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MINIREVIEWS

Comprehensive review on the benefits and physiological basis of yoga

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Abstract

Yoga is widely considered as a method to improve psychological and physiological status of humans. A review is done about the benefits of yoga from the literature in modern medicine. The common benefits are in physical fitness, mental state, attention, processing speed, memory, cognitive functions and executive functions. Studies have demonstrated the benefits of yoga in metabolic syndrome with reduction of blood sugar, cholesterol, and hypertension. Yoga reduces the age-related deterioration in cardiovascular functions, improves cardiac performance, and makes pulmonary function better. The physiologic mechanisms of yoga are reduction of stress and inflammation, increased gray matter volume, improved neural network flexibility, and reorganization of attentional network. Several studies showed that yogic practices down-regulate the hypothalamopituitary adrenal axis and the sympathetic nervous system. Recent clinical *in vivo* experiments suggests that yoga enhances inhibitory mediator gamma-aminobutyric acid and enhances peripheral oxytocin levels. Serotonin and melatonin levels are also increased.

Key Words: Yoga; Posture; Breathing exercise; Meditation; Stress; Cognition; Inflammation

Core Tip: There is a wide array of evidence for the physiological benefits of yoga. A simple and compiled practice of asana (stable posture), pranayama (breathing exercise), and dhyana (meditation) will be an ideal wellness program to be included in holistic medicine. But the safety also should be ensured.

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INTRODUCTION

Yoga is an ancient holistic practice originated in India. It is now widely considered as a method to improve psychological and physiological status of humans. The importance of this is growing as the stresses of life and work are increasing. Yoga is widely considered as a method of relaxation and well-being. But the scientific basis is to be scrutinized. The purpose of this study is to analyze the possible scientific basis of yoga.

METHODOLOGY

A comprehensive review of literature is done in PubMed, Scopus, Google Scholar, and EMBASE for articles about yoga. There is enormous literature on yoga and its benefits. The articles from 1971 were included. Only English articles were selected. They were screened for scientific content. This is divided into three sections. The first part is about the concept and the steps of yoga from the literature on ancient knowledge. The search words were the principle and parts of yoga. The second part is about the benefits of yoga from the literature in modern medicine. The search words were the benefits of yoga: (1) Psychiatric; (2) Neurological; (3) Metabolic; (4) Cardiovascular; (5) Cardiorespiratory; (6) Musculoskeletal; (7) Inflammatory; and (8) Oncological. The reviews, meta-analyses, randomised controlled trials (RCTs), and cross-sectional surveys were analyzed. The emphasis was given for meta-analyses and RCTs. Only the articles describing the systemic benefits in modern physiological terms were included. Articles lacking in methodology were excluded. Bibliographical articles also were excluded. The third section is the search of physiological mechanisms from the literature on physiological research. Weightage was given for experimental studies. The adverse effects of yoga also were analysed subsequently. There were 10 surveys, 26 reviews, 42 clinical trials, 4 experimental studies, and 11 theoretical articles in the articles included. Three articles were those describing the principles of yoga. A descriptive analysis was done for a narrative review. The Preferred Reporting Items for Systematic reviews and Meta-Analyses flow diagram is added as Figure 1.

WHAT IS YOGA

The origin of yoga[1] is considered to be around between 3000 before the current era (BCE) to 5000 BCE, as evidenced from archeological excavations and ancient Indian scriptures including Vedas[2-6]. But it was compiled by Patanjali in the yoga sutras (300-200 BCE)[1,3-5,7]. The purpose of the yoga is the knowledge of the self, and the union of the self with the body[1,2,4-6]. The word means union. Eight steps (Astanga)[1-5] are described to achieve this: (1) Yama (universal life ethics); (2) Niyama (individual observances); (3) Asana (physical postures); (4) Pranayama (breath control); (5) Pratyahara (control of the senses); (6) Dharana (concentration); (7) Dyana (meditation); and (8) Samadhi (state of integration and peace)[6-10]. Asana means sitting, firm but relaxed, for a long period for flexibility, and meditation[8,10]. Pranayama is a 3-step method to control breathing, *viz.* inhaling, retaining, and exhaling. Dharana is concentration by focusing on a single point or object. These are the main steps towards meditation. So, the basic procedure of yoga is to sit steadily, take controlled deep breaths, and meditate with concentration.

