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Effect of Yoga on the Autonomic Nervous System: Clinical Implications in the Management of Atrial Fibrillation

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Abstract

Atrial fibrillation (AF) affects about 1.5% of the U.S. population, especially aging persons, resulting in substantial morbidity and mortality. Although radiofrequency catheter ablation is the accepted treatment for AF, failure of this therapy is common. Given that the onset of AF is preceded by a primary increase in the sympathetic drive followed by marked modulation towards vagal pre-dominance, it is likely that stress precipitates and exacerbates AF. The authors searched the databases of Ovid MEDLINE, Pub Med, APA PsycNET, Alt Health Watch via EBSCO host, and CINAHL to evaluate the effects of yoga as a complementary health approach on the autonomic nervous system and how this mind-body modality, if added to conventional treatment, might contribute importantly to reducing or eliminating stress as a trigger for AF. Articles written in English and published in peer-reviewed journals between 2003 and 2017, reporting on research of yoga on autonomic nervous system, were identified. Twenty articles met the inclusion criteria, revealing that yoga resulted in a significant shift in autonomic balance towards vagal dominance; reduction in heart rate and blood pressure; reduction in indices of ventricular repolarization dispersion in patients with ventricular arrhythmias; significant reduction in stress, anger, depression, and anxiety; and improvements in neuroendocrine release, emotional processing, and social binding. Given these literature review findings, the authors provide an integrative overview of biological mechanisms and substrates that mediate AF, which can be targets for future research evaluating how the practice of selected styles of yoga can mitigate the onset of AF.

Keywords: Yoga; Heart rate variability; Stress; Autonomic nervous system; Atrial fibrillation

Abbrevations: ANS: Autonomic Nervous System; PNS: Parasympathetic Nervous System; HRV: Heart Rate Variability; HF: High Frequency; LF: Low Frequency; VLF: Very-Low-Frequency; ULF: Ultra-Low-Frequency; SDDN: Standard Deviation of Normal-to-Normal; RMSSD: Root Mean Square of Successive Differences; NN50: Number of Pairs of Successive NN (R-R) Intervals that Differ By More Than 50 Milli Seconds; pNN50: Proportion of RR Intervals >50 Msec; FEV1: Forced Expiratory Volume in 1 Second; FVC: Forced Vital Capacity; FEF: Forced Expiratory Flow; PEmax: Maximum Peak Expiratory Flow Rate; PImax: Maximum Inspiratory Flow Rate; GABA: Gamma Amino-Butyric Acid; QOL: Quality of Life; Min: Minute/s; Yr: Year/s; MET: Metabolic Equivalent of Task; AF: Atrial Fibrillation; PAF: Paroxysmal Atrial Fibrillation; QOL: Quality of Life; VAS: Visual Analogue Scale; SD: Standard Deviation; Min: Minute/s

Introduction

Atrial fibrillation (AF), the most common sustained cardiac arrhythmia, is seen in approximately 1.5% of the U.S. population [1] and results in substantial morbidity and mortality [2]. One of the largest U.S. epidemiological studies, the Framingham Heart Study, predicted that AF prevalence doubles with each advancing decade of age, from 0.5% at age 50-59 years to almost 9% at age 80-89 years, independent of the increasing prevalence of known predisposing conditions [2]. Although medical treatment involving radiofrequency catheter ablation has become the well-accepted management strategy for AF [3] failure of this therapy is common, with only two-thirds or less of the patients treated remaining free of AF on long-term follow-up [3]. Early recurrence of atrial tachyarrhythmia, usually defined as arrhythmia recurrence within the first 3 months following ablation, is frequently associated with late recurrence of atrial tachyarrhythmia [4,5]. Acute myocardial injury and the subsequent inflammatory response, as well as modifications of the cardiac autonomic nervous system, provide an early and potentially reversible pro-arrhythmic substrate because of altered atrial myocardial conduction and refractoriness [3]. Research has shown that psychological stressors and imbalance in the autonomic nervous system (ANS) are the most common triggers for paroxysmal AF [6,7]. The mind-body therapy yoga has been shown to reduce stress and maintain autonomic nervous system balance [8]: hence, use of complementary health approaches such as yoga, which are low-cost interventions, might contribute importantly to reducing stress, help individuals maintain balance in the ANS, and thereby prevent recurrence of AF. In this article, the authors provide an overview of AF, the effects of yoga on lessening stress and maintaining ANS balance, and suggest through a psychoneuroimmunological framework the possible mechanisms by which the practice of yoga could mitigate AF episodes and symptoms.

Atrial fibrillation and associated symptoms

Cumulative lifetime risk estimates reveal that AF is primarily a disease of aging. In U.S. and European community-based cohort studies, the estimated lifetime risk of AF is 22% to 26% in men and 22% to 23% in women by age 80 years [9]. The effects of heart failure, valvular disease, myocardial infarction, and ischemic stroke on AF are substantial. Heart failure increases the risk of AF by a 4.5-fold in men and a 5.9-fold in women. Valvular heart disease increases the risk of AF by a 1.8-fold in men and a 3.4-fold increase in women, with myocardial infarction significantly increasing the risk of AF by 40% in men [2]. Likewise, AF is a potent risk factor for ischemic stroke, increasing the risk of stroke 5-fold, thus leading to about 15% of all strokes nationally [10].

The most common AF symptoms include palpitations, shortness of breath, fatigue, dizziness, and anxiety. In a study of 100 randomly selected patients with AF, 88% reported palpitations on exertion, 86% reported palpitations at rest, 70% reported shortness of breath on exertion, 87% reported reduced physical ability, and 59% reported anxiety [6]. Adults with major depression, anxiety, or somatization disorder generally have an associated increase in the severity of their AF symptoms [11].

Quality of life in individuals with AF

AF contributes to increased morbidity in the elderly by adversely affecting their quality of life (QOL) and by deterioration in myocardial function, increasing susceptibility to heart failure, stroke, hospitalization, and mortality [12]. Evaluation of QOL in a group of 264 female patients with AF enrolled in the Canadian Trial of Atrial Fibrillation (N = 403) showed that women had significantly more impaired QOL than men, specifically related to physical rather than emotional functioning [13]. In another study, outpatients with documented AF (N = 152) reported substantially poorer QOL than healthy controls [14]. Three of the four well-known randomized controlled trials (STAF, PIAF, RACE) comparing rate versus rhythm control demonstrated a greater improvement in QOL in patients receiving rate control [15] than those in the rhythm control group. However, the Atrial Fibrillation Follow-up Investigation of Rhythm Management (AFFIRM) trial revealed a similar improvement in QOL for both rate and rhythm control groups [15].

