EFFECT OF YOGIC PRACTICES ON DIFFERENT SYSTEMS OF HUMAN BODY

Dr Madanmohan MD
Professor and Head, Department of Physiology &
Programme Director, ACYTER, JIPMER, Puducherry – 605 006

INTRODUCTION: The term "yoga" and the English word "yoke" are derived from Samskrit root "yuj" which means union. Yoga is a psycho-somatic-spiritual discipline for achieving union & harmony between our mind, body and soul and the ultimate union of our individual consciousness with the Universal consciousness (Madanmohan, 2008). Yoga is mind-body technique which involves relaxation, meditation and a set of physical exercises performed in sync with breathing. Being holistic, it is the best means for achieving physical, mental, social and spiritual well being of the practitioners. This can be achieved by systematic and disciplined practice of ashtang (eight-limbed) yoga described by sage Patanjali. The first two limbs of ashtang yoga are yam and niyam which are ethical code and personal discipline for the development of our moral, spiritual and social aspects. 3rd and 4th limbs are asan and pranayam which help in our physical development and improvement of physiological functions. 5th and 6th limbs are pratyahar and dharna for controlling our senses and making our mind one-pointed, calm and alert. The final two limbs of dhyan and samadhi result in inner peace, ecstasy, higher level of consciousness and the ultimate union of our individual consciousness with the Universal Consciousness, resulting in God realization. The result is unfoldment of a unique spiritual personality that is a blessing for the whole humanity. Yoga helps in developing our total personality in an integrated and holistic manner.

Relevance to medical professionals: Healthy life can be considered as a by-product of practicing yogic techniques since it has been observed that yoga practitioners are physically and mentally healthier and have better coping skills to stressors than the normal population. Yoga is widely practiced and globally accepted. Hence, it can be very well integrated as a health promoting tool in our society. Healthy people as well as patients may inquisitively approach medical professionals to take consultation about yoga. Yoga is an experiential science. If this knowledge about yoga invokes interest in the medical professionals and they practice it themselves, it might open up new avenue in bringing together our traditional heritage of yoga and today's' objective knowledge of modern medicine. Documented scientific evidence strongly indicates that yoga has promotive, preventive as well as curative potential. As a non-pharmaco therapeutic and safe modality, it can be used as an effective lifestyle adjunct to medical treatment to reduce drug dosage and improve quality of life of the patients. It is to be emphasized that yoga is very effective for prevention as well as management of all-pervading stress and stress-related disorders. Modern medicine is very effective in controlling infections, performing surgeries and managing diseases. However, it has limited role in stress-based, chronic degenerative, old age and lifestyle related disorders which are the bane of modern society. Yoga has been found to be very effective in these conditions. Our public health delivery system is under-staffed, fund-starved and reeling under severe economic burden. Knowledge of inexpensive, effective and easily administrable yogic techniques by health professionals will go a long way in helping us achieve the WHO goal of providing "physical, mental, spiritual and social health" to the society.

CARDIO-RESPIRATORY SYSTEM

Yoga practice leads to decrease in heart rate and blood pressure: Madanmohan et al (1983) studied the effect of shavasan and savitri pranayam (a yoga-breathing technique characterized by slow, rhythmical and deep breathing cycles) in trained subjects (yoga training > 1 year) and found significant decrease in oxygen consumption, heart rate and diastolic blood pressure. They attributed it to the ability of the subjects to achieve a state of deep psychosomatic relaxation. Shavasan alone has been shown to be effective in the treatment of hypertension (Datey et al 1969; Patel and North1975). This was attributed to a decrease in the frequency and intensity of proprioceptive and enteroceptive impulse traffic reaching the hypothalamus.

Yoga improves cardio-respiratory efficiency: Madanmohan et al (2008) have reported that yoga training of six weeks duration attenuates the sweating response to step test and produces a marked increase in respiratory pressures and endurance in 40 mm Hg test in both male and female subjects. In another study, they reported that 12 weeks of yoga practice results in significant increase in maximum expiratory pressure, maximum inspiratory pressure, breath holding time after expiration, breath holding time after inspiration, and hand grip strength (Madanmohan, 1992). Joshi et al (1992) have also demonstrated that six weeks of pranayam breathing course resulted in improved ventilatory functions in the form of lowered respiratory rate, and increases in the forced vital capacity, forced expiratory volume at the end of 1st second, maximum voluntary ventilation, peak expiratory flow rate, and prolongation of breath holding time. Similar beneficial effects were observed by Makwana et al (1988) after 10 weeks of yoga practice. Increase in inspiratory and expiratory pressures suggests that yoga training improves the strength of expiratory and as well as inspiratory muscles. Respiratory muscles are like skeletal muscles. Yogic techniques involve isometric contraction which is known to increase skeletal muscle strength. Breath holding time depends on initial lung volume. Greater lung volume decreases the frequency and amplitude of involuntary contractions of respiratory muscles, thereby lessening the discomfort of breath holding. During yoga practice, one consistently and consciously over-rides the stimuli to respiratory centers, thus acquiring control over the respiration. This, along with improved cardio-respiratory performance may explain the prolongation of breath holding time in yoga trained subjects.

Yoga improves exercise tolerance: Bera and Rajapurkar (1993) have reported that yoga training results in significant improvement in cardiovascular endurance and anaerobic threshold. This is consistent with the findings of Muralidhara & Ranganathan (1982) who have reported an improvement in cardiac recovery index after 10 week yoga training program as indicated by Harvard step test. Raju et al (1994) have found that subjects who practised pranayam could achieve higher work rates with reduced oxygen consumption per unit work and without increase in blood lactate levels. The blood lactate levels were significantly low at rest. Madanmohan et al (2004) have demonstrated that two months of yoga training decreases basal heart rate, blood pressure, rate-pressure product (RPP = heart rate x systolic blood pressure / 100) and double product (Do P = heart rate x mean blood pressure / 100) in healthy subjects. Rate-pressure product and double product are indices of myocardial oxygen consumption and load on the heart. After yoga training, a given level of exercise leads to a milder cardiovascular response, suggesting better exercise tolerance. These findings are consistent with findings of Ray et al (2001) that yoga training increases muscular endurance, delays onset of fatigue and enables one to perform work at lesser VO_2 max. Palatini (1988) has reported that in comparison to normotensives, the increase in

diastolic blood pressure in response to isometric exercise is substantially more in hypertensives. An exaggerated cardiovascular reactivity to the stressors is known to be a risk factor for cardiovascular diseases whereas reduced reactivity is an indicator of fitness. Therefore, a reduction in exercise-induced stress on cardio-vascular system by yoga training has physiological significance as well as clinical applications. Goleman and Schwartz (1976) used measures of heart rate, phasic skin conductance, self report and personality to compare meditation and relaxation group response to stressful stimuli. Subjects either meditated or rested after which they viewed films depicting accidents as stressors. Increased heart rate returned to pre-stress level more quickly in subjects practicing meditation than just relaxing. Bharshankar et al (2003) examined the effects of yoga training for more than 5 years on cardiovascular function in subjects above 40 yr of age. They found significant reduction in resting pulse rate, systolic blood pressure, diastolic blood pressure and Valsalva ratio indicating increase in baroreflex sensitivity and concluded that yoga reduces the age related deterioration in cardiovascular functions.