The neuroanatomy is described in yogic literature as chakras and nadis[11-13]. Chakras are described as the centers located at the midline of the human body. The seven primary chakras are muladhara (perineum), svadhisthana (sacral plexus), manipura (solar or celiac plexus), anahata (cardiac plexus), vishuddha (throat), ajna ('third eye', pineal), and sahasrara (crown). The nadis described are ida, pingala, and sushumna. Sushumna is at the center of the spine, and ida and pingala are on the sides of the spine. Thus, it seems that the spinal cord, its levels, the plexuses, and the brain are described from below. The nadis on both sides are probably the sympathetic chains. Sahasrara means thousand-petaled and possibly describes the brain with lots of sulci and gyri. The aim of the meditation is described as to elevate the concentration and energy level to the brain through the spinal column[12]. Swadhisthana or scaral chakra was considered to be related to sexual function[13]. It is astonishing that neuroanatomy and physiology were described in BCE in a manner similar to the modern knowledge. This was at the time when the western philosophers were divided as cardiocentrists and encephalocentrists on the debate about the seat of mind. The similarity of neuroanatomy is depicted in Figure 2.

The mind and consciousness are also described in detail in yoga sutras[3,14]. The mind or chitta comprises of the conscious, subconscious and the unconscious[14]. Carl Gustav Jung, was of the opinion that Patanjali related philosophy with applied psychology and he worked on understanding of the mind and the training of the mind[15]. The inputs to the mind from the senses are to be controlled[3]. The modulations or fluctuations of mind are calmed through the meditation [3,16]. A greater concentration and focus of mind are the aims[6]. The state in meditation is compared to the trance state in hypnosis and has relaxation, altered perception, and increased concentration[14].

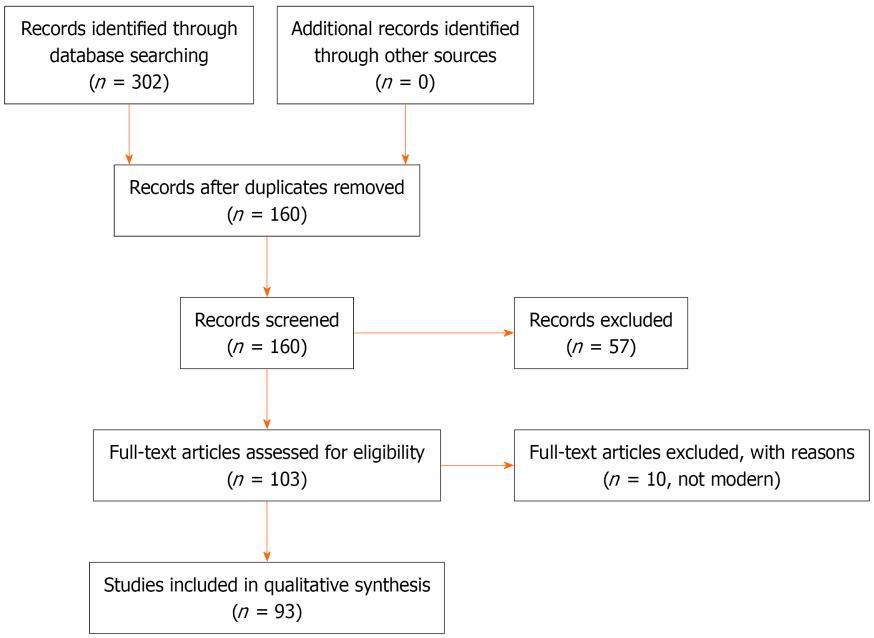

Figure 1 Preferred Reporting Items for Systematic reviews and Meta-Analyses flow diagram.

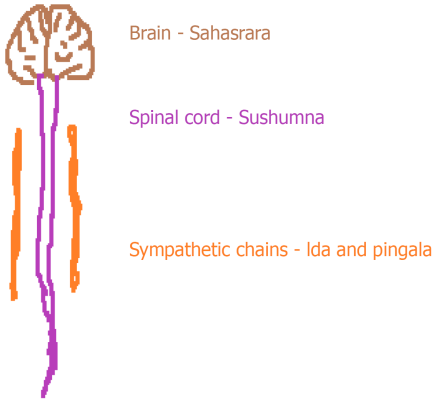

Figure 2 The similarity of yogic knowledge to neuroanatomy; brain with multitude of gyri is described as sahasrara; spinal cord is termed as sushumna; ida and pingala on sides are actually the sympathetic chains.

Yoga is practiced in several ways. Although the Astanga yoga is the comprehensive one, the Hatha yoga is the more popularly practiced one. Hatha yoga preaches mainly physical exercises, postures (asana), and breathing exercises (pranayama)[1,2,4,5,8]. This is widely adopted in the West[7,8].

So, when viewing on the basis of current knowledge, the important components of yoga are: A stable posture, deep breathing exercises, relaxation, concentration, and meditation to raise the mental status to advanced cognition. The essential components of yoga are depicted in Figure 3.