Health care costs associated with AF

A national survey estimated that direct medical costs were 73% higher in patients with AF compared with matched control subjects, representing a net incremental cost of $8705 per patient per year and a national incremental cost between $6 and $26 billion [16]. Retrospective analyses of three federally funded U.S. databases using 2001 data [17] found that approximately 2,34,000 hospital outpatient department visits, 2,76,000 emergency room visits, 3,50,000 hospitalizations, and 5 million office visits were attributable annually to AF. The total annual medical cost for the treatment of AF in the inpatient, emergency department, and hospital outpatient settings estimated at $6.65 billion is likely an underestimate as costs for long-term anticoagulation, stroke prevention, inpatient drugs, and hospital-based physician services were not included [17]. Patients with AF enrolled in the Fibrillation Registry Assessing Costs, Therapies, Adverse events, and Lifestyle (FRACTAL) study who were managed with cardioversion and pharmacotherapy incurred AF and other cardiovascular-related health care costs of $4000 to $5000 per year [18]. Among patients with recurrent AF, the frequency of recurrence was strongly associated with higher resource use, with each recurrence increasing annual costs by an average of $1600 [18]. The cost-effectiveness of catheter ablation is difficult to determine because of differences in the experience levels of centers treating these patients, use of technology, and rates of reimbursement, each of which affects cost calculations [19]. Researchers evaluating the cost-effectiveness of AF ablation compared with rhythm control or anti arrhythmic agents have shown that ablation treatment results in improved quality-adjusted life expectancy, although at a higher cost [18,19].

Atrial fibrillation and stress

Researchers have shown that psychological stressors and imbalance in the autonomic nervous system are the most common triggers for paroxysmal AF [6,7]. Acute life stressors affect the development and spontaneous conversion of AF and are thought to be mediated by the sympathetic nervous system. This hypothesis is supported by increased circulating catecholamine following an acute life stress and by observation that beta-adrenergic blockade prevents abnormal heart rhythm disturbances triggered by acute life stress [5]. In a study of 100 randomly selected patients with idiopathic paroxysmal atrial fibrillation, 54% reported psychological stress as the most common triggering factor for AF [6]. In another study of 116 patients with AF without an obvious cause, acute life stress significantly affected the development and spontaneous conversion of AF [7].

Atrial fibrillation and the autonomic nervous system

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The autonomic innervations to the heart from the brain, the spinal cord (extrinsic system) and the ganglion plexi of the heart itself comprise the local ANS (intrinsic system) [20]. This intrinsic cardiac ANS of the heart and the pericardium serves as more than a relay station for the intrinsic projections of the vagal-sympathetic system from the brain and spinal cord to the heart. Supporting this theory is the fact that ablation of the major ganglion plexi at the pulmonary vein atrial entrances either eliminates or markedly diminishes AF inducibility. Also, this intrinsic cardiac autonomic system can act independently to modulate numerous cardiac functions, including automaticity, contractility, and conduction [20].

In addition to the sympathetic component of the ANS, the parasympathetic component has been shown to play a role in AF [21]. Amar et al. [22] showed that the onset of AF was preceded by a primary increase in the sympathetic drive followed by marked modulation toward vagal pre-dominance. The physiologic studies by Patterson et al. [23] further indicate that sympathetic stimulation plays an important modulatory role in the emergence of focal drivers for AF in the presence of an increased vagal tone. The ANS is involved in the genesis of both AF triggers (i.e., ectopic foci that result from interaction between vagal and sympathetic stimulation) and the creation of a more established AF substrate that is needed for the maintenance of AF and is enhanced in the presence of structural heart disease [21]. It has been shown that the abnormal electrical conduction within the pulmonary veins could be sustained only in the presence of isoproterenol or acetylcholine, indicating that sympathomimetic or cholinergic stimulation appears to be necessary to promote the development of sustained focal activity in the pulmonary veins [21].

Relationship between autonomic nervous system and measurement of heart rate variability

Heart rate variability (HRV), the variance between the R-R intervals or complete cardiac cycle on the electrocardiogram, can be used to assess the balance between the sympathetic and parasympathetic branches of the ANS [24]. Efferent sympathetic and parasympathetic activity is integrated in and with the activity occurring in the heart's intrinsic nervous system. Thus, HRV is considered a measure of neurocardiac function that reflects heart-brain interactions and ANS dynamics [25]. HRV is assessed with various analytical approaches, although the most commonly used are frequency domain (power spectral density) analysis and time domain analysis [25]. The European Society of Cardiology and the North American Society of Pacing and Electrophysiology Task Force Report on HRV divided heart rhythm oscillations into 4 primary frequency bands: high-frequency (HF), low-frequency (LF), very-low-frequency (VLF), and ultra-low-frequency (ULF) [24]. It is often assumed that a low LF:HF ratio reflects greater parasympathetic activity relative to sympathetic activity [25]. In contrast, a high LF:HF ratio may indicate higher sympathetic activity relative to parasympathetic activity as can be observed when people engage in meeting a challenge that requires effort and increased sympathetic activation. Alternatively, it can indicate increased parasympathetic activity as it occurs during slow breathing. Time domain indices quantify the amount of variance in the inter-beat-intervals using statistical measures. The three most important and commonly reported time domain measures are the standard deviation of normal-to-normal (SDNN), the SDNN index, and the root mean square of successive differences (RMSSD) [25]. The modulation of vagal tone helps maintain the dynamic autonomic regulation important for cardiovascular health. Reduced parasympathetic (high frequency) activity has been found in cardiac pathologies and in patients under stress or suffering from panic, anxiety, or worry [24].

Yoga as a complementary health approach in treating atrial fibrillation

Yoga, an ancient discipline from India, is a mind-body exercise in which both physical and mental disciplines are brought together to achieve peacefulness of mind and body, resulting in a relaxed state that is useful in managing stress and anxiety. To date, two studies have assessed the impact of yoga on AF. One, a proof-of-concept study [26], revealed that 60-minute Iyengar yoga sessions at least twice a week for 3 months improved symptoms, arrhythmia burden, heart rate, blood pressure, anxiety and depression scores, and several domains of QOL in adults with paroxysmal AF. A second study [27] using mediyoga as the intervention, showed that this style of yoga might potentially lower blood pressure, lower heart rate in patients with paroxysmal AF, and improve QOL compared to a control group.

Given the potential positive impact of yoga on decreasing AF episodes and symptoms as shown in Table 1, the authors conducted an extensive computerized search of diverse databases (Ovid MEDLINE, Pub Med, APA PsycNET, Alt Health Watch via EBSCO host, CINAHL), using key terms of heart rate variability and autonomic nervous system, to assess the effect of yoga on the ANS. These computerized searches yielded 230 studies (Ovid MEDLINE = 25, Pub Med = 31, APA PsycNET = 16, Alt Health Watch = 153, CINAHL = 5), which were then reviewed for eligibility. Inclusion criteria were English language articles reporting on studies that (a) enrolled subjects 18 years and older and (b) were published between 2003 and 2017 in peer-reviewed scientific journals.

Table 1: Studies reporting effects of yoga on atrial fibrillation [1].