Yoga balances Autonomic nervous system: Autonomic nervous system consists of two limbs; sympathetic nervous system and parasympathetic nervous system. Although individual asan and pranayam practices can selectively affect sympathetic or parasympathetic nervous system, the overall effect of yoga practice is to bring a state of parasympathetic dominance. Vempati and Telles (2002) assessed the effect of yoga based guided relaxation on autonomic variables and found that power of the low frequency component of heart-rate variability spectrum reduced, whereas the power of high frequency component increased, suggesting a reduced sympathetic activity. Also, subjects with a baseline ratio of LF/HF > 0.5 showed a significant decrease in the ratio after guided relaxation, while subjects with a ratio < or = 0.5 at baseline showed no such change. The results suggest that sympathetic activity decreased after yoga based guided relaxation. Vijayalakshmi et al (2004) studied the effect of yoga based relaxation training on modulation of stress induced by isometric handgrip test in hypertensive patients and found that after 4 weeks of supervised yoga training, there was optimization of sympathetic response and restoration of autonomic regulatory reflex mechanisms. Telles et al (1994) have demonstrated that pranayam breathing through right nostril results in an increase in sympathetic activity whereas left nostril breathing reduces it. Shannahoff-Khalsa et al (1993) studied the effects of unilateral forced nostril breathing on the heart and found that forced right nostril breathing increases heart rate compared to left forced nostril breathing whereas end diastolic volume and stroke volume was more with forced left nostril breathing. These results demonstrate a unique autonomic modulation by uni-nostril breathing that can be used therapeutically. Telles et al (1993) found that after giving 3 months yoga training to sports teachers (average 8.9 years physical training), there was significant improvement in their general health in terms of body weight and blood pressure reduction and improved lung functions. There was also evidence of decreased autonomic arousal and psychophysiological relaxation, heart rate and respiratory rate reduction and improved somatic steadiness demonstrated by decreased errors in steadiness test. They suggested that practicing yoga may help to bring about a balance and optimization of autonomic functions. Sharma et al (2008) have reported a decrease in pulse and respiratory rates and increase in galvanic skin resistance in healthy subjects after 2 months practice of sahaj yoga meditation. Physiological basis of galvanic skin resistance is change in sympathetic tone occurring in the skin and subcutaneous tissue in response to a change in affective state of the subject. Changes in peripheral autonomic tone alter sweating and cutaneous blood flow, which in turn change galvanic skin resistance.

Yoga modifies coronary artery disease risk factors: Yoga has preventive, promotive as well as curative potential. Yoga based lifestyle confers so many advantages to the practitioner that beyond doubt it is the best ever designed lifestyle in the history of mankind. Scientific studies have started giving documented evidence to this belief of the practitioners. Since lifestyle related diseases such as coronary artery disease, obesity and hypertension are alarmingly on the rise in our modern society, yoga based lifestyle should be given a special place in preventing and managing these diseases. Schmidt et al (1997) found out that there was significant reduction in cardiovascular risk factors after 3 months of residential yoga and meditation training program that included low fat lacto-vegetarian diet. Body mass index, total serum and LDL cholesterol, fibrinogen, and blood pressure were significantly reduced especially in the subjects with elevated levels. Obesity is an independent risk factor for coronary artery disease (Tani et al 2009). In a study on 40 male student volunters (12-15 years), Bera and Rajapurkar (1993) found that after 1 year of yoga practice, there was significant improvement in ideal body weight, body density, cardiovascular endurance and anaerobic power. Mahajan et al (1999) demonstrated that subjects with known ischemic heart disease and as well as healthy subjects practicing yoga showed a regular decrease in all lipid parameters except HDL. Thus, the effect of yogic lifestyle on some of the modifiable risk factors could probably explain the preventive and therapeutic beneficial effect observed in coronary artery disease. Murugesan et al (2000) have demonstrated that regular yoga practice of 1 hour/day done for a period of 11 weeks was as effective as medical therapy in controlling high blood pressure in hypertensive subjects. Selvamurthy et al (1998) found that baroreflex sensitivity was reduced in essential hypertension. They administered 3 week course of yoga exercises consisting of head-up and head-down tilt asanas and administered a battery of tests including cardiovascular responses to head-up tilt, cold pressor response at 4 ^{o}C, alpha index of EEG, blood catecholamines and plasma renin activity. Results showed that at the end of 3 weeks, there was significant reduction in blood pressure in the patients indicating gradual improvement in baroreflex sensitivity. Likewise, changes in other parameters indicated progressive attenuation of sympatho-adrenal and renin-angiotensin activity. Similar beneficial changes have been found with the practice of various forms of meditation. Barnes et al (2004) reported decrease in heart rate and systolic & diastolic blood pressure in school children after 3 months of meditation practice.

Reversal of Heart disease: Manchanda et al (2000), Ornish et al (1990) and Yogendra et al (2004) have conducted prospective, randomized and controlled trials on angiographically proven coronary artery disease patients with yoga intervention for 1 year and demonstrated that yoga based lifestyle modification helps in regression of coronary lesions and improvement in myocardial perfusion. This translated into clinical and symptomatic improvement.

