discussion

We report significant changes in Standard Deviation of NN intervals (SDNN), The root mean square of successive differences between normal heartbeats (RMSSD), total power, LF, VLF, and LF/HF ratio after SN, whereas in the SCE group, significant changes were observed in SDNN, total power, HF, and VLF. On comparing the two groups, we report significant changes in SDNN, total power, HF, and LF.

After performing SN [Tables 2 and 4], there was a marginal increase in heart rate. SDNN, which represents overall HRV, increased, indicating a positive health outcome. A higher pNN50 was observed after SN, which is associated with a more flexible autonomic nervous system (ANS), better cardiovascular fitness, lower stress levels, and overall improved health. RMSSD, representing parasympathetic influence and relaxation, also increased, suggesting that the subject had good autonomic balance and better cardiovascular health. The increase in HF power indicated an enhancement in parasympathetic nervous system (PNS) activity, promoting relaxation and recovery. The increase in LF power suggested a combined influence of both sympathetic and parasympathetic activity, possibly indicating an adaptive response to the physical and mental demands of SN. An increase in VLF power, while less common and influenced by various physiological processes, would require longer recordings for a more reliable

Table 3: Baseline characteristics of participants from the two different groups (Surya Namaskar and stationary cycling exercise) of the study

Variables	Mean±SD		$P^{\$}$
	SG (*n*=20)	SCE (*n*=20)	
Age (years)	39.6±3.61	39.95±3.76	0.765
Gender (male)	20	20	0.102
Body weight (kg)	72.31±10.55	69.57±10.35	0.343
Height (cm)	166±5.21	163.36±5.38	0.126
BMI (kg/m^2)	26.36±4.54	25.34±4.24	0.398
Systolic blood pressure (mmHg)	128.36±5.60	127.26±8.02	0.366
Diastolic blood pressure (mmHg)	81.10±9.36	81.84±7.86	0.765
Pulse pressure (mmHg)	47.26±9.90	45.42±5.82	0.285

SCE: Stationary cycling exercise, SG: Surya Namaskar group, BMI: Body mass index, SD: Standard deviation

Table 4: Trends in heart rate variability parameters in both groups

Parameters	After SN	After stationary bike EG
Heart rate	Increased marginally	Increased marginally
Time domain		
SDNN	Increased	Decreased
pNN50	Increased	Decreased
RMSSD	Increased	Decreased
Frequency domain		
HF	Increased	Decreased
LF	Increased	Decreased
VLF	Increased	Decreased
LF/HF	Increased	Decreased

SN: Surya Namaskar, EG: Exercise group, LF: Low frequency, VLF: Very LF, HF: High frequency, SDNN: Standard deviation of NN intervals, RMSSD: Root mean square of successive differences between normal heartbeats

interpretation. The LF/HF ratio increased, potentially indicating a relative dominance of sympathetic activity, but its exact meaning can vary due to various factors.

After stationary exercise bikes [Tables 2 and 4], the heart rate marginally increased, and SDNN decreased, showing a shift toward sympathetic dominance during exercise to meet increased oxygen and nutrient demands. This decrease in number of times an hour in which the change in successive normal sinus (NN) intervals exceeds 50 ms (pNN50) reflected the temporary autonomic balance shift. Postexercise recovery led to increased parasympathetic activity. The decrease in HF power indicated a reduction in parasympathetic activity, reflecting the increased demand for energy and oxygen during exercise. A decrease in LF power suggested a reduction in overall autonomic modulation during the recovery phase after exercise. The decrease in VLF power indicated a temporary shift in autonomic balance as the body returned to baseline after exercise. The decrease in LF/HF ratio suggested a relative increase in parasympathetic activity, promoting relaxation and recovery. In summary, the changes in HRV parameters after stationary bike exercise demonstrated a transition from active exercise to recovery and relaxation, with a shift toward a more balanced autonomic state dominated by the PNS. This is a common response as the body works to restore homeostasis and support recovery.