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Article/ Study	Purpose	Sample	Inclusion-Exclusion Criteria	Intervention Description	Research Design	Outcome Measures	Results	Conclusion
Lakkireddy et al. [26]	Purpose to examine the impact of yoga on AF burden, QOL, depression, and anxiety scores	103 consecutive eligible paroxysmal atrial fibrillation patients screened; 52 enrolled and 49 completed study. Age: 60.6 SD+ 11.5 23 males and 26 females	Inclusion criteria: Patients with paroxysmal AF between 18 and 80 yrs of age Exclusion criteria: Patients with a history of AF ablation within 3 months, contraindications for yoga training, life expectancy <1 year, advanced heart failure, and those who practiced any form of yoga in preceding 6 months	Structured Iyengar yoga training at least twice weekly;60 min training sessions were conducted in groups of 15-20 people in a yoga studio by a certified professional yoga instructor; During each yoga session, 10 min of pranayamas, 10 min of warm-up exercises, 30 min of asanas, and 10 min of relaxation exercises performed; An educational DVD provided to guide home yoga practice;Compliance reinforced with biweekly phone calls	Single- center, prospective, self-controlled pre-post study	AF symptoms and episodes using self-reported diary and cardiac non-looping monitor; SF-36;Zung self-rated anxiety scale and Zung self-rated depression scale	Yoga training reduced symptomatic AF episodes ($p< 0.001$),symptomatic non-AF epi-sodes ($p< 0.001$), asymptomatic AF episodes ($p< 0.001$), depression and anxiety ($p< 0.001$; improved QOL parameters of physical functioning, general health, vitality, social functioning, and mental health domains on SF-36;Significant decrease in heart rate, systolic and diastolic blood pressure after yoga ($p< 0.001$)	In patients with paroxysmal AF, yoga improves symptoms, arrhythmia burden, heart rate, blood pressure, anxiety and depression scores, and several domains of QOL
Wahlstrom M et al. [27]	To investigate whether yoga can improve QOL and decrease blood pressure and heart rate in patients with PAF	80 participants with a new diagnosis of PAF were randomized to either a yoga intervention group or a control group; Intervention group: mean age 64 SD+ 7, n= 33 (16 males, 17 females); Control group: mean age 63 SD+ 8, n= 36 (26 males, 10 females)	Inclusion criteria: New diagnosis of PAF necessitating pharmacological treatment for at least 3 months Exclusion criteria: Patients with difficulties understanding Swedish language, patients with multiple concurrent medical conditions (i.e., cancer, heart failure, and renal failure with symptoms) or cognitive dysfunction	Mediyoga 1 time/ week X 12 weeks in group sessions specifically designed for people with cardiac diseases; Each session started with deep breathing for 5-10 min followed by three movements (back flex, back roll, and SatKriya) that included two breathing techniques; Subsequent meditation (10 min) and relaxation (10 min)	Randomized controlled design	Two generic health-related QOL questionnaires: - Short- Form Health Survey (SF-36) -VAS-scale from EuroQOL-5D (EQ-5D)used	At end of 12-week intervention, yoga group averaged higher on SF-36 mental health scores but no differences in EQ-5D VAS- scale and physiological health score seen between the two groups; At end of study, yoga group had significantly lower heart rate ($p=0.024$) and systolic ($p=0.033$) and diastolic blood pressure ($p<0.001$) compared to the control group	Yoga with light movements and deep breathing might lead to improved QOL, lower blood pressure, and lower heart rate in patients with PAF compared to a control group

Table 2: Studies reporting effects of yoga on the ANS [1].

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Article/ Study	Purpose	Sample	Inclusion-Exclusion Criteria	Intervention Description	Research Design	Outcome Measures	Results	Conclusion
Sengupta P [28]	To develop a state-of-the-art review of health impacts of yoga and pranayama				Review of Literature			Yoga and pranayama reduce stress and anxiety, improves autonomic nervous system balance by triggering neuro-hormonal mechanisms by the suppression of sympathetic activity, improves physical health of cancer patients
Brown RP et al. [29]	To propose a neurophysiologic model to clarify mechanisms by which SudharshanKriya yogic breathing can be used to balance the autonomic nervous system and influence psychologic and physiologic parameters				Grounded theory		A proposed neurophysiologic model that postulates the following: -Strengthening, balancing and stabilizing the autonomic and stress response systems -Decreasing chemoreflex sensitivity - Improved baroreflex response - Shifting to Parasympathetic dominance via vagal stimulation - Balancing of cortical areas (synchronization) by thalamic nuclei -Calming effect on the cortical area involved in executive functions such as anticipation, planning, and worry -Activation of limbic systems leading to stimulation of forebrain reward systems and emotional release. Increased release of prolactin and oxytocin enhancing feelings of calmness and social bonding	SudharshanKriya yoga may improve autonomic function, neuroendocrine release, emotional processing, and social binding; The authors' model might be of heuristic value in identifying areas for future clinical research related to yogic breathing

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Markil N et al. [30]	To compare acute sympatho-vagal changes as measured by HRV responses to yoga nidra relaxation alone compared to yoga nidra relaxation preceded by hatha yoga	15 women and 5 men (mean age 29.15, SD ±6.98, range 18-47 yrs)	Inclusion criteria: Healthy men and women Exclusion criteria: previous history of musculo-skeletal disorders, cardiovascular disease, taking medications that affect heart rate and blood pressure, known cardiac arrhythmias, engaged in regular aerobic exercise or strength training exercise >3 days per week over prior 6 months	Yoga plus relaxation group included 20 min of rest followed by traditional 60-min Hatha yoga session followed by 30 min of yoga nidra relaxation; Relaxation group included 20 min of supine rest followed by 30 min of yoga nidra relaxation	Randomized counter-balanced trial	Baseline heart rate, and indices of HRV, including time and frequency domains	Significant changes in heart rate and HRV indices from baseline in both yoga plus relaxation group and relaxation alone group	Changes in heart rate and HRV reflect a favorable shift in autonomic balance to para sympathetic branch of ANS, occurring for both yoga nidra relaxation and yoga nidra relaxation preceded by Hatha yoga
Dabhade AM et al. [31]	To evaluate potential beneficial effects of *pranayama* on indices of ventricular re Polarization dispersion by measuring QTd and JTd on a 12 lead surface ECG in patients with arrhythmia	27 enrolled in pranayama sessions with 15 included in final analysis (12 males, mean age 68 , SD± 11 years, EF mean 28 SD ± 9%); 12 patients had arrhythmia secondary to ischemic cardiomyopathy and others had arrhythmia secondary to non-ischemic dilated cardiomyopathy	Inclusion criteria: Presence of diagnosed arrhythmia, echocardiographic evidence of depressed left ventricular function (EF <40%), absence of active ischemia as revealed by a clinical examination or by exercise testing at time of enrollment, a stable medical regimen for at least 2 weeks prior to starting session and during entire session, absence of recent coronary revascularization procedures (≤ 3 months), no history of MI in 8 weeks prior to enrollment Exclusion criteria: Class IA/ III anti-arrhythmic medications, inability to complete *pranayama* session, absence of sinus rhythm at entry or comple-tion of session; a complete bundle branch block of any kind	All patients completed 12- week program (36 *pranayama* sessions with each session consisting of 5 different *pranayama* practices (Bhastrika- 10 mins, Kapalbhati- 10 mins, Anilom-vilom- 15 mins, Bhramari- 5 times/day, and Udgit- 5 times/ day) for 45 mins; Before entering sessions, participants underwent symptom-limited exercise testing that usually consisted of a treadmill protocol	Single-group pre-post test design	Ventricular repolarization dispersions (QTd, JTd), metabolic parameters (changes in exercise capacity and anaerobic threshold)	- Exercise capacity increased from 4 ± 1 MET to 5 ± 2 MET (about 25%) after *pranayama* and peak oxygen consumption increased from 15±4 ml O2/Kg/ min to 16 ± 6 ml; O2/Kg/ min after *pranayama* (did not reach statistical significance); - Statistically significant decreases in all intervals (QTd, QTc-d, JTd, JTc-d) at the comple-tion of the *pranayama* program	Pranayama significantly reduced the indices of significant ventricular repolarization dispersion in patients with arrhythmia, suggesting that interventions such as yoga, which increases PNS and GABA activity, might be effective in treatment resistant subjects who failed to respond to pharmacologic agents that increase activity in the GABA system