MUSCULOSKELETAL SYSTEM

Scientific studies on yoga demonstrate that yoga improves dexterity, strength and musculo-skeletal coordination of the practitioners. Postures assumed during yoga practice are mainly isometric exercises which provide optimally maintained stretch to the muscles. Series of asans involve assumption of the pose followed by counterpose i.e. it involves co-ordinated action of synergistic and antagonistic muscles which brings increased steadiness, strength, stamina, flexibility, endurance, anaerobic power, better neuro-muscular coordination and improved ortho-static tolerance. Body weight is itself used to provide load to the muscles and bones. This load

bearing strengthens the bones and prevents age-related weakening, thus helping in prevention of osteoporosis. A properly selected set of exercises stretches nearly all joints and joint capsules without much danger of injuries and exhaustion. Bera and Rajapurkar (1993) have reported significant improvement in ideal body weight, body density, cardiovascular endurance and anaerobic power as a result of 1 year yoga training in children aged 12-15 years. Clearly, yoga practices should be started at an early life. Hart and Tracy (2008) studied effects of Bikram yoga on strength, steadiness and balance in 10 young adults (29 +/- 6 years). 24 yoga sessions of supervised, standardized postures for 1.5 hr were conducted for 8 weeks. They reported that even short-term yoga program of this type in young adults improved the balance, produced modest improvements in leg strength, and improved leg muscle control for less steady subjects. Dhume and Dhume (1991) compared the relative effectiveness of dextroamphetamine and yogic meditation on the performance of medical students to concentrate on the task to balance on a balance board. The performance of meditators went on steadily and progressively increasing throughout the period of 10 trial days with overall percentile rise of 27.8% while amphetamine use deteriorated the task performance of students. Therefore, yogic meditation is of merit to achieve concentration for mental as well as physical task such as neuro-muscular coordination and dexterity. Raghuraj and Telles (2008) studied the effect of breathing through one nostril on the lateralization of hand grip strength.130 right hand dominant school children 11 to 18 yr were randomly assigned to 5 groups. Each group had a specific yoga practice in addition to the regular program for a 10 day yoga camp. The practices were: (i) right-, (ii) left-, (iii) alternate nostril breathing (iv), breath awareness and (v) practice of mudras. Hand grip strength of both hands was assessed initially and at the end of 10 days for all 5 groups. The right, left and alternate nostril breathing groups had a significant increase in grip strength of both hands, ranging from 4.1% to 6.5% without any lateralization effect. The breath awareness and mudra groups showed no change. Hence, this study suggests that yoga breathing through a particular nostril or through alternate nostrils increases hand grip strength of both hands without lateralization. Raju et al (1994) demonstrated that in trained athletes, practice of pranayam for 2 years resulted in achieving higher work rates with reduced oxygen consumption per unit work and without any increase in blood lactate levels. Also, the blood lactate levels were significantly lower at rest in the athletes after pranayam practice. Ray et al (2001) studied the effect of training in hatha yogic exercises on aerobic capacity and perceived exertion after maximal exercise in young adults. They found that absolute value of VO_2 max increased significantly in the yoga group after 6 months of training. The perceived exertion scores after maximal exercise decreased significantly in the yoga group after the 6 months training period. Therefore, the practice of hatha yogic exercises along with games helps to improve aerobic capacity. Chaya et al (2006) found that yoga practices (asan, meditation and pranayama) for a minimum period of six months results in significantly lower basal metabolic rate of the yoga practitioners as compared to that of the non-yoga group. It may be linked to reduced arousal, with the long term practice of yoga using a combination of stimulatory and inhibitory yogic practices. DiBenedetto et al (2005) reported that 8 week Iyengar hatha yoga practice improved hip extension, increase stride length, and decrease anterior pelvic tilt in healthy elders and that yoga programs tailored to elderly adults may offer a cost-effective means of preventing or reducing age-related changes in these indices of gait function.

YOGA PROMOTES PHYSICAL FITNESS

Yogic techniques are known to improve one's overall performance and work capacity. Sharma et al (2008) conducted prospective controlled study to explore the short-term impact of a comprehensive but brief lifestyle intervention based on yoga, on subjective well being in normal and diseased subjects. Normal healthy individuals and subjects having hypertension, coronary artery disease, diabetes mellitus or a variety of other illnesses were included in the study. They reported significant improvement in the subjective well being scores of 77 subjects within a period of 10 days as compared to controls. Therefore, even brief intervention can make an appreciable contribution to primary prevention as well as management of lifestyle diseases. Oken et al (2006) found that hatha yoga practices for 6 months by seniors (65-85 years) resulted in significant improvement in quality of life and physical measures compared to walking exercise and wait-list control groups.

NERVOUS SYSTEM

Scientific evidence shows that practice of yoga and meditation has tremendous impact on the functioning of nervous system. Yoga promotes relaxation in the practitioners but at the same time helps them in increasing their attention and other cognitive abilities.

Electroencephalographic (EEG) studies: EEG studies show that yoga and meditation practice lead to increase in alpha rhythm, inter-hemispheric coherence & homogeneity in the brain. Alpha rhythm is prominent in awake adults in relaxed state with eyes closed. Its frequency varies from 8-13 Hz and amplitude varies from 50-100 microvolts. Each region has characteristic alpha rhythm but alpha waves of greatest amplitude are recorded from the occipital and parietal regions of cerebral cortex. Meditation entrains the focus of the practitioner on the inner or outer object of focus, which brings about clarity of thought, reduces number of mental distractions and increases relaxed awareness. This ultimately leads to increased concentration and improvement in other important cognitive domains. Khare and Nigam (2000) studied EEG of 30 normal healthy individuals practicing meditation and found that the percentage of alpha waves and coherence was higher in them. This suggested good homogeneity, uniformity and increased orderliness of brain. Sharma et al (2007) also found an increase in alpha activity in healthy subjects after 2 months practice of Sahaj yoga meditation. Sarang & Telles (2006) studied the impact of cyclic meditation consisting of yoga postures interspersed with periods of supine rest on EEG. They found significant reduction of peak latencies of P300 and increase in P300 peak amplitudes in the yoga practitioners. These results demonstrate that cyclic meditation enhances cognitive processing underlying generation of the P300. Stancák Jr & Kuna (1994) found after 10 min of forced alternate nostril breathing by trained practitioners, there was increase in mean power of beta band and partially alpha band of EEG. Also, there was decrease in hemisphere asymmetry in the beta 1 band. This shows that forced alternate nostril breathing has a balancing effect on the functional activity of the left and right brain hemispheres.