THE BENEFITS OF YOGA

There are multitude of benefits of yoga reported in literature. A cross-sectional survey by Telles *et al*[17] from India reported benefits of yoga in 94.5% of the respondents. The common benefits were improvement in physical fitness, mental state and cognitive functions. An adverse effect was reported by 1.9%. The common adverse effects were soreness and pain, muscle injuries and fatigue. The data from the2012 National Health Interview Survey showed that the prevalence of the practice of yoga was 13.2% of United States adults[18]. The positive outcomes cited were reduced stress (84.7%), improved overall health (81.0%), improved emotional wellbeing (67.5%), improved sleep (59.1%), and increased sense of control over their health (56.9%). The prevalence of practice has increased to 14.3% of the United States population in 2017[19]. Yoga can be considered as a holistic stress management technique[5]. Snaith *et al*[20] did a web-based survey in South Australian yoga practitioners in 2014 and 2015. The months of practice showed a positive correlation with mindfulness and self-compassion and negative correlation with depression, anxiety and stress scores.

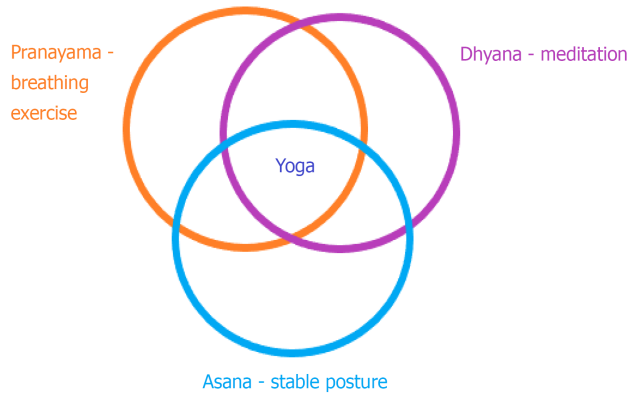

Figure 3 Essential parts of yoga-asana (stable and comfortable posture), pranayama (breathing exercise), and dhyana (meditation).

The data of 175 patients from the integrated lifestyle programs conducted at All India Institute of Medical Sciences (AIIMS) in 2002 and 2003 showed improvement in both state and trait anxiety scores with postures and breathing exercises (asanas and pranayama)[21]. Shavasana (corpse pose) has been very good for relaxation in many studies.

Psychiatric

An RCT centred in New York University showed that Kundalini yoga (KY) (based on the principle of raising energy level from the low spinal region to brain) was more efficacious for generalized anxiety disorder, compared to stress education [22]. A systematic review of eight controlled trials by Kirkwood *et al*[23] showed the encouraging results of yoga in anxiety and obsessive-compulsive disorder. Pilkington *et al*[24] reviewed five RCTs on the effects of yoga on depressive disorders and found potential benefits. A meta-analysis for ten studies by Cabral *et al*[25] showed that that yoga therapy is an effective adjunct treatment for several psychiatric disorders (*viz.* depression, anxiety, posttraumatic stress disorder, and schizophrenia). It has been found to be effective for insomnia also[5]. Recent clinical *in vivo* experiments suggests that yoga enhances inhibitory mediator gamma-aminobutyric acid (GABA) and enhances peripheral oxytocin levels[26]. Serotonin and melatonin levels are increased in yogic practitioners[5,27]. Several studies showed that yogic practices down-regulate the hypothalamopituitary adrenal (HPA) axis and the sympathetic nervous system[1,24]. Controlled studies show that yoga decreases stress and levels of salivary cortisol[28,29].

Neurological

According to the principle of yoga, meditation should improve cognition. It has been found to be beneficial in the cognitive decline of old age due to prolonged cortisol and cytokine exposure[6]. Yoga practice regulates stress and improves cognitive function. There are reports of improvement of working memory and attentive mindfulness with yoga sessions[9]. An RCT done by the National Institute of Mental Health and Neurosciences, showed that yoga-based practice for six months by the elderly had beneficial effects on cognitive functions such as delayed recall of verbal and visual memory, attention, executive function and psychomotor speed[30].

Morphometric analysis in magnetic resonance imaging (MRI) has shown that yoga practitioners have greater gray matter volume in frontal, limbic, temporal, occipital, and cerebellar regions[31]. This was associated with fewer cognitive failures than the control group (CG). Voxel-based morphometry, and cytoarchitectonic mapping have shown more gray matter in the hippocampus in those practicing meditation for 20 years, compared to controls[32]. A pilot study by Eyre *et al*[33] showed that yoga is as effective as memory enhancement training in improving functional connectivity in relation to verbal memory performance. Resting state functional MRI (fMRI) showed increased connectivity between the default mode networks and frontal medial cortex, pregenual anterior cingulate cortex, right middle frontal cortex, posterior cingulate cortex, and left lateral occipital cortex. An RCT by Grzenda *et al*[34] demonstrated that KY had a significant improvement in subjective cognitive impairment compared to memory enhancement training at 24-weeks. KY altered interferon-gamma (IFN-γ) and other aging-associated psycho-neuro-immune pathways. The levels of chemokine eotaxin-1, an aging marker, was not increased in KY practitioners.