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Bidwell AJ et al. [32]	To assess whether 10 weeks of yoga training might improve QOL and HRV in patients with asthma	19 females, age: 20-65 years old with clinical and functional evidence of mild to moderate asthma as assessed by physician	Inclusion criteria: FEV1/FVC ratio of < 80% predicted, use of a bron-cho-dilator at least once daily, symptoms of wheezing and/or coughing for a minimum of 2 years that improves either spontan-eously or with drug therapy Exclusion criteria: Smoking ≥2 cigarettes per day; participated in yoga in the previous 12 months; diagnosis of hypertension and major orthopedic injuries prohibiting performance of various yoga postures; currently taking medications such as beta blockers that would alter autonomic function	1-hour super-vised yoga sessions/10 weeks led by certified yoga instructor Each class consisted of 10 min of relaxation/ deep breathing exercises followed by 40 min of Hatha yoga postures; sessions finished with 10 min of meditation to control stress levels; Additionally, participants supposed to perform 30-min session/wkly at home using a written lesson plan; 1-hour sessions 2/wk/10 weeks in group settings and 30 min sessions of 1 time/wk for following 10 weeks in a group setting	Randomized controlled trial	St. George's Respiratory Questionnaire to assess QOL and an isometric exercise test to assess HRV pre- and post-intervention	Significant improvements in QOL observed with yoga training, although no changes were found in control group; yoga group demonstrated decreased parasympathetic modulation (HF); increased sympathetic (LF) and sympatho vagal modulation (Log LF/HF) in response to isometric forearm (IFE) exercise with no change in control group	Yoga training improved QOL in women with mild-to-moderate asthma and resulted in decreased parasympathetic and increased sympathetic modulation in response to an IFE
Raghuraj P &Telles S [33]	To study effects of three yoga breath-ing practices (right nostril yoga breathing (RNYB), left nostril yoga breath-ing (LNYB), and alter-nate nostril yoga breathing (ANYB) compared to breath awareness(BAW)	21 male volunteers 18- 45 yrs (mean age 27.5, SD ±6.3)	Inclusion criteria: Healthy volunteers not on any medications and not using any wellness strategy; no history of smoking or respiratory ailments, including nasopharyngeal abnormalities; all right handed and had experience in practicing 3 yoga breathing techniques ranging between 3-48 months; all completed 3 months of intensive, residential yoga training Exclusion criteria: Women excluded given autonomic and respiratory variables vary with phases of menstrual cycle	Participants assigned to five sessions as five possible sequences; Sequence 1= RNYB, LNYB, ANYB, BAW and NB; Sequence 2= LNYB, ANYB, BAW, NB, RNYB; Sequence 3= ANYB, BAW, NB, RNYB, LNYB; Sequence 4= BAW, NB, RNYB, LNYB, ANYB; Sequence 5= NB, RNYB, LNYB, ANYB, BAW; For each sequence five sessions of 40 min each conducted on 5 different days; Each 40-min session consisted of 30 min during which subjects practiced any one of the four breathing techniques or did not do any breath manipulation (in the control session); each 30 min period preceded and followed by 5- min 'rest periods' without breath manipulation		Heart rate, skin conductance, finger plethysmogram amplitude, breath rate, blood pressure, frequency domain analysis of HRV	RNYB can increase sympathetic tone and cardiac sympathetic activity given it increases BP and HR; LNYB resulted in decrease in systolic BP and mean BP; ANYB resulted in both decrease in both systolic and diastolic BP, increase in HR, skin conductance level, LF power, LF/HF ratio of the HRV spec-trum	Yoga breathing practices result in physiologic effects on autonomic activity by increasing sympathetic response, which could have been related to slower breath rate; ANYB resulted in decrease in both systolic and diastolic blood pressure

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Mourya M, et al. [34]	To analyze whether breath-ing exercises practiced in various forms of meditations such as yoga might in-fluence autonom-ic functions and serve as basis of therapeutic bene-fit to hyperten-sive patients	60 men and women patients 20-60 yrs of age with Stage I essential hy-pertension	Inclusion criteria: Diagnosis of essential Stage 1 hypertension with systolic BP 140-159 mm Hg and diastolic BP 90-99 mm Hg; (Some not on any medications, while others were re-ceiving diuretics or angiotensin-con-verting enzyme receptors or both)	Participants ran-domly assigned into one of 3 groups (20/ group); Group 1 had no intervention, Group 2 practiced slow-breathing exercise, and Group 3 practiced fast breathing exercises 15 min twice daily 10-12 hours apart for 3 months	Random-ized, pro-spective, controlled clinical study	Baseline and post-inter-ven-tion BP, auto-nomic function tests such as standing-to-ly-ing ratio, im-mediate heart rate response to standing (30:15), valsal-va ratio, heart rate variation with respira-tion, hand-grip test, and cold pressor response	BP decreased longitudinally over 3-months in both in-ter-vention groups; S/L ratio, 30:15 ratio, E/I ratio, and BP response in hand grip and cold pressor test showed significant changes only in patients practicing the slow breathing exercise	Both types of breathing exercises benefit patients with hyperten-sion; However, improvement in both sym-pathetic and parasympathet-ictic reactivity might be the mechanism that is associat-ed in those practicing the slow-breathing exercise
Pramanik T, et al. [35]	To evaluate immediate effects of slow pace bhastrika pranayama for 5 min on heart rate and blood pres-sure and effect of same breathing exercise for same duration follow-ing oral intake of hyoscine-N-bu-tyl-bromide (parasympathetic blockade)	39 volun-teers (age 25-40 yrs) practiced bhastrika pranayma and 10 volunteers practiced bhastrika Pranayama 30-min after oral intake of hyos-cine-N-butyl bromide	Inclusion criteria: Healthy, non-smoker, see-tary volunteers	One set of slow pace bhastrika Pranayama for 5 min (respiratory rate 6/min)	Two-group experi-mental design	Heart rate and blood pressure	Following bhastrika pranayamic breath-ing for 5 min both systolic and diastolic blood pressure decreased signifi-cantly, with a slight decrease in heart rate; The group of volunteers whose heart rate and BP were compared before and after breathing exercise following intake of hyoscine-N-butyl-bromide showed no significant alteration in either of these para-meters	Slow pace Bhastrika Pranayama ex-ercise showed a strong tendency to improving the ANS through enhanced activation of the parasympathet-ictic system