An increase in heart rate was observed in both the SN and SCE groups indicating sympathetic stimulation as well as muscular exertion in both the groups. These findings are similar to the findings of Bhavanani *et al*., who also reported increased HR, before and after repetitive practices of SN.[16] SDNN, which is an indicator of overall heart rate, was significantly higher in the SG, similar to the findings of Malhotra *et al*., who observed an increase in SDNN after practicing SN. This suggests that the ANS is effectively regulating its functions and coping with stress after repeated SNs.[17] The significantly reduced values of SDNN in the EG are consistent with the findings of Farinatti *et al*., who also reported decreased SDNN at the end of the postexercise period owing to both combined parasympathetic and sympathetic modulations.[18] The type of physical activity performed significantly influences its cardiovascular effects. Research has demonstrated that the isometric contraction of muscle-induced increase in heart rate is proportional to the muscle force generated during the isometric contraction.[19,20] Yoga is characterized by slow, static isometric components. The practice of SN involves both the static and dynamic components of physical activity.[21]

In a study by Singh *et al*., in the SG, they reported a statistically significant rise in the HF component which is following our results as well. However, in contrast to our results, they observed a noteworthy decrease in the LF/HF and a nonsignificant decrease in LF values.[2] The LF component (0.04–0.15 Hz) indicates baroreceptor activity and sympathetic activity during rest and exercise, while the HF band is an indicator of vagal activity (parasympathetic). An increase in the LF and HF bands indicates dominant sympathetic and parasympathetic activity, respectively.[22]

In tasks requiring vigilance and attention, sympathetic activation is necessary, whereas efferent vagal (parasympathetic) activity is observed in autonomic maneuvers.[23-25] Some studies indicate that yoga practice enhances parasympathetic activity, influencing sensory input control to the brain and improving mood. Long-term yoga practitioners have been reported to exhibit a well-balanced vagal activity.[23-25] However, the overall impact of yoga on the ANS and its exact mechanisms remains not fully understood, leading to inconsistent findings in various research studies.[24,26]

In the EG, we found a significant decrease in SDNN, total power, HF, and VLF. Tulppo *et al*. found that in both moderately and highly aerobically trained groups, there was a statistically significant increase in the normalized high-frequency (HF) spectral component. Simultaneously, there was a decrease in the normalized low-frequency (LF) component, accompanied by a marked decline in the LF/HF ratio.[27] Sandercock *et al*. in a meta-analysis reported an increase in HF power after exercise training.[28] In a study by Singh *et al.*(2017),[2] the spot jogging group showed a statistically significant decrease in mean values of LF and LF/HF components, whereas a statistically insignificant decrease was observed in HF values.

The variations in HRV measures identified between the groups engaged in SN and SCE indicate that these two exercise modalities generate distinct physiological reactions. The elevated SDNN values observed in the SG suggest an augmentation in the total HRV, potentially indicating a favorable state of autonomic equilibrium and cardiovascular well-being. The observed higher values of total power, HF, and LF in the SG indicate an augmentation of parasympathetic and sympathetic regulation, which in turn enhances cardiovascular adaptability and reactivity. The distinctive amalgamation of active postures, regulated respiration, and rhythmic movements in SN may potentially contribute to its advantageous impact on HRV. These factors have the potential to enhance the coordination between the sympathetic and parasympathetic divisions of the ANS, resulting in enhanced cardiovascular performance. The activity known as the stationary bike, although proven to be useful in improving cardiovascular fitness, may not stimulate the autonomic system to the same degree, leading to comparatively lower values in HRV parameters. The results of this study underscore the potential benefits of integrating social networking into exercise regimens for persons aiming to improve their cardiovascular well-being. Examples of social networking in exercise for cardiovascular well-being include running clubs, online fitness communities, fitness tracking apps, virtual fitness classes, and walking groups. These help individuals connect, share progress, and stay motivated. Nevertheless, additional investigation is required to clarify the fundamental mechanisms that contribute to the observed variations in HRV values among the two groups engaged in different exercise regimens. In addition, future research should consider factors such as participants' age, their physical fitness levels, and the duration of their exercise sessions. This approach will broaden our understanding of how the type of exercise relates to HRV. In essence, the suggestion is to study a more diverse range of individuals with varying exercise habits to gain a more comprehensive perspective on this relationship.