A systematic review by Hoy *et al*[35] showed significant improvements in attention, processing speed, memory, and executive function, after a yoga-based intervention in four of six RCTs. A meta-analysis of eleven studies by Bhattacharyya *et al*[36] demonstrated that yoga-related mind-body interventions had significant beneficial effects on memory, executive function, and attention and processing speed, in the elderly with cognitive decline. A comprehensive meta-analysis of fMRI studies by Boccia *et al*[37] using the activation likelihood estimation revealed that meditation activates the brain area involved in processing self-relevant information, such as the precuneus, the area involved in processing self-regulation, focused problem-solving, and adaptive behavior, such as the anterior cingulate cortex, the area involved in interoception and in monitoring internal body states, such as the insula, the area involved in reorienting attention, such as the angular gyrus, and the areas involved in processing the "experiential enactive self", such as the premotor cortex and the superior frontal gyrus.

Metabolic

RCT and cohort studies have demonstrated the benefits of yoga in metabolic syndrome with reduction of blood sugar, cholesterol, and hypertension[38,39]. A prospective study conducted at Punjab University showed that serum levels of low-density lipoprotein, total cholesterol, and high-density lipoprotein were found significantly improved after thirty days of common yoga protocol[40]. A clinical trial in Thailand showed significant decrease in mean stress scores and blood pressure, heart rate, and body mass index levels, with a yoga program[41]. Studies have demonstrated that yogic practices decrease the blood level of catecholamines, plasma renin activity, urinary vanillylmandelic acid and blood pressure and enhance cardiovagal function[41-43]. These findings suggest attenuation of sympatho-adrenal and renin-angiotensin activity. A comparative study at AIIMS showed significantly lower levels of blood lactate and higher levels of antioxidant superoxide dismutase (SOD), glutathione, and catalase in practitioners as compared to non-practitioners of Sudarshan Kriya[44]. A review of 70 studies by Innes *et al*[45] showed that yoga improved the indices of the insulin resistance syndrome, including glucose tolerance and insulin sensitivity, lipid profiles, and blood pressure and reduced oxidative stress.

Cardiovascular

There are reports of benefits in cardiovascular disease also. Comparative studies have shown that yoga reduces the age-related deterioration in cardiovascular functions and improves cardiac performance[27,46]. Khattab *et al*[47] found that yogic relaxation is associated with increased RR interval, heart rate variability, and thus increased cardiac vagal modulation. A clinical trial by Manchanda *et al*[48] in AIIMS, showed that revascularisation procedures were less frequently required in the patients with coronary artery disease, doing yogic exercises. Coronary angiography repeated at one year showed regression of more lesions in the yoga group (YG). The Yoga My Heart Study, showed improvement in symptoms, arrhythmia burden, heart rate, blood pressure, anxiety and depression scores, and quality of life (QoL) in patients with paroxysmal atrial fibrillation after training in yoga[49]. The Yoga-CaRe trial in India concluded that a yoga-based cardiac rehabilitation program can improve self-rated health and return to pre-infarct activities after acute myocardial infarction[50]. Although the major adverse cardiovascular events were less in the YG, there was lack of statistical significance.

A meta-analysis of eleven RCTs by Dutta *et al*[51] showed that yoga is an effective adjunct therapy for improving peak oxygen consumption, exercise capacity, N-terminal pro-brain natriuretic peptide, and QoL in patients with for chronic heart failure (HF). A mechanistic review by Murugesan[52] compiled the possible ways of beneficial effects on cardiovascular system. Increased GABA production, decreased firing of the HPA axis, and improved baroreceptor sensitivity reduces hypertension. Reduced inflammation and oxidative stress reduces atherosclerosis. Increase in parasympathetic tone, and improvement in QT dispersion reduces arrhythmias. Decreased renin-angiotensin-aldosterone system (RAAS) activation, and reduced inflammatory and oxidative stress improves HF.

Cardiorespiratory

Many respiratory benefits are expected, since the breathing exercises are essential part of yoga. The respiratory and cardiovascular systems are functionally linked. A comparative study in Kurnool showed significantly better pulmonary function tests in the group of yoga practitioners compared to the sedentary group[53]. The tests were: Percentage of forced vital capacity (FVC), percentage of forced expiratory volume in first second (FEV1), percentage of FEV in third second, percentage of peak expiratory flow rate, and percentage of FEV1/FVC ratio. An RCT in São Paulo showed that there were significant increases in maximal expiratory pressure and maximal inspiratory pressure, and a significant decrease in the low frequency component (a marker of cardiac sympathetic modulation) and low frequency/high frequency ratio (marker of sympathovagal balance) of heart rate variability after 4 months of yoga respiratory training [54]. An RCT in Ataturk demonstrated statistically significant improvement in Asthma Control Test and Asthma Quality of Life Scale scores in bronchial asthma patients after 6 weeks of yoga sessions[55]. Yoga can be an adjuvant in the non-pharmacological management of asthma.