***Sleep*:** Yoga has been reported to increase the quality of sleep. Patra and Telles (2009) studied the effect of cyclic meditation, a technique that combines yoga postures interspersed with supine rest on polysomnographic measures and self rating of sleep on the night following the day on which 30 male participants practiced cyclic meditation. This was compared with another night when they had had two sessions of supine rest of equal duration on the preceding day. On the night following cyclic meditation, the percentage of slow wave sleep was significantly higher than in the night following

supine rest, whereas the percentage of rapid eye-movement sleep and the number of awakenings per hour were less. Following cyclic meditation, the self rating of sleep based on visual analog scales showed an increase in the feeling that the sleep was refreshing, an increase in feeling "good" in the morning, an overall increase in sleep duration, and decreases in the degree to which sleep was influenced by being in a laboratory as well as any associated discomfort. It was concluded that practicing yoga postures in a particular sequence can improve the objective and subjective quality of sleep of the participants.

Yoga practice decreases Anxiety levels: A large number of studies show that the practice of yoga can produce significant decrease in the basal anxiety scores. Khalsa et al (2009) found that two months of yoga and meditation techniques can reduce performance anxiety and mood disturbance in young professional musicians. Javnbakht et al (2009) reported that participation in a two-month yoga program lead to a significant reduction in perceived levels of anxiety in women who suffered from anxiety disorders. Kozasa et al (2008) reported significant reduction in scores on anxiety, depression, and tension after one month practice of yoga program. Woolery et al (2004) found that subjects who participated in a 5 week yoga course demonstrated significant decreases in self-reported symptoms of depression and trait anxiety. Sharma et al (2005) found that two months of sahaj yoga meditation by patients of major depression who were on anti-depressant medication led to higher rates of remission, statistically more reduction in Hamilton depression and anxiety scores as compared to those patients who were only on anti-depressant medication. Similarly, Michalsen et al (2005) reported that 3 month Iyengar yoga program for women suffering from mental distress resulted in significant improvements in perceived stress, state and trait anxiety, subjective well-being, vigor and decrease in salivary cortisol, fatigue and depression. Physical well-being also increased, and those subjects suffering from headache or back pain reported marked pain relief. From this it is clear, yoga has got a potential role as a component in the management of depressive and anxiety disorders. Malathi and Damodaran (l999) studied the effect of yogic practices on anxiety status during routine activities and prior to examination in first year MBBS students. They found a decrease in their anxiety status as assessed by Spillberger's anxiety scale. In addition, the anxiety scores which rose prior to exams showed a statistically significant reduction on the day of exam. The results of the exam indicated a statistically significant reduction in number of failures in yoga group as compared to the control group. The improvement in various parameters such as sense of well being, feeling of relaxation, improved concentration, self confidence, improved efficiency, good interpersonal relationship, increased attentiveness, lowered irritability levels, and an optimistic outlook in life were some of the beneficial effects enjoyed by the yoga group as indicated by feedback score. These results point to the beneficial role of yoga in not only causing reduction in basal anxiety level but also attenuating the increase in anxiety score in stressful states such as examinations. Apparently, a decrease in anxiety scores in yoga practitioners leads to their better adjustment to the environmental & internal stressors. Therefore, they are able to perform their duties with calm disposition which improves their performance. Gupta et al (2006) reported a decrease in state and trait anxiety scores in healthy subjects as well as patients after 10 days of yoga based lifestyle intervention program. These observations suggest that even short term yoga program can lead to reduction in stress and anxiety in the individuals.

Yoga improves cognitive functions: Cognitive functions are intellectual processes by which one becomes aware of, perceives, or comprehends ideas. These functions help us to focus on the problem, process the required information, arrive at the logical conclusion, make decision and then execute the task. Studies show that practice of yogic techniques cause improvement in aspects of

perception, thinking, reasoning, and remembering the task. Yogic techniques especially dhyan and shavasan improve attentiveness. Increased attentiveness decreases response time or reaction time. Reaction time is an index of the processing ability of central nervous system and a simple means of determining sensory-motor performance. Madanmohan et al (1992) reported that yoga practice for 12 weeks results in significant reduction in visual and auditory reaction times in the normal adult male volunteers. Malathi and Parulkar (1989) also reported reduction in auditory and visual reaction time after yoga training. Similar, findings were also demonstrated by the practice of mukh bhastrika pranayam (a yogic technique in which breath is actively blasted out in 'whooshes' following a deep inspiration) on reaction time (Bhavanani et al, 2003). A decrease in reaction time indicates an improved sensory-motor performance and enhanced processing ability of central nervous system. This may be due to greater arousal, faster rate of information processing, improved concentration and / or an ability to ignore extraneous stimuli. Sarang and Telles (2007) reported that there were improved scores and fewer errors on Letter Cancellation task; a left-hemisphere dominant task, after practice of yoga based relaxation technique. These results suggest that yoga practice brings about a greater improvement in this task which requires selective attention, concentration, visual scanning abilities, and a repetitive motor response. In another study (2006), they reported a reduction in the peak latencies of P300 after yoga based relaxation technique. Clearly, yogic meditation enhances cognitive processes underlying the generation of P300.

Scientific studies also show that unilateral forced nostril breathing affects cerebral hemispheric dominance. Telles et al (2007) evaluated the effect of three yoga breathing practices (right, left, and alternate nostril breathing) on performance of letter-cancellation task. The letter-cancellation task scores were significantly improved, i.e., there were fewer errors following right and alternate nostril yoga breathing. In another study, Joshi and Telles (2008) found that left nostril breathing increases performance of participants in the spatial cognitive task. Therefore, left nostril breathing increases the spatial tasks whereas, right nostril breathing increases verbal tasks. These results may be related to the enhancement of contralateral hemispheric function found with selective nostril breathing.

Yoga has beneficial effects on other cognitive functions. Telles et al (2006) studied the performance of participants on mirror-tracing task. The star to be traced was six pointed and the outline was made of 60 circles (4 mm in diameter). They found improved reversal ability, eye-hand co-ordination, speed and accuracy in the yoga group which is necessary for mirror star tracing. Telles et al (1997) found that one month practice of yoga led to significant decrease in the degree of optical illusion assessed by using standard Muller-Lyer lines. This can be attributed to a combination of focusing and defocusing involved in yoga practice, as these factors are known to influence the degree of illusion. Vani et al (1997) reported a progressive increase in critical flicker fusion frequency following 10 day yoga training programme. The critical flicker fusion frequency is the frequency at which a flickering stimulus is perceived to be steady, with higher values suggesting greater perceptual accuracy.