Sinha *et al*. published two studies in the *Indian Journal of Physiology and Pharmacology* in 2004 and 2012 comparing the cardiorespiratory parameters of SN and SCE.[29,30] In the 2004 study, the researchers compared the cardiorespiratory responses of 20 healthy young men to SN and SCE at similar energy expenditure levels. The results showed that SN elicited higher heart rate, respiratory rate, and oxygen consumption than bicycle ergometer exercise. The researchers concluded that SN is a more effective form of exercise for improving cardiovascular fitness than bicycle ergometer exercise.[29] In the 2012 study, the researchers compared the cardiorespiratory responses of 20 healthy young women to SN and SCE at different exercise intensities. The results showed that Su elicited higher heart rate and respiratory rate than SCE at all exercise intensities. However, oxygen consumption was similar between the two exercises at all exercise intensities except for the highest intensity. The researchers concluded that SN is a more effective form of exercise for improving cardiovascular fitness than SCE, especially at higher exercise intensities.[30] Overall, the two studies by Sinha *et al*. suggest that SN is a more effective form of exercise for improving cardiovascular fitness than SCE. This is likely because SN is a more dynamic and holistic form of exercise that involves multiple muscle groups. Unlike this study., whose primary focus was on cardio-respiratory parameters such as VO2 max, our research is centered on HRV and its implications for autonomic balance.

Conclusions

This study demonstrates that SN leads to statistically significant differences in HRV parameters compared to SCE. The higher values of SDNN, total power, HF, and LF in the SG indicate a potentially greater impact on ANS modulation and cardiovascular health. Incorporating SN into exercise routines may offer unique benefits for individuals aiming to improve their overall cardiovascular function. Further research is warranted to fully comprehend the physiological mechanisms responsible for these differences and to establish personalized exercise recommendations based on HRV analysis.

Limitations and future research

Overall, the increased HF, LF, VLF, and LF/HF ratio after SN might suggest a modulation in ANS activity. These changes could potentially reflect a transient adaptation to the physical exertion and mental engagement of the yoga practice. It is worth noting that the interpretation of HRV changes is complex and can be influenced by multiple factors, including individual characteristics, practice consistency, and overall health. Therefore, for a comprehensive assessment, it is recommended to monitor HRV over an extended period and consider other physiological and subjective markers of well-being.

Females should have been included, there should be more sample size, and the subjects should have been randomly distributed.

Ethical clearance

Approval was granted by the Institute Ethics Committee for Student Research at AIIMS, Bhopal, under the registration numbers (IEC nos. IM079 and IM0427).

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Conflicts of interest

There are no conflicts of interest.