A meta-analysis by Anshu *et al*[56] provided moderate evidence for the efficacy of yoga as a complementary therapy in patients with mild to moderate asthma. The results showed a significant improvement in FEV1, FVC, FEV1/FVC, and peak expiratory flow rate. A meta-analysis by Li *et al*[57] demonstrated that yoga rehabilitation in patients with chronic obstructive pulmonary disease showed significant improvements in 6-minute walking distance, Borg scale scores, FEV1 value, $PaCO_2$, St. George's Respiratory Questionnaire scores, and Chronic Obstructive Pulmonary Disease Assessment Test scores.

Musculoskeletal

Musculoskeletal system benefits are also expected because physical postures and exercises are the third important part of yoga. A review by Saud *et al*[58] concluded that yoga is beneficial as a complimentary and palliative treatment for various musculoskeletal diseases including myositis, fibromyalgia, idiopathic inflammatory myopathy, chronic low back pain, and knee osteoartrhritis. A meta-analysis of RCTs by Wieland *et al*[59] showed moderate evidence in favor of yoga in improving chronic non-specific low back pain, compared to non-exercise controls at three and six months. The possible mechanisms for these changes include improved flexibility and muscular strength, increased relaxation, and improved body awareness. A literature review by Halappa[60] suggested that yoga should be integrated in sports sciences for the management of musculoskeletal injuries and associated mental trauma. The high intensity physical activities lead to immune suppression, oxidative stress, muscle damage, coronary risk, and psychiatric disorders. Yoga can counter these adverse effects. An RCT of 8-weeks yoga programme among the National Health Service employees demonstrated enhanced health-related QoL, reduced disability due to back pain, and lower absence due to musculoskeletal diseases, at

6-month follow-up[61]. The programme was found to be cost-effective.

Inflammatory

There is evidence that yoga practices modulate inflammatory markers, namely interleukin (IL)-1β, IL-6, tumour necrosis factor-alpha (TNF-α), IFN-γ, C-reactive protein (CRP) and hormones such as cortisol[2]. An RCT conducted in Jawaharlal Institute of Postgraduate Medical Education and Research, showed that twelve-week yoga therapy was beneficial for rheumatoid arthritis patients in reducing the disease activity, IL-1α, and cortisol levels[62]. An RCT in Georgia concluded that yoga may be a beneficial for exercise capacity, and inflammatory markers in the therapy for HF[63]. The markers of inflammation such as IL-6, high-sensitivity CRP, and extracellular SOD showed a significant improvement with an 8-week yoga-based program in patients with compensated systolic HF. An RCT done among the industrial workers of Lonavla showed that 12-weeks of yoga training could reduce the pro-inflammatory cytokine IL-1β and increase anti-inflammatory cytokine IL-10[64].

A systematic review by Djalilova *et al*[65] demonstrated that yoga can reduce inflammation across a multitude of chronic conditions such as heart disease, cancer, and rheumatoid arthritis. Most of the studies reported positive effects on inflammatory biomarkers *viz*. IL-6, CRP, and TNF. A meta-analysis of 26 RCTs by Mishra *et al*[66] revealed that practicing yoga can positively impact immune-mediated and inflammatory diseases by downregulating pro-inflammatory markers and increasing anti-inflammatory markers. Majority of the studies showed a significant reduction in inflammatory markers such as IL-6, TNF-α, and CRP in the YG compared to the CG. Some studies showed improvement in markers of cellular immunity *viz*. IFN-γ, IL-10, and transforming growth factor-beta; and improvement in markers of improved mucosal defense such as immunoglobulin A, IL-6, and IL-2.

Oncological

Cancers are associated with chronic deteriorating health states and psychological trauma. So, yoga can be a good adjuvant in palliation. An RCT conducted at the Bangalore Institute of Oncology resulted in significant decrease in reactive and chronic anxiety, depression and distressful symptoms, and improvement in QoL for stage II and III breast cancer patients during the various stages of conventional treatment, following yoga intervention, compared to the CG [67]. An RCT was conducted at the University of Texas M. D. Anderson Cancer Center, on the effect of Tibetan yoga in patients with lymphoma[68]. There were significant improvements in the sleep-related outcomes such as better subjective sleep quality, faster sleep latency, longer sleep duration, and less use of sleep medications. The University of Rochester Cancer Center conducted a nationwide, multicenter RCT using Yoga for Cancer Survivors program[69]. There were greater improvements in sleep quality measured by the Pittsburgh Sleep Quality Index, daytime dysfunction, wake after sleep onset, sleep efficiency, and medication use after intervention. A secondary analysis of the Yoga for Cancer Survivors study showed that there was improvement in the memory impairment also[70]. An RCT at the Ohio state university demonstrated reduction in fatigue and reduction in the inflammatory markers such as IL-6, TNF-α, and IL-1β after 3 months of yoga in breast cancer survivors[71]. A review by Lin *et al*[72] concluded that yoga improves sleep, lowers cancer-related fatigue, reduces cognitive impairment, decreases psychological distress, and decreases musculoskeletal symptoms among cancer survivors during treatment.