Yoga practices alter brain blood flow and brain metabolism: Herzog et al (1990) used positron emission tomography (PET) for measuring regional cerebral metabolic rate of glucose (rCMRGlc) to delineate cerebral metabolic responses to external or mental stimulation. They found that ratios of frontal vs. occipital rCMRGlc were significantly elevated during meditation. These altered ratios were caused by a slight increase of frontal rCMRGlc and a pronounced reduction in primary and secondary visual centers. Lou et al (1999) studied the impact of yog nidra on cerebral blood flow by PET scan technique and found a regional alteration of flow while the mean blood flow remains

unaltered. There is increased blood flow to posterior sensory and associative cortices known to participate in imagery tasks during meditation whereas in the resting state of normal consciousness, differential activity was found in dorso-lateral and orbital frontal cortex, anterior cingulate gyri, left temporal gyri, left inferior parietal lobule, striatal and thalamic regions, pons and cerebellar vermis and hemispheres, structures thought to support an executive attentional network. These findings enhance our understanding of the neural basis of different aspects of consciousness. Recent studies have shown that yoga and meditation practices have benefit not only on higher-order cognitive functions but they also alter brain structures and therefore, brain activity. Holzel et al (2008) compared MRI brain images of mindfulness (vipassana) meditators (2 hr daily practice for 8.6 years) and compared the regional gray matter concentration to that of non-meditators matched for sex, age, education and handedness. Meditators had greater gray matter concentration in the right anterior insula, which is involved in interoceptive awareness. This group difference presumably reflects the training of bodily awareness during meditation. Furthermore, meditators had greater gray matter concentration in the left inferior temporal gyrus and right hippocampus. These regions are deeply involved in meditation. The mean value of gray matter concentration in the left inferior temporal gyrus was predictable by the duration of meditation training, corroborating the assumption of a causal impact of meditation training on gray matter concentration. These results suggest that meditation practice is associated with structural differences in regions that are typically activated during meditation and in regions that are relevant for the task of meditation. In another recent study, Luders et al (2009) studied anatomical correlates of long-term meditation and found significantly larger gray matter volumes in meditators in the right orbito-frontal cortex, right thalamus and left inferior temporal gyrus. In addition, meditators showed significantly larger volumes of the right hippocampus. Both orbito-frontal and hippocampal regions have been implicated in emotional regulation and response control. Thus, larger volumes in these regions might account for meditators' singular abilities and habits to cultivate positive emotions, retain emotional stability, and engage in mindful behavior. These changes seem to be independent of a specific style and practice of meditation. Future longitudinal analyses are necessary to establish the presence and direction of a causal link between meditation practice and brain anatomy.

***Neuro-transmitters*:** Regular practice of yoga and meditation alters levels of various neuro-transmitters in the brain. Kjaer et al (2002) used PET scan technique to demonstrate 65% increase in endogenous dopamine release in the ventral striatum during yoga nidra meditation. Yoga nidra is associated with decreased blood flow in prefrontal, cerebellar and subcortical regions, structures thought to be organized in open loops subserving executive control. In the striatum, dopamine modulates excitatory glutamatergic synapses of the projections from the frontal cortex to striatal neurons, which in turn project back to the frontal cortex via the pallidum and ventral thalamus. They found that increased striatal dopamine release during meditation is associated with the experience of reduced readiness for action. They suggested that being in the conscious state of meditation causes a suppression of cortico-striatal glutamatergic transmission which provides in vivo regulation of conscious states at the synaptic level. Streeter et al (2007) demonstrated that in experienced yoga practitioners (n=8), brain GABA levels increase after a session of yoga. Yoga practitioners completed a 60 minute yoga session and comparison subjects completed a 60 minute reading session. This suggests that the practice of yoga should be explored as a treatment for disorders with low GABA levels such as depression and anxiety disorders.

STRESS: Stress is known to adversely affect immune functions and neuroendocrine axis of the body which leads to various disease states. Reactive oxygen species have been implicated in the etiology of a host of degenerative diseases including cardiovascular disease, diabetes, cancer, Alzheimer's disease, and other neurodegenerative disorders and in aging. In addition, they also play a role not only in acute conditions such as trauma, stroke and infection, but also in physical exercise and stress. Maini (2000) studied the effect of Sahaj yoga meditation on lipid peroxidation in 60 young medical students in the age group of 17-20 years and found a statistically significant decrease in malonyl di aldehyde levels and increase in RBC count, packed cell volume, total leucocyte count, and mean corpuscular fragility. They concluded that sahaj yoga practice leads to a decrease in stress and decreases lipid peroxidation levels in the blood. Yadav et al (2005) measured the concentration of thiobarbituric acid reactive substances in blood as an indicator of oxidative stress at the beginning and at the end of a comprehensive yoga-based lifestyle modification program for nine days. The serum concentration of thiobarbituric acid decreased significantly from 1.72 +/- 0.72 nmoles/ml on day 1 to 1.57 +/- 0.72 nmoles/ml after intervention. This study indicates that even a brief practice of yogic lifestyle can significantly reduce oxidative stress and help in promoting healthy life. Yoga also increases immune resistance. Kochupillai et al (2005) reported increase in natural killer cells in cancer patients who had completed their standard therapy after practicing sudarshan kriya yoga & pranayam breathing techniques. Satyapriya et al (2009) studied the effect of integrated yoga practice and guided yogic relaxation on both perceived stress and measured autonomic response in healthy pregnant women. Subjects were randomized for practicing yoga and deep relaxation or standard prenatal exercises 1 hour daily. Perceived stress decreased by 31.57% in the yoga group and increased by 6.60% in the control group. They concluded that yoga practice reduces perceived stress and improves adaptive autonomic response to stress in healthy pregnant women.