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Patra S &Telles, S [36]	To compare ef-fects of practicing day time cyclic meditation with effects of supine rest practice on HRV during sleep	30 male volunteers ranging in age from 20 to 30 yrs (mean 22.3, SD ±4.6 yrs)	Inclusion criteria: Healthy with no history of smoking or alcohol use (none were on medications and none used any wellness strate-gies)	Sessions conducted 3 days apart with par-ticipants to practice super-vised cyclic meditation (CM) two times a day (i.e., at 06:00hr and 18:45 hr followed by a full-night sleep recording beginning at 21:00 on same day; as a control for cyclic medi-ta-tion after 3 days participants practiced unguided supine rest in Shavasana twice a day at same time and duration as the CM sessions, with monitoring done by same yoga instructor, although participants received no instruc-tions; Each session lasted for 22.5 mins with participants re-porting to sleep lab at 21:00 for whole night polysomnography recording	Non-ran-domized, sin-gle-group, crossover design	Heart rate, breath rate, HRV spectrum (LF, HF, LF/HF ratio, NN50, pNN50, TINN)	During the night following cyclic med-itation, a decrease in heart rate, LF power, LF/HF ratio, and an increase in pNN50 were noted; No changes noted on the night following supine position rest	Yoga prac-tice of cyclic medita-tion during daytime appears to shift sympatho-vagal balance in favor of parasym-pathe ticdom-inance and a corresponding shift in the sympathovagal balance during sleep on the following night
Santaella DF et al. [37]	To test wheth-er a 4-month respiratory training program (Bhastrika pran-ayama) improves respiratory function, cardiac sympatho-vagal balance and QOL in healthy elderly subjects	76 healthy elderly subjects enrolled and 29 completed the study 46 subjects excluded from study	Inclusion criteria- Healthy elderly adults with age > 60 (Mean Age 68, SD ± 6 yrs; 34% males; BMI mean 25 SD± 3 kg/m2) Exclusion cri-teria- Age <60 years, previous knowledge of and training in yoga respiratory exercises, inability to comply with protocol (not attending >40% of the classes); presence of any cardiovascular diseases or other diseases, and use of medications that could affect autonomic modu-lation of the heart mainly because of atrial fibrillation, other diseases, use of anti-hyperten-sion, and thyroid hormone replace-ment drugs	Subjects underwent 30 min of supervised training classes im-mediately after twice weekly routine yoga class; subjects also instructed to perform specific exe-cises twice daily for 10 min in morning and afternoon consisting of either stretching (control, n=14) or yoga respiratory exercises -Bhastrika pranayama (yoga, n=15)	Ran-domized controlled design	Pulmonary function: FEV1, FVC, FEF 25-75%, PEmax and PImax flow rate; Heart rate variability, spontaneous baroreflex, and QOL	Improvements in FVC and FEV1 in yoga group did not reach statistical sig-nificance compared with control group; In contrast, PE max and PI max increased significantly in Yoga group compared with control group; Yoga group show-ed a significant decrease in LF component of HRV in LF/HF ratio; No significant changes in either group on Spontaneous baro-reflex noted; Yoga group had marginal changes in overall QOL, autonomy and interaction between present, past and future	4 months of re-spiratory train-ing in Bhastrika pranayama increased respi-ratory function and improved cardiac para-sympathetic modulation in a group of health elderly subjects.

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Telles S et al. [38]	To assess changes in autonomic and respiratory variables in normal healthy volunteers before, during, and after four types of meditation (viz., cancalata, ekagrata, Dharana, and dhyana) on separate days	30 healthy volunteers ranging from 20-45 years (mean age 29.1, SD±5.1 years); Average experience practicing meditation on Sanskrit syllable Om (Mean 20.95 months, SD± 14.21 months)	Exclusion criteria: chronic illnesses especially psychiatric and neurological disorders; females excluded because autonomic variables tend to vary with phases of the menstrual cycle	Each partici-pant assessed in four sessions on 4 different days at same time of day, including two meditation sessions- dharana (meditative focusing) and dhyana (meditative defocusing or effortless meditation); two control sessions- ekagrata (non-meditative focused thinking) and cancalata (random thinking); All four sessions consisted of 3 states: pre (5 min), during (20 min) and post (5 min) on the 4 separate days	Randomized controlled single-group design	Respiratory rate, heart rate, skin resistance, amplitude of digit pulse volume, frequency domain and time domain analysis of HRV	Maximum changes in autonomic variables and the breath rate during Dhyana, including decreased heart rate - increase in digit pulse volume (based on the photoplethysmo-gram amplitude) - increase in skin resistance, reduction in breath rate; - decrease in LF power of HRV, increase in HF power, increase in NN50 and pNN50 in time domain analysis of HRV indica-tive of para-sympathetic activity	Changes during dhyana sug-gestive of reduced activity in different sub-divisions of sympathetic nervous system activity, showing a shift in autonomic balance towards vagal dominance
Vempati RP &Telles S [39]	To identify whether the experience of yoga prac-tice showed greater reduction in physiol-gi-cal arousal after 'Guided relaxation' (with instructions) compared to 'Supine rest' without instructions	35 male volunteers, age 20-46 yrs (mean 27.5, SD 4.7); average yoga practice = 30.2 months (SD 25.7);	Inclusion criteria: completed a 5.5-month residential yoga course	Subjects categorized into either guided relaxation (GR) or supine rest (SR) groups using baseline LF/HF ratio of their HRV; separate relax-ation sessions held on diff-erent days at same time of day; sessions lasted 20 min with 10 min of guided relax-ation or supine rest	Two-group crossover design	Oxygen consumption, skin conductance, frequency domain of HRV	Reduction in skin conductance and heart rate noted both after GR or SR; decrease in finger plethysmogram noted after SR sug-gestive of increased sympathetic tone; Following guided relaxation subjects with baseline LF/HF ratio of >0.5 showed a significant decrease in LF/HF ratio, whereas same subjects showed no change in the ratio after SR; subjects with baseline LF/HF ratio of ≤0.5 at baseline showed no change after GR	Both GR and SR reduced physiological arousal, with changes in a larger number of autonomic variables following GR