PHYSIOLOGICAL MECHANISMS

There are many postulates on the physiological mechanisms of yoga, based on the effects and indirect evidence. Wallace *et al*[73] described transcendental meditation as a wakeful hypometabolic physiological state. They observed decrease in respiratory rate and oxygen consumption during transcendental meditation. Electroencephalogram showed increase in the intensity of slow alpha waves and occasional theta waves. Thus, meditation seems to modify the activity of ascending reticular activating system and the autonomic centers in the brainstem. Tooley *et al*[74] postulates that higher plasma melatonin levels in the period following meditation could be the reason for the effect of yoga against stress. Jerath *et al*[75] published a hypothesis that voluntary slow deep breathing increases inhibitory neural impulses by activating stretch receptors of the lungs. Inhibitory current synchronizes neural elements in the heart, lungs, limbic system and cortex. Synchronization within the hypothalamus and the brainstem induces the parasympathetic response.

Yogic practices can change perceptions. An early study by Rani and Rao[76] demonstrated increased body awareness in Hatha yoga practitioners. A comparative study at the University of Rome demonstrated better vestibular and proprioceptive perception for Ashtanga yoga practitioners as evidenced by the verticality judgment task in the rod and frame tests[77]. Telles *et al*[78] showed increased visual perception of flickering of intermittent light of fixed luminance in yoga trainees. A study on North American yoga practitioners found neuroanatomical enhancements of the insula that were related to higher cold pain tolerance[79].

Voss *et al*[6] compiled the beneficial mechanisms of yoga as reduction of chronic stress and inflammation, increased gray matter volume, improved neural network flexibility, reorganization of default mode network, and reorganization of attentional network. A review by Riley and Park[80] showed that positive affect, self-compassion, inhibition of the posterior hypothalamus and salivary cortisol mediated the reduction in stress due to yoga. Kuntsevich *et al*[81] classified the physiological modulations of yogic practices into four pathways: (1) Humoral factors; (2) Nervous system activity; (3) Cell trafficking; and (4) Bioelectromagnetism. The mechanisms postulated were restoration of deranged physiology, promotion of homeostatic negative feedback loops over non-homeostatic positive feedback loops, and normalizing cellular signaling networks amidst stresses. Mondal described the mechanisms of yogic postures (asanas) as stretch, contraction, neuromuscular coordination, sense reduction and higher brain activation[82]. The stretch activates the

muscle spindles; the contraction activates Golgi tendon organs; and the neuromuscular coordination activates the vestibular apparatus. The action of yoga in stretching is similar to the proprioceptive neuromuscular facilitation to enhance the range of motion and the motor activity[83].

A review of studies by De and Mondal[84] concluded that yogic intervention increases the alpha, beta, and delta wave band power in frontal, central, parietal, occipital, and temporal lobes, thus improving perceived cognition, working memory, attention, and perception. Mondal[85] proposed the physiological beneficiary mechanisms of breathing exercise (pranayama) as activation of mechanoreceptors and chemoreceptors in the respiratory system and in the circulatory system, activation of the respiratory and circulatory centres in the pons and medulla, and the activation of the cerebellum, limbic system and the cerebral cortex.

A review was published by van Aalst *et al*[86] on neuroimaging of yoga comprising of 34 studies using MRI, positron emission tomography, or single-photon emission computed tomography. The consistent findings seen were increased gray matter volume in the insula and hippocampus, increased activation of prefrontal cortical regions, and functional connectivity changes within the default mode network. The cerebral blood flow was influenced according to the type and focus of the meditation. The neurotransmitter and metabolite changes observed were increased dopaminergic release, increased GABA levels, and increased N-acetyl aspartate, and decreased myoinositol[87-89]. Increased GABA level is associated with stress reduction. N-acetyl aspartate is the indicator of neuronal integrity and myoinositol is the indicator of glial cell damage.