ENDOCRINE AND REPRODUCTIVE SYSTEM

Studies have shown that practice of yoga orchestrates fine tuning and modulates neuro-endocrine axis which results in beneficial changes in the practitioners. Chaya et al (2008) reported significant decrease in fasting plasma insulin in the yoga practitioners. They also found that long term yoga practice (for 1 year or more) is associated with increased insulin sensitivity and attenuation of the negative relationship between body weight or waist circumference and insulin sensitivity. Manjunatha et al (2005) studied the effect of four sets of asanas in random order for 5 consecutive days and observed that performance of asanas led to increased sensitivity of B cells of pancreas to the glucose signal. They proposed that this increased sensitivity is likely to be a sustained change resulting from a progressive long-term effect of asanas. Schmidt et al (1997) found a reduction in urinary excretion of adrenaline, nor adrenaline, dopamine and aldosterone, a decrease in serum testosterone and luteinizing hormone levels and an increase in cortisol excretion, indicating optimal changes in hormones. Kamei et al (2000) found changes in brain waves and blood levels of serum cortisol during yoga exercise in 7 yoga instructors and found that alpha waves increased and serum cortisol significantly decreased. Tooley et al (2000) found significantly higher plasma melatonin levels in experienced meditators in the period immediately following meditation compared with the same period at the same time on a control night. It was concluded that meditation can affect plasma melatonin levels. It remains to be determined whether this is achieved through decreased hepatic metabolism of the hormone or via a direct effect on pineal physiology. Either way, facilitation of higher physiological melatonin levels at appropriate times of day might be one avenue through

which the claimed health promoting effects of meditation occur. In another study, Harinath et al (2004) evaluated the effects of 3 month hatha yoga practice and Omkar meditation on melatonin secretion in healthy subjects. Yoga group subjects practiced selected yogic asanas for 45 minutes and pranayam for 15 minutes during the morning, whereas during the evening hours these subjects performed preparatory yogic postures for 15 minutes, pranayam for 15 minutes, and meditation for 30 minutes daily for 3 months. Results showed that yoga practice for 3 months resulted in an improvement in cardiorespiratory performance and psychological profile. The plasma melatonin also showed an increase after three months of yogic practice. Also, the maximum night time melatonin levels in yoga group showed a significant correlation with well-being score. These observations suggest that yogic practices can be used as psychophysiologic stimuli to increase endogenous secretion of melatonin, which, in turn, might be responsible for improved sense of well-being.

***Effect on pregnancy*:** Narendran et al (2005) found that yoga practices including physical postures, breathing, and meditation practiced by pregnant women one hour daily resulted in an increase in birth weight, decrease in preterm labor, and decrease in IUGR either in isolation or associated with PIH, with no increased complications. Beddoe et al (2009) found that women practicing yoga in their second trimester reported significant reductions in physical pain from baseline to post intervention. Women in their third trimester showed greater reductions in perceived stress and trait anxiety. From this it is clear that yoga can be used to prevent or reduce obstetric complications.

CONCLUSIONS

Yoga affects every cell of the body. It brings about better neuro-effector communication, improves strength of the body, increases the optimum functioning of all organ-systems, increases resistance against stress and diseases and brings tranquility, balance, positive attitude and equanimity in the practitioner which makes him lead a purposeful and healthier life.

REFERENCES

1. Barnes VA, Davis HC, Murzynowski JB, Treiber FA. Impact of meditation on resting and ambulatory blood pressure and heart rate in youth. Psychosom Med. 2004; 66: 909-14.
2. Beddoe AE, Paul Yang CP, Kennedy HP, Weiss SJ, Lee KA. The effects of mindfulness-based yoga during pregnancy on maternal psychological and physical distress. J Obstet Gynecol Neonatal Nurs. 2009; 38:310-9.
3. Bera TK and Rajapurkar MV. Body composition, cardiovascular endurance and anaerobic power of yogic practitioner. Indian J Physiol Pharmacol 1993; 37: 225-228.
4. Bharshankar JR, Bharshankar RN, Deshpande VN, Kaore SB, Gosavi GB. Effect of yoga on cardiovascular system in subjects above 40 years. Indian J Physiol Pharmacol. 2003; 47: 202-206.
5. Bhavanani AB, Madanmohan, Udupa K. Acute effect of Mukh bhastrika (a yogic bellows type breathing) on reaction time. Indian J Physiol Pharmacol. 2003; 47: 297-300.
6. Chaya MS, Kurpad AV, Nagendra HR, Nagarathna R. The effect of long term combined yoga practice on the basal metabolic rate of healthy adults. BMC Complement Altern Med. 2006 ;6: 28
7. Chaya MS, Ramakrishnan G, Shastry S, Kishore RP, Nagendra H, Nagarathna R, Raj T, Thomas T, Vaz M, Kurpad AV. Insulin sensitivity and cardiac autonomic function in young male practitioners of yoga. Natl Med J India. 2008; 21: 215-6.
8. Datey KK, Deshmukh SN, DalviCP, Vinekar SL. "Shavasana": A yogic exercise in the management of hypertension'. Angiology 1969; 20: 325-333.
9. Dhume RR and Dhume RA. A comparative study of the driving effects of dextroamphetamine and yogic meditation on muscle control for the performance of balance board. *Indian Journal Physiol Pharmacol* 1991; 35: 191-94.