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Dolgoff Kaspar R et al. [40]	To evaluate clinical utility of laughter yoga in improving psychologi-cal and physiolo-gy-ical measures in outpatients awaiting organ transplant	2 women and 4 men, age 51-69 yrs; 3 awaiting heart trans-plant and 3 awaiting lung transplant	Inclusion criteria: Awaiting organ transplant Exclusion criteria: major surgery in prior 3 months, history of hernia or uncontrolled hypertension; NYHA Class IV heart failure; on vasopressors or intravenous iono-tropes	A control period of 1 week during which participants complet-ed controlled inter-ventions at beginning and end of week; After control period, participants com-pleted seven laughter yoga sessions over 3 weeks conducted by a certified therapist; Participants com-pleted one additional control intervention at study termination; Controlled interven-tion involved group discussions on topics such as the study procedures, personal introductions, partici-pants medical history and experiences with stress, and closing remarks with review of participants' study experiences	Non-ran-dom-ized,con-trolled, crossover design	Psychologi-calmeasures, including fluctuations in current mood, anxiety, depres-sion; Physiolog-icalmeasures of blood pressure, heart rate, and HRV	Participants showed improved immediate mood (vigor-activity and friendliness) and increased HRV meas-ures for both SDNN and RMSDD so that scores are within or closer to normal range; Both laughter and con-trolled interventions appeared to improve long-term anxiety	The laughter yoga therapy might improve HRV and some aspects of mood.
Satyapri-ya M. et al. [41]	To assess effects of integrated yoga prac-tice and guided yogic relaxation on perceived stress and measured autonomic re-sponse in healthy pregnant women	122 healthy women recruited be-tween 18th and 20th wk of pregnancy at prenatal clinics to be followed un-til 36thwk of pregnancy; 90 completed study	Inclusion criteria: 18th to 20th wk of pregnancy, primigravida or multigravida when participant had at least one living child Exclusion criteria: Multigravida without any living child, multiple pregnancies, ma-ternal physical abnormalities, psy-chiatric problems, pregnancyasso-ciated diabetes and hypertension, pregnancy from invitrofertiliza-tion, intrauterine growth restriction in a previous pregnancy, fetal abnormality on ul-trasound scan, and previous exposure to yoga	45 participants randomly assigned to intervention group practicing yoga and deep relaxation for 1- hr/day; 45 participants assigned to control group and practiced standard pre-natal exercise with supine rest for 1- hr/day	Prospec-tive ran-domized 2-arm study	Perceived stress and HRV (LF, HF and LF:HF) during 18th week, 20th week, and 36th week	Perceived stress de-creased by 31.57% in yoga group and increased by 6.6% in control group; During guided relax-ation in yoga group, the high frequency band of HRV increased by 64% in the 20thwk and 150% in the 36thwk; The LF and the LF:HF ratio was reduced signifi-cantly; The LF band remained decreased after deep relaxation in the 36th week in yoga group	Yoga reduces perceived stress and improves adaptive auto-nomic response to stress in healthy preg-nant women

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Wolever RQ et al. [42]	To evaluate via-bility and proof-of- concept for two mind-body stress reduction programs (one therapeutic yoga-based and other mindful-ness-based) and to evaluate two delivery venues of a mindful-ness-based inter-vention (online vs in-person)	239 subjects-63 in Califor-nia and 176 in Con-necti-cut with 205 com-pleting study; 23.4% male; aver-age age 42.9 yrs; Non-Hispanic = 93.7%, White = 78.2%, Asian = 7.9%, African American = 6.3%	Inclusion criteria: Score of ≥16 on 10-item Perceived Stress Scale Exclusion criteria: Arrhythmia re-quiring medication or pacemaker, pregnancy, tobacco use, medications affecting heart rate; any major medical condition (e.g., COPD, CHF, Angina, traumatic brain injury and type I Diabetes) or psychological disorder (i.e., post-traumatic stress disorder, major depression, bipolar disorder, psychosis, severe anxiety, panic dis-orders; practicing yoga several times a week currently or participation in an extended meditation or yoga retreat of ≥2 days in past 5 years	239 partici-pants random-ized to either 12-week viniyoga stress reduction program or 1 of 2 mindfulness-based programs or control group assessment (assessment only) Viniyoga taught by trained teachers with instructional handouts provided for home practice; half the partici-pants received a DVD to support home practice; two mindfulness-at- work programs identical except one was provided 'in-person' in a conventional classroom, other one provided through on-line virtual classroom allowing for real-time bidirectional commu-nication	Ran-domized controlled trial	Stress, sleep quality, mood, and pain levels; work productiv-ity, mindfulness, blood pressure, HRV, and breathing rate	Compared with control group, mind-body interventions showed significantly greater improve-ment on perceived stress, sleep quality, and heart rhythm coherence ratio of HRV; The two delivery venues for the mindfulness program basically produced equivalent results	Mindful-ness-based and therapeutic yoga pro-grams might provide viable and effective interventions to target high stress level, sleep quality, and autonomic balance in employees
Khattab K et al. [45]	To determine if Iyengar yoga practice significantly increases cardiac para-sympathetic nervous mod-ulation among healthy yoga practitioners	11 healthy yoga prac-titioners(7 women and 4 men, mean age: 43 SD ± 11, age range: 26-58 yrs; experience = 3 years of regular Iyengar yoga practice; 4 certified as teachers of Iyengar yoga) were com-pared to an age and gen-der matched group of healthy individuals who had not been prac-ticing any relaxation techniques	Inclusion criteria: Healthy volun-teers with 3 yrs of regular practice in Iyengar yoga Exclusion criteria: Presence of any cardiovascular diseases	Each volunteer subjected to training units of 90 min once a week over 5 succes-sive weeks; During 2 sessions, practi-tioners engaged in an Iyengar yoga program developed for cardiac patients; For 3 ses-sions each practiced a placebo pro-gram of relax-ation; ambu-latory 24-hr holter monitoring complet-ed with all sessions; yoga practitioner group compared to a matched group of healthy individuals not practicing any relaxation techniques	Non-ran-domized, experi menttal, control-led design	Time-domain HRV: rMSSD, SDNN, SDNNi, SDANN	Mean R-R interval found to be signifi-cantly higher during time of yoga inter-vention compared to placebo and control; increase in HRV signifycantly higher during yoga exercise than during placebo and control activity, especially for pa-rameters associated with vagal tone (i.e., SDNNi, rMSSD)	Relaxation by yoga training is associated with a significant increase of cardiac vagal modulation; Because this method is easy to apply and leads to a deep mental and physical relax-ation, it could be a suitable intervention during cardiac rehabilitation to shift ANS balance to an increase in vagal activity and potentially decrease cardi-ac mortality