Finally, there are studies revealing that yoga can influence the expression of genes also[90]. An RCT was conducted at the University of California Los Angeles to know the effect of yoga intervention on inflammation-related gene expression in breast cancer survivors[91]. Bioinformatics analysis indicated reduced activity of the pro-inflammatory transcription factor nuclear factor-kappa B, increased activity of the glucocorticoid receptor, and reduced activity of cyclic AMP responsive element binding protein in the YG. Another RCT conducted at University of California Los Angeles investigated the effects of Kirtan Kriya meditation on the activity of inflammatory and antiviral transcription control pathways in family dementia caregivers compared to relaxing music listening[92]. The observations were the reduced activity of nuclear factor-kappa B and increased activity of interferon response factors, suggesting a reversal of patterns linked to stress. An RCT in Sapporo Medical University found that mindfulness-based stress reduction improves cognitive function in older adults by enhancing the level of miRNA-29c in neuron-derived extracellular vesicles and preventing the neuronal loss[93].

Adverse events

There are many reports of adverse effects and events associated with yogic exercises. A cross-sectional national survey among German yoga practitioners revealed that one in five experienced at least one acute adverse effect and one in ten reported at least one chronic adverse effect[94]. The vast majority of these were musculoskeletal, *viz*. muscle or joint pain or strains. But rarely, cerebral hemorrhage and aggravation of glaucoma also occurred. Vigorous forms of yoga were associated with higher risk of injuries. It may lead to meniscal damage which is a risk factor for osteoarthritis. Studies show that poor physical health, chronic disease, and lack of supervision are the other predisposing factors for adverse effects. A large-scale Japanese survey conducted in 2508 attendees demonstrated that 27% of yoga class attendees experienced some type of adverse event[95]. The mild problems were muscular pain, joint pain, muscle cramp, dizziness, numbness, and cough. The moderate and severe events were less and included subarachnoid hemorrhage, subluxation of the hip joint, Achilles tendon rupture, arrhythmia, hyperventilation, and dyspnea. Old age, and diseases such as intervertebral disk disease, high or low blood pressure, glaucoma, retinal detachment, and atherosclerosis can predispose to adverse events. These can be reduced and prevented by training of instructors, establishing safety guidelines, and updating students with safe practices[96]. Vigorous steps, head-down posture (Sirshasana or headstand), and hyperventilation should be avoided. The World Health Organization is in the preparation of benchmarks for training in yoga.

DISCUSSION

It can be found that yoga is actually based on the primitive neuropsychological knowledge of ancient Indian scholars. The basic idea was to concentrate on the inner neurological centers of the body and raise the consciousness level to the advanced parts of the brain. The essential components of yoga are a comfortable and stable position, breathing exercises, and meditation. The neuroanatomy described in the ancient yogic literature has resemblance to the current knowledge. The aim of yoga was narrated as to elevate the energy level from below to up through concentration and meditation. The respiration is usually an involuntary function. Breathing exercises help in regularizing such a function.

Some of the physiological benefits of yoga are repeatedly described in several studies. It enhances GABA, oxytocin, serotonin and melatonin levels. Yogic practice down-regulates the HPA axis, the sympathetic nervous system and the RAAS. It decreases the blood level of catecholamines, plasma renin activity, vanillylmandelic acid, and salivary cortisol. Yogic practitioners have lower levels of blood lactate and higher levels of antioxidant SOD, glutathione, and catalase. The studies show a significant reduction in inflammatory markers such as IL-6, TNF-α, and CRP with yoga. There is improvement in markers of cellular immunity *viz*. IFN-γ, IL-10, and transforming growth factor-beta; and improvement in markers of improved mucosal defense such as immunoglobulin A, IL-6, and IL-2. The fMRI showed increased connectivity between the default mode networks and frontal medial cortex, pregenual anterior cingulate cortex, right middle frontal cortex, posterior cingulate cortex, and left lateral occipital cortex. Another inference from fMRI studies is that meditation activates the areas such as precuneus, anterior cingulate cortex, insula, angular gyrus, premotor cortex and the superior frontal gyrus.

Table 1 Benefits of yoga

Systems	Mechanism	Benefits
Psychiatric	Enhances gamma-aminobutyric acid, oxytocin, serotonin and melatonin levels	Useful in stress, anxiety, insomnia, depression, obsessive compulsive disorder, posttraumatic stress disorder, and schizophrenia
Neurological	Increased grey matter volume, improved neural network flexibility, and modulation of ascending reticular activating system	Improvement in cognitive functions such as memory, attention, executive function and psychomotor speed
Metabolic	Reduction of blood sugar, cholesterol, hypertension, and oxidative stress	Reduction of blood pressure, heart rate, and body mass index and improvement of glucose tolerance
Cardiovascular	Down-regulation of the hypothalamopituitary adrenal axis, the sympathetic nervous system and the renin-angiotensin-aldosterone system. Reduction in oxidative stress	Increased RR interval, heart rate variability, improved peak oxygen consumption, and exercise capacity. Reduction in atherosclerosis
Respiratory	Improvement in FEV1, FVC, FEV1/FVC, and peak expiratory flow rate	Better disease control in asthma patients, and better 6-minute walking distance of chronic obstructive pulmonary disease patients
Musculoskeletal	Activation of the muscle spindles by stretch, activation of Golgi tendon organs by contraction, improved flexibility, and increased relaxation	A complimentary treatment for myositis, fibromyalgia, idiopathic inflammatory myopathy, chronic low back pain, and knee osteoartrhritis
Inflammatory	Reduction ininterleukin-6, tumour necrosis factor-alpha, and C-reactive protein	Reduction of inflammation in chronic conditions such as heart disease, cancer, and rheumatoid arthritis
Oncological	Decrease in anxiety, better sleep quality, and reduction of inflammation	Improvement of sleep, reduction of fatigue, reduction of cognitive impairment, decrease of psychological distress, and amelioration of musculoskeletal symptoms in cancer survivors