References

1. Hagins M, Moore W, Rundle A. Does practicing hatha yoga satisfy recommendations for intensity of physical activity which improves and maintains health and cardiovascular fitness? BMC Complement Altern Med 2007;7:40.
2. Singh P, Yogesh MK, Mendonca NL, Jamuna BL. Surya Namaskar versus spot jogging-effects on cardiovascular and HRV parameters in young adults: A pilot study. Chairman Ed Board 2017;5:218.
3. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, *et al.* Physical activity and public health: Updated recommendation for adults from the American college of sports medicine and the American Heart Association. Circulation 2007;116:1081-93.
4. Kesaniemi YK, Danforth E Jr., Jensen MD, Kopelman PG, Lefèbvre P, Reeder BA. Dose-response issues concerning physical activity and health: An evidence-based symposium. Med Sci Sports Exerc 2001;33:S351-8.
5. Mody BS. Acute effects of Surya Namaskar on the cardiovascular and metabolic system. J Bodyw Mov Ther 2011;15:343-7.
6. Labarthe D, Ayala C. Nondrug interventions in hypertension prevention and control. Cardiol Clin 2002;20:249-63.
7. Gimbel MA. Yoga, meditation, and imagery: Clinical applications. Nurse Pract Forum 1998;9:243-55.
8. Malhotra V, Javed DJ, Bharshankar R, Porter P. Fast pace sun salutations (FPSS) yoga postures influence brain waves activity in addition to heart rate variability pattern: A pilot study. Med J DY Patil Vidyapeeth 2023. [doi: 10.4103/mjdrdypu.mjdrdypu_590_22].
9. Riebe D, Ehrman JK, Liguori G, Magal M. General principles of exercise prescription. In: ACSM's Guidelines for Exercise Testing and Prescription. 10th ed., Ch. 6. Philadelphia, PA: Wolters Kluwer/Lippincott Williams and Wilkins; 2018. p. 143-79.
10. Physical Activity Guidelines Advisory Committee [PDF-4.6MB]. Physical Activity Guidelines Advisory Committee Report, 2008. Washington, DC: U.S. Department of Health and Human Services; 2008.
11. Cooper KH. The Aerobics Program for Total Well-Being. New York: Bantam Books; 1982.
12. Hill DW, Shephard RJ, Broekhoff J. Sensitivity of the Cooper 12-minute run test to changes in VO2 max in elite athletes. J Strength Cond Res 1992;6:89-92.
13. Bassett DR Jr., Howley ET. Cooper's 12-minute run test as a predictor of running performance in a longer-duration endurance event. J Appl Physiol 1997;82:1112-5.
14. Heart Rate Variability: Theoretical Aspects and Opportunities of Clinical Application. Institute of Biomedical Problems Moscow Medical Academy Named after I.M. Sechenov. Moscow. St. Petersburg: Scientific Research Laboratory Dinamika; 2002.
15. Yuryevich SK, Alekseevich SY. Development and Research of Mathematical Modeling Methods and Analysis of Bioelectrical Signals. St Petersburg: Scientific Research Laboratory Dynamika; 2001.
16. Bhavanani AB, Ramanathan M, Balaji R, Pushpa D. Immediate effects of Suryanamaskar on reaction time and heart rate in female volunteers. Indian J Physiol Pharmacol 2013;57:199-204.
17. Malhotra V, Thakare AE, Hulke SM, Javed D, Dixit AK, Wakode SL, *et al.* Heart rate variability among healthy untrained adults during mild intensity stationary cycling exercise. Adv Biomed Res 2023;12:55.
18. Farinatti PT, Brandão C, Soares PP, Duarte AF. Acute effects of stretching exercise on the heart rate variability in subjects with low flexibility levels. J Strength Cond Res 2011;25:1579-85.
19. Franklin BA. Cardiovascular responses to exercise and training. In: Exercise and Sports Science. Philadelphia: Lippincott Williams and Wilkins; 2000. p. 107-16.
20. Gálvez JM, Alonso JP, Sangrador LA, Navarro G. Effect of muscle mass and intensity of isometric contraction on heart rate. J Appl Physiol (1985) 2000;88:487-92.
21. Ray US, Mukhopadhyay S, Tomer OS, Sinha B, Pathak A, Thakur L, *et al.* Physiological Responses during the Practice of Individual Yogic Exercises (Asanas) Yogic Breathing (Pranayama) and Meditation in Yoga Tranees and Proficient. Delhi: DRDO: Ministry of Defence Report No; RD-P1-96/DIP-212 (USR); 2000.
22. Billman GE. The LF/HF ratio does not accurately measure cardiac sympatho-vagal balance. Front Physiol 2013;4:26.
23. Subramanya P, Telles S. Performance in the Stroop task and simultaneously recorded heart rate variability before and after meditation, supine rest and no-intervention. Int J Brain Cogn Sci 2015;4:8-14.
24. 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;18:491-519.
25. Muralikrishnan K, Balakrishnan B, Balasubramanian K, Visnegarawla F. Measurement of the effect of Isha Yoga on cardiac autonomic nervous system using short-term heart rate variability. J Ayurveda Integr Med 2012;3:91-6.
26. De A, Mondal S, Deepeshwar S. Single bout of yoga practices (Asana) effect on low frequency (LF) of heart rate variability-a pilot study. Int J Med Public Health 2019;9:160-3.
27. Tulppo MP, Hautala AJ, Mäkikallio TH, Laukkanen RT, Nissilä S, Hughson RL, *et al.* Effects of aerobic training on heart rate dynamics in sedentary subjects. J Appl Physiol (1985) 2003;95:364-72.
28. Sandercock GR, Bromley PD, Brodie DA. Effects of exercise on heart rate variability: Inferences from meta-analysis. Med Sci Sports Exerc 2005;37:433-9.
29. Sinha SN, Prasad R, Sinha U. Cardiorespiratory responses to Suryanamaskar and bicycle ergometer exercise in healthy young men. Indian J Physiol Pharmacol 2004;48:363-8.
30. Sinha SN, Prasad R. Comparative cardiorespiratory responses of healthy young women to Suryanamaskar and bicycle ergometer exercise. Indian J Physiol Pharmacol 2012;56:1-6.