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Mura-likrish-nan K et al. [46]	To assess effect of Isha yoga, a system of yoga programs offered by Isha Foundation, on cardiovascu-lar autonomic ner-vous system through short-term HRV	14 healthy Isha yoga practitioners (12 men, 2 women; mean age 31.57 ±5.83 yrs) com-pared with age- and gen-der-matched non-yoga practitioners	Inclusion criteria: Between age18-40 yrs; Additionally, for yoga group engaging in Isha yoga practices for 1.5 hours/ day, 5 times/ wk minimum for ≥6 months Exclusion criteria: Medical illness or on medication or exercise regime; obese; smoking; taking recreational drugs or alcohol; For non-Yoga control group previous exposure to yoga or exercise practice	Practice of Isha yoga for ≥6 months, including Surya Nam-askar, Hatha yoga, Sakthichalana Kriya, Shambhavi Maha Mudra and Shoonya meditation	Cross-sec-tional design	Baseline heart rate, BP, pulse pressure, fre-quency domain analysis of HRV (R-R interval, LF, HF, LF nu, HF nu, LF/HF ratio) and time domain analysis of HRV (SDNN, RMSSD, NN50, pNN50); Frequency and time domain HRV parame-ters measured in supine rest position and time domain parameters measures ob-tained for deep breathing	Statistically signif-icant differences between Isha yoga practitioners and controls in both frequency and time domain analyses of HRV indices, with no difference in resting heart rate between groups	Practitioners of Isha Yoga showed well-balanced beneficial activity of vagal efferents; an overall increased HRV, and sym-patho-vagal bal-ance compared to non-yoga practitioners during supine rest and deep breathing
Melville GW et al. [47]	To compare effect of seated yoga posture and guided medita-tion practice on physiological and psychological markers of stress	20 adults (mean Age: 39.6, SD ± 9.5), Sex: 8 men, 12 women; BMI 22.5, range (19.8-44.1) One obese participant with type 2 diabetes mel-litus; Other controlled diseases among co-hort included asthma (n=3), chron-ic fatigue (n=2), and hyperten-sion (n=1); No history of tobacco use; None engaged in yoga and/or meditation over previous year	Inclusion criteria: Adult age ≥ 18 yrs, employed full-time in a sedentary job(i.e., office-based posi-tion) Exclusion criteria: uncontrolled illness, use of medication known to alter heart rate or blood pres-sure, and acute or chronic medical condition that would impede assessment of out-come measures	5-min baseline assessment followed by engaging in one of three conditions (yoga, meditation, or control group assign-ment) for 15 min Control group partic-ipants instructed to continue with their office work with same movement level and talking restrictions as applied to the base-line recording	Explor-atory study, involving with-in-sub-jects crossover design	Perceived stress, blood pressure, heart rate, respiratory rate, indices of HRV	- Significant reduc-tion in perceived stress immediately post-yoga and post-meditation versus control - Both systolic and diastolic pressure significantly reduced in meditation versus control - Respiratory rate decreasedsignifi-cantly during yoga and meditation and increased in control group, but regressed toward baseline val-ue during post-inter-vention period - Yoga significantly increased heart rate compared to control and meditation decreased heart rate compared to control - Change in heart rate significantly different between yoga and meditation throughout interven-tion period - Increase in HRV indices of LF, and LF: HF ratio detected during initiation of physical postures; Trend towards increase in SDDN noted in meditation versus control at end of interven-tion and during beginning of postinter-vention phase	15 mins of chair-based yoga postures or guided med-itation in office work-space can acutely improve several physiological and psycholog-ical markers of stress; These effects are par-tially mediated by reduced re-spiratory rate

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Shapiro D et al. [48]	To present data on yoga as a comple-mentary health inter-ven-tion treatment for depresssed patients on anti-depressant medications but who are only in partial remission regarding their depression	27 women and10 men; 17 completed interven-tion and pre-and post assessments; 33 White, 1 African American, 3 Asian-Amer-ican; age range 20-71 yrs; 6 were students, 3 retirees, 2 unemployed, 26 employed; hours of exercise per week=5.4 (range 0-30); alcohol drinks per week= 1.3 (range 0-8)	Inclusion criteria: All participants diagnosed with unipolar major depression with partial remission Exclusion criteria: >3 months of prior yoga practices; Axis I diagnose of bipolar disorders, delirium, demen-tia, schizophrenia, or other psy-chotic disorders, including current substance-re-lated or eating disorders and suicidal thoughts or tendencies; any medical illness that would pose a safety concern or limit study partic-ipation	Yoga interven-tion provided in 3 groups of 12-13 participants for 60-90 mins 3 times/wk/8-weeks (total of 20 sessions per group), with ses-sions led by 3 highly experienced Iyengar yoga teachers, rotat-ing over the sessions	Sin-gle-group outcome design	Psycholog-ical mea-sures:17-item Hamilton-D, Quick Inventory of Depressive Symptoms, Symptom Check List, Spiel-berger Anger Expression Scale, Speilberg-er Trait Anxiety Inventory, Cook-Medley Hostility Scale, Pittsburgh Sleep Scale, SF-36 Short Form Health Survey Physiolog ical measures: heart rate, blood pres-sure, measures of HRV, barore-flex sensitivity	Significant reduc-tions were shown for depression, an-ger, anxiety, neurotic symptoms and LF HRV in 17 com-pleters. Eleven out of these completers achieved remission levels post-interven-tion. Participants who remitted differed from the non-remitters at in-take on several traits and on physiological measures indicative of a greater capac-ity of emotional regulation. Moods improved before and after the yoga classes	Yoga produces many beneficial emotional, psy-chological and biological ef-fects in patients diagnosed with depression

The 20 articles that met the inclusion criteria are shown in Table 2. Seventeen were interventional studies with 14 of these using random sampling; 3 used non-randomized sampling techniques. One of the studies included a discussion of the effect of yoga on the parasympathetic and GABA systems [8] and the other study reviewed the health impacts of yoga and pranayama [28]. The review also identified two relevant articles that provided additional information on the impact of yoga on the ANS. One of the articles, provided a review of the health impacts of yoga and pranayama [28] and the second proposed a neurophysiologic model to clarify the mechanisms by which SudharshanKriya yogic breathing balance the autonomic nervous system activity [29].

Sample characteristics

The participants in all 17 interventional studies were adults aged 18 years or older. Three studies included only male participants, with the rationale for excluding females being the tendency in variation of the autonomic variables with the phases of the menstrual cycle in females. However, Markil et al. [30] included 15 women in their study, completing the study during the follicular phase of the menstrual cycle given that the luteal phase causes increase in sympathetic activity. One study did not mention the sex of the participants. Of the 17 interventional studies, 8 were completed in India, 5 within the United States, 1 in each completed in Australia, Germany, Brazil, and Nepal. Women and ethnic minorities were under represented in these studies. Most of the studies except for Dabhade et al. [31] excluded patients with arrhythmias and those on any medications such as beta-blockers and anti-arrhythmic medications that have significant effect on heart rate and rhythm.

The studies reviewed showed that participation in a yoga intervention resulted in a significant shift in autonomic balance towards vagal dominance; a reduction in heart rate and systolic, diastolic, and mean blood pressure; a reduction in the indices of ventricular repolarization dispersion (QTd, JTd) in patients with ventricular arrhythmias; significant reduction in stress, anger, depression, anxiety, and neurotic symptoms; and improvements in neuroendocrine release, emotional processing, and social binding. Both time and frequency domain indices of heart rate variability showed significant changes towards parasympathetic modulation. Bidwell, et al. [32] found that yoga training for females with mild to moderate asthma decreased parasympathetic activity and increased sympathetic modulation as assessed by isometric forearm exercise. Yoga not only causes increased parasympathetic tone but when needed decreases the highly active parasympathetic nervous system to maintain a balanced autonomic nervous system activity.