FEV: Forced expiratory volume; FVC: Forced vital capacity.

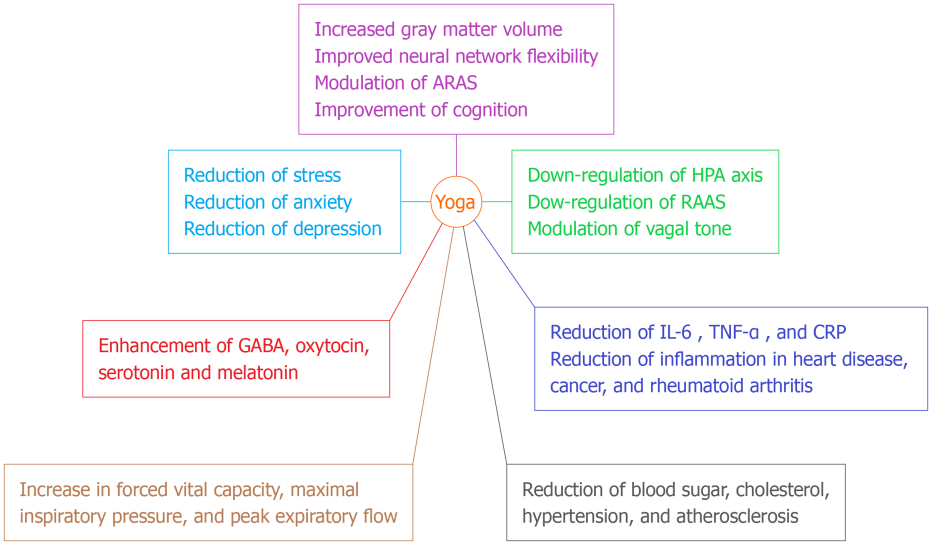

Figure 4 Summary of physiological benefits of yoga in different systems. ARAS: Ascending reticular activating system; CRP: C reactive protein; GABA: Gamma-aminobutyric acid; HPA: Hypothalamopituitary adrenal; IL-6: Interleukin-6; RAAS: Renin-angiotensin-aldosterone system; TNF-α: Tumor necrosis factor alpha.

The safety of the practices also should be ensured. There are reports of major adverse events such as cerebral and subarachnoid hemorrhage, cardiac arrhythmia, and dyspnea. It will be ideal if the diverse yogic practices are simplified and compiled into simple and stable posture (asana), breathing exercises (pranayama), and meditation (dhyana). This should be according to the principles, the proven benefits, and the safety. The main risks are associated with complicated postures (asana). So, it will be ideal if the postures are made simple and safe. Prior consultation and supervision of a doctor also will add to safety. The beneficial effect of yoga is summarized in Table 1 and Figure 4. The guidelines to reduce adverse events are summarized in Table 2.

Table 2 Guidelines to prevent adverse events during yoga

Guidelines
Standardisation of practices with essential steps: Posture (asana), breathing exercise (pranayama), and meditation (dhyana)
Avoidance of vigorous exercises, headstand (sirshasana), and hyperventilation
Practices under supervision
Training of instructors
Frequent health check-ups during practices

CONCLUSION

Yoga is an ancient Indian practice which is very beneficial for holistic medicine. The essential components are asana (stable posture), pranayama (breathing exercise), and dhyana (meditation). The neuroanatomy described in the yogic literature has striking similarities with the current knowledge. There are a lot of studies on the benefits of yoga. The positive effects repeatedly seen in the studies are: (1) Reduction of stress; (2) Increased gray matter volume; (3) Improved neural network flexibility; (4) Modulation of ascending reticular activating system; (5) Improvement of cognition; (6) Down-regulation of HPA axis and the RAAS; (7) Modulation of vagal tone, enhancement of GABA, oxytocin, serotonin and melatonin levels; and (8) Reduction of inflammatory markers such as IL-6, TNF-α, and CRP. The safety of the practices also should be ensured in view of the adverse events such as cerebral, subarachnoid hemorrhage, and cardiac arrhythmia.

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