10. DiBenedetto M, Innes KE, Taylor AG, Rodeheaver PF, Boxer JA, Wright HJ, Kerrigan DC. Effect of a gentle Iyenger yoga program on gait in the elderly: an exploratory study.Arch Phys Med Rehabil. 2005; 86: 1830-7.
11. Goleman D J and Schwartz G. E. Meditation as an intervention in stress reactivity. *J Consult Clin Psychol.* 1976 Jun; 44: 456-66.
12. Gupta N, Khera S, Vempati RP, Sharma R, Bijlani RL. Effect of yoga based lifestyle intervention on state and trait anxiety. Indian J Physiol Pharmacol. 2006; 50: 41-47.
13. Harinath K, Malhotra AS, Pal K, Prasad R, Kumar R, Kain TC, Rai L, Sawhney RC. Effects of Hatha yoga and Omkar meditation on cardiorespiratory performance, psychologic profile, and melatonin secretion. J Altern Complement Med. 2004; 10:261-68.
14. Hart CE, Tracy BL. Yoga as steadiness training: Effects on motor variability in young adults. J Strength Cond Res. 2008 Sep; 22: 1659-69.
15. Herzog H, Lele VR, Kuwert T, Langen KJ, Rota Kops E, Feinendegen LE. Changed pattern of regional glucose metabolism during yoga meditative relaxation. Neuropsychobiology. 1990; 23:182-7.
16. Hölzel BK, Ott U, Gard T, Hempel H, Weygandt M, Morgen K, Vaitl D. Investigation of mindfulness meditation practitioners with voxel-based morphometry. Soc Cogn Affect Neurosci. 2008; 3:55-61.
17. Javnbakht M, Hejazi Kenari R, Ghasemi M. Effects of yoga on depression and anxiety of women. Complement Ther Clin Pract. 2009; 15: 102-104.
18. Joshi LN, Joshi VD, Gokhale LV. Effect of short term 'Pranayam' practice on breathing rate and ventilator functions of lung. Indian J Physiol Pharmacol. 1992; 36: 105-108.
19. Joshi M and Telles S. Immediate effects of right and left nostril breathing on verbal and spatial scores. Indian J Physiol Pharmacol. 2008; 52:197-200.
20. Kamei T, Toriumi Y, Kimura H, Ohno S, Kumano H, Kimura K. Decrease in serum cortisol during yoga exercise is correlated with alpha wave activation. Percept Mot Skills. 2000; 90: 1027-32.
21. Khalsa SB, Shorter SM, Cope S, Wyshak G, Sklar E. Yoga Ameliorates Performance Anxiety and Mood Disturbance in Young Professional Musicians. Appl Psychophysiol Biofeedback. 2009 Aug 6. [Epub ahead of print]
22. Khare KC, Nigam SK. A study of electroencephalogram in meditators. Indian J Physiol Pharmacol. 2000 Apr; 44: 173-8.
23. Kjaer TW, Bertelsen C, Piccini P, Brooks D, Alving J, Lou HC. Increased dopamine tone during meditation-induced change of consciousness. Brain Res Cogn Brain Res. 2002; 13: 255-9.
24. Kochupillai V, Kumar P, Singh D, Aggarwal D, Bhardwaj N, Bhutani M, Das SN. Effect of rhythmic breathing (Sudarshan Kriya and Pranayam) on immune functions and tobacco addiction. Ann N Y Acad Sci. 2005; 1056:242-52.
25. Kozasa EH, Santos RF, Rueda AD, Benedito-Silva AA, De Ornellas FL, Leite JR. Evaluation of Siddha Samadhi yoga for anxiety and depression symptoms: a preliminary study. Psychol Rep. 2008; 103:271-274.
26. Lou HC, Kjaer TW, Friberg L, Wildschiodtz G, Holm S, Nowak M. A 15O-H2O PET study of meditation and the resting state of normal consciousness. Hum Brain Mapp. 1999;7:98-105.
27. Luders E, Toga AW, Lepore N, Gaser C. The underlying anatomical correlates of long-term meditation: larger hippocampal and frontal volumes of gray matter. Neuroimage. 2009; 45:672-8.
28. Madanmohan (2008). Introducing Yog to Medical Students-The JIPMER Experience: Advanced Centre for Yoga Therapy, Education and Research.
29. Madanmohan, Mahadevan SK, Balakrishnan S, Gopalakrishnan M, Prakash ES. Effect of six weeks yoga training on weight loss following step test, respiratory pressures, handgrip strength and handgrip endurance in young healthy subjects. Indian J Physiol Pharmacol 2008; 52: 164-170.
30. Madanmohan, Rai UC, Balavittal V, Thombre DP, Swami Gitananda. Cardiorespiratory changes during savitri pranayama and shavasan. The yoga review 1983; 3: 25-34.
31. Madanmohan, Thombre DP, Balakumar B, Nambinarayanan TK, Thakur S, Krishnamurthy N, Chandrabose A. Effect of yoga training on reaction time, respiratory endurance and muscle strength. Indian J Physiol Pharmacol. 1992; 36:229-33.

32. Madanmohan, Udupa K, Bhavanani AB, Shathapathy CC, Sahai A. Modulation of cardiovascular response to exercise by yoga training. Indian J Physiol Pharmacol 2004; 48: 461-465.
33. Mahajan AS, Reddy KS, Sachdeva U. Lipid profile of coronary risk subjects following yogic lifestyle intervention. Indian Heart J. 1999; 51: 37-40.
34. Maini S. The effect of Sahaja Yoga on Lipid Peroxidation. *MD Thesis*. Delhi University, 2000.
35. Makwana K, Khirwadkar N, Gupta HC. Effect of short term yoga practice on ventilatory function tests. Indian J Physiol Pharmacol. 1988 Jul-Sep; 32:202-208.
36. Malathi A and Damodaran A. Stress due to medical exams- role of yoga. Indian J Physiol Pharmacol. 1999; 43: 218-24.
37. Malathi A and Parulkar VG. Effect of yogasanas on the visual and auditory reaction time. Indian J Physiol Pharmacol. 1989; 3: 110-2.
38. Manchanda SC, Narang R, Reddy KS, Sachdeva U, Prabhakaran D, Dharmanand S, Rajani M, Bijlani R. Retardation of coronary atherosclerosis with yoga lifestyle intervention. J Assoc Physicians India. 2000; 48: 687-94.
39. Manjunatha S, Vempati RP, Ghosh D, Bijlani RL. An investigation into the acute and long-term effects of selected yogic postures on fasting and postprandial glycemia and insulinemia in healthy young subjects. Indian J Physiol Pharmacol. 2005; 49: 319-24.
40. Michalsen A, Grossman P, Acil A, Langhorst J, Lüdtke R, Esch T, Stefano GB, Dobos GJ. Rapid stress reduction and anxiolysis among distressed women as a consequence of a three-month intensive yoga program. Med Sci Monit. 2005; 11: CR555-561.
41. Muralidhara DV and Ranganathan KV. Effect of yoga practice on cardiac recovery index. Indian J Physiol Pharmacol1982; 26: 279-283.
42. Murugesan R, Govindarajulu N, Bera TK. Effect of selected yogic practices on the management of hypertension. Indian J Physiol Pharmacol. 2000; 44: 207-10.
43. Narendran S, Nagarathna R, Narendran V, Gunasheela S, Nagendra HR. Efficacy of yoga on pregnancy outcome. J Altern Complement Med. 2005; 11: 237-44.
44. Oken BS, Zajdel D, Kishiyama S, Flegal K, Dehen C, Haas M, Kraemer DF, Lawrence J, Leyva J. Randomized, controlled, six-month trial of yoga in healthy seniors: effects on cognition and quality of life. Altern Ther Health Med. 2006; 12:40-47.
45. Ornish D, Brown SE, Scherwitz LW, Billings JH, Armstrong WT, Ports TA, McLanahan SM, Kirkeeide RL, Brand RJ, Gould KL. Can lifestyle changes reverse coronary heart disease? The Lifestyle Heart Trial. Lancet. 1990; 336: 129-33.
46. Palatini P. Blood pressure behavior during physical actitvity. Sports Med 1988; 5: 353-374.
47. Patel C and North WRS. Randomised controlled trial of yoga and biofeedback in management of hypertension. Lancet 1975; 19: 93-95.
48. Patra S and Telles S. Positive impact of cyclic meditation on subsequent sleep. Med Sci Monit. 2009; 15: CR375-81.
49. Raghuraj P, Telles S. Immediate effect of specific nostril manipulating yoga breathing practices on autonomic and respiratory variables. Appl Psychophysiol Biofeedback. 2008; 33: 65-75.
50. Raju PS, Madhavi S, Prasad KV, Reddy MV, Reddy ME, Sahay BK, Murthy KJ. Comparison of effects of yoga & physical exercise in athletes. Indian J Med Res. 1994; 100:81-6.
51. Ray US, Mukhopadhyaya S, Purkayastha SS, Asnani V, Tomer OS, Prashad R, Thakur L and Selvamurthy W. Effect of exercises on physical and mental health of young fellowship trainees. Indian J Physiol Pharmacol 2001; 45: 37-53.
52. Satyapriya M, Nagendra HR, Nagarathna R, Padmalatha V. Effect of integrated yoga on stress and heart rate variability in pregnant women. Int J Gynaecol Obstet. 2009; 104:218-22.
53. Sarang SP and Telles S. Immediate effect of two yoga-based relaxation techniques on performance in a letter-cancellation task. Percept Mot Skills. 2007; 105: 379-85.
54. Sarang SP and Telles S. Changes in p300 following two yoga-based relaxation techniques. Int J Neurosci. 2006; 116:1419-30.
55. Shannahoff-Khalsa DS, Kennedy B. The effects of unilateral forced nostril breathing on heart. Int J Neurosci. 1993; 73: 47-60.
56. Sharma R, Gupta N, Bijlani RL. Effect of yoga based lifestyle intervention on subjective well-being. Indian J Physiol Pharmacol. 2008; 52: 123-31.
57. Sharma VK, Das S, Mondal S, Goswami U. Effect of sahaj yoga on autonomic patients in healthy subjects and patients of major depression. Biomedicine 2008; 28: 139-141.