Right nostril yoga breathing can increase sympathetic tone and cardiac sympathetic activity, resulting in increased blood pressure and heart rate. Left nostril yoga breathing can decrease systolic and mean blood pressure while alternate nostril breathing can decrease both systolic and diastolic blood pressure [33]. Slow breathing exercises can improve sympathetic and parasympathetic reactivity [34]. Slow pace

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Bhastrikapranayama exercise has shown a strong tendency towards improving function of the ANS through enhanced activation of the parasympathetic system [35]. Yoga practice of cyclic meditation during the day appears to shift sympatho-vagal balance in favor of parasympathetic dominance during sleep on the following night which promotes improved quality of sleep [36]. Four months of respiratory training in Bhastrika pranayama increased respiratory function and improved cardiac parasympathetic modulation in a group of healthy elderly subjects [37]. The changes during Dhyana (meditation) [38] and guided relaxation [39] resulted in reduced activity of the sympathetic nervous system showing a shift in autonomic balance towards vagal dominance. Laughter yoga therapy for individuals awaiting heart transplant showed improvement in vigor-activity, friendliness, and long-term anxiety. It also improved HRV measures within or close to normal ranges from being low at baseline perhaps related to reduced vagal stimulation [40]. Integrated yoga practice reduced perceived stress and improved adaptive autonomic response to stress in healthy pregnant women [41].

The styles of yoga reported on in the research reviewed include Hatha yoga, viniyoga, Ishayoga, Iyengar yoga, laughter yoga, integrated yoga, yoga nidra relaxation, meditation (cancalata, ekagrata, dharana, dhyana), pranayama (Bhastrika, Kapalbhati, Anilom-vilom, Bhramari, Udgit), cyclic meditation, guided relaxation and yoga breathing practices. Yoga postures, breathing exercises, pranayama, and meditation reportedly led to a significant shift in autonomic balance towards vagal dominance, which can prevent tachycardia, an important goal in the management of AF.

Only 4 studies mentioned the number of participants who completed the studies, with attrition rates ranging from 3.3% to 54.06%. The primary reasons for participants not completing a study were drop outs, irregular attendance at intervention sessions, and relocation following study enrollment. Higher attrition occurred in 'in-person' mindfulness therapy groups (27.3%) compared to the 'online' mindfulness meditation groups (3.8%) [42], giving rise to the need to consider the format and location of yoga interventions. Also, the studies reviewed did not provide an explicit theoretical or conceptual framework to explain the basis for the yoga interventions used with the study population.

A psychoneuroimmunological framework to explain effects of yoga on AF

To address the deficit in the literature regarding theoretical or conceptual frameworks in the studies reviewed, the authors identified a psychoneuroimmunological framework adapted from McCain et al.

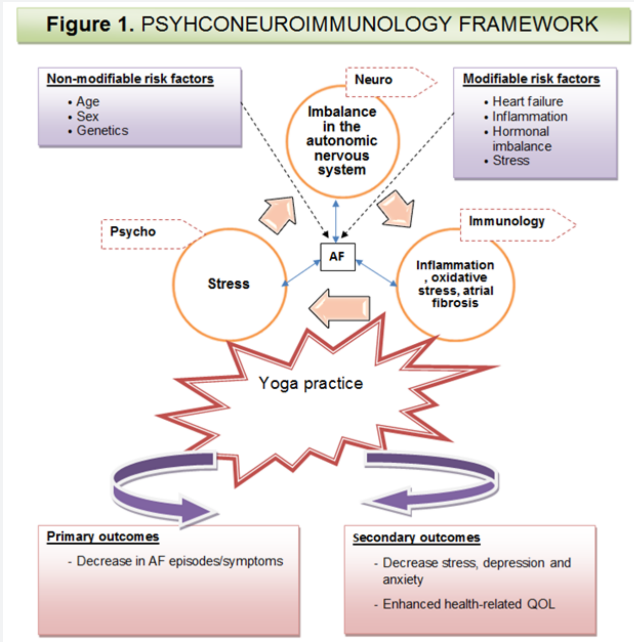

Figure 1: Depicts the non-modifiable and modifiable risk factors for development of atrial fibrillation. Psychological stress and the resulting neurological imbalance in the autonomic nervous system trigger inflammation and atrial fibrosis creating the substrate for onset and sustaining persistent atrial fibrillation. The framework indicates that yoga practice can potentially foster the electrical stability of the heart by decreasing stress and re-establishing the autonomic nervous system balance, thereby lessening AF episodes, AF symptoms, stress, depression, and anxiety, thus improving patients' health-related quality of life.

[43] shown in Figure 1 to depict the electrical, mechanical, and structural changes in the heart that lead to a stress-related imbalance in the ANS resulting in AF. Yoga interventions can potentially foster the electrical stability of the heart by maintaining ANS balance and lessening AF episodes, AF symptoms (palpitations, shortness of breath, dizziness, and fatigue), stress, depression, and anxiety, thus improving the participants' health-related QOL. Modulating factors such as stress can cause imbalance in the ANS, which, in turn, can lead to AF. Persistent AF causes inflammation and fibrosis of the atria, resulting in a fixed substrate for re-entry and consequent sustained episodes of AF [21], making treatment options to break this re-entrant cycle challenging. Triggers for atrial fibrosis include the activation of the renin-angiotensin-aldosterone system, inflammation, and oxidative stress [44]. The combination of normal and diseased atrial fibers in conjunction with local fibrosis results in spatial dispersion of atrial refractoriness and causes localized conduction abnormalities, including intra-atrial conduction block and slow conduction [44]. Thus, the interplay of stress (psycho), imbalance in the ANS (neuro), activation of the renin-angiotensin-aldosterone system, inflammation and oxidative stress resulting in atrial

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fibrosis (immuno) triggers AF and creates a substrate for persistent AF. Mind-body approaches use the concept of body and self-awareness to promote rechanneling of energy within the body thereby maintaining an internal balance. This mind-body balance can further reduce [47] psychological stressors that are important modulating factors in AF and modulate the ANS to parasympathetic dominance in maintaining a stable myocardium, thereby preventing arrhythmias.

Conclusion

Even though the time span of the yoga interventions reported in the studies reviewed ranged from a few minutes to months, all the studies demonstrated some beneficial effect in maintaining nervous system balance and significant impact on selected physiological and psychological factors, thereby improving the participants' overall QOL. Given its impact on modulating autonomic system balance and reducing psychological stress, selected styles of yoga might be considered as cost-effective complementary health approaches in managing AF episodes and symptoms. Further rigorous study is warranted to clarify further the specific mechanisms involved in the use of yoga in patients diagnosed with AF.

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