58. Sharma VK, Das S, Mondal S, Goswami U, Gandhi A. Effect of sahaj yoga on depressive disorders. Indian J Physiol Pharmacol. 2005; 49: 462-68.
59. Sharma VK, Das S, Mondal S, Goswami U, Gandhi A. Comparative effect of sahaj yoga on EEG in patients of major depression and healthy subjects. Biomedicine 2007; 27: 95-99.
60. Schmidt T, Wijga A, Von Zur Mühlen A, Brabant G, Wagner TO. Changes in cardiovascular risk factors and hormones during a comprehensive residential three month kriya yoga training and vegetarian nutrition. Acta Physiol Scand Suppl. 1997; 640:158-62.
61. Selvamurthy W, Sridharan K, Ray US, Tiwary RS, Hegde KS, Radhakrishan U, Sinha KC. A new physical approach to control essential hypertension. Indian J Physiol Pharmacol. 1998; 42: 205-13.
62. Stancák A Jr, Kuna M. EEG changes during forced alternate nostril breathing. Int J Psychophysiol. 1994; 18: 75-79.
63. Streeter CC, Jensen JE, Perlmutter RM, Cabral HJ, Tian H, Terhune DB, Ciraulo DA, Renshaw PF. Yoga asana sessions increase brain GABA levels: a pilot study. J Altern Complement Med. 2007; 13: 419-26.
64. Tani S, Nagao K, Anazawa T, Kawamata H, Furuya S, Takahashi H, Iida K, Matsumoto M, Washio T, Kumabe N, Hirayama A. Association of body mass index with coronary plaque regression: 6-month prospective study. J Atheroscler Thromb. 2009; 16: 275-82.
65. Telles S, Nagarathna R, Nagendra HR, Desiraju T. Physiological changes in sports teachers following 3 months of training in Yoga. Indian J Med Sci. 1993; 47: 235-8.
66. Telles S, Nagarathna R, Nagendra HR. Breathing through a particular nostril can alter metabolism and autonomic activities. Indian J Physiol Pharmacol.1994; 38: 133-137.
67. Telles S, Nagarathna R, Vani PR, Nagendra HR. A combination of focusing and defocusing through yoga reduces optical illusion more than focusing alone. Indian J Physiol Pharmacol. 1997; 41: 179-82.
68. Telles S, Raghuraj P, Maharana S, Nagendra HR. Immediate effect of three yoga breathing techniques on performance on a letter-cancellation task. Percept Mot Skills. 2007; 104:1289-96.
69. Telles S, Praghuraj P, Ghosh A, Nagendra HR. Effect of a one-month yoga training program on performance in a mirror-tracing task. Indian J Physiol Pharmacol. 2006; 50:187-90.
70. Tooley GA, Armstrong SM, Norman TR, Sali A. Acute increases in night-time plasma melatonin levels following a period of meditation. Biol Psychol. 2000; 53: 69-78.
71. Vani PR, Nagarathna R, Nagendra HR, Telles S. Progressive increase in critical flicker fusion frequency following yoga training. Indian J Physiol Pharmacol. 1997 Jan; 41(1):71-4.
72. Vempati RP, Telles S. Yoga based guided relaxation reduces sympathetic activity judged from baseline levels. Psychol Rep. 2002; 90: 487-94.
73. Vijayalakshmi P, Madanmohan, Bhavanani AB, Patil A and Kumar Babu P. Modulation of stress induced by isometric handgrip test in hypertensive patients following yogic relaxation training. Indian J Physiol Pharmacol. 2004; 48: 59-64.
74. Yadav RK, Ray RB, Vempati R, Bijlani RL. Effect of a comprehensive yoga-based lifestyle modification program on lipid peroxidation. Indian J Physiol Pharmacol. 2005; 49: 358-62.
75. Yogendra J, Yogendra HJ, Ambardekar S, Lele RD, Shetty S, Dave M, Husein N. Beneficial effects of yoga lifestyle on reversibility of ischaemic heart disease: caring heart project of International Board of Yoga. J Assoc Physicians India. 2004; 52: 283-289.
76. Woolery A, Myers H, Sternlieb B, Zeltzer L. A yoga intervention for young adults with elevated symptoms of depression. Altern Ther Health Med. 2004; 10:60-63.