Original Article

Indian Journal of Ancient Medicine and Yoga
Volume 6 Number 3, July - September 2013

Physiological and Therapeutic Effects of Pranayama and Yogic Breathing In Health and Disease: A Focused Update

Kumar Senthil P.*, Adhikari Prabha, Jeganathan***, D'Souza Sydney C.******

Abstract

Background: Pranayama is the integral part of yoga which utilizes voluntary controlled breathing also termed as Yogic breathing.

Objective: The objective of this review paper was to describe the role of pranayama in prevention and treatment of disease through its effects on various bodily systems.

Methods: Systematic independent literature search of PubMed was done using keywords pranayama AND yogic breathing IN title by two testers. Consensus was achieved in presence of the third tester. The suitable citations were identified and selected studies were grouped under prevention and treatment of diseases for each bodily system.

Results: The final list of 33 selected studies- 19 studies on its effects on various systems in healthy subjects (cardiovascular=8, metabolic=1, autonomic nervous system=4, central nervous system=5, psychological=1), and 14 studies on its efficacy in patients with various disorders (cardiovascular=2, immunological=1, metabolic=2, pulmonary=3, neurological=2, psychological=3, adverse events=1) which unanimously showed both short-term and long-term benefits for pranayama and yogic breathing on all body systems in healthy and diseased subjects.

Conclusion: From the reviewed evidence, it is recommended that Pranayama is effective in treatment of most disease conditions and could thus be a viable and affordable treatment option for both patients with diseases and for normal individuals towards health promotion and fitness.

However, future large scale population-based pragmatic clinical trials are needed to provide strong recommendations on its effectiveness.

Key-words: Yoga; Pranayama; Alternate nostril breathing; Voluntary controlled breathing.

Introduction

Pranayama is derived from the terms 'prana' meaning life force or vital energy, and 'ayama' meaning to extend or draw out.[1] Pranayama is one of the ancient techniques developed and practised by 'yogis' or 'sages' in the historical period. The practice of pranayama dates back to ages, where it was more regarded as an 'art'. The best scientific rationale for pranayama could be understood from an example; a dog breathes at a rate of 60/min and it lives for 6 years while a tortoise breathes at a much slower rate of 1 per 6 min and it lives for 600 years. This natural example emphasizes the importance of slower rate of breathing which was practised as slow deep breathing.

Asana, pranayama, and meditation are three main techniques of yoga practiced in India over thousands of years to attain functional harmony between the body and mind. Though mind-body medicine was also part of traditional medicine, recent evidence suggested this inter-relationship through psychosomatic disorders and psychosocial issues among patients with physical

Author's Affiliation: *Founder-President, Academy of Orthopaedic Manual Physical Therapists (AOMPT)™, Freelancer Physiotherapist and private practitioner, Mangalore, India, **Professor, Department of Medicine, ***Professor, Department of Physiology, ****Professor, Department of Neurology, Kasturba Medical College (Manipal University), Mangalore, India.

Reprint's request: Senthil P. Kumar, Founder-President, Academy of Orthopaedic Manual Physical Therapists (AOMPT)™, Freelancer Physiotherapist and private practitioner, Mangalore, India.

E-mail: senthilparamasivamkumar@gmail.com

(Received on 22.04.2013, accepted on 11.06.2013)

illnesses.[2]

There is a need to establish scientific evidence for an ancient treatment technique of pranayama. Thus the objective of this review paper is to provide evidence for pranayama in promotion of health and treatment of disease through a systematic literature search of published studies.

Materials and Methods

Study design: Systematic review of published studies.

Search methods: Independent search was done by two testers using specific search strategy and consensus was obtained on discussion with the third tester.

Search strategy: Search was conducted using keywords 'pranayama OR yogic breathing OR alternate nostril breathing' IN title' in PubMed. Initial screening of obtained citations was done by title and then by abstract to assign suitability for review.

Selection criteria: Studies on pranayama in healthy subjects and in diseased individuals published in English from 1992 to 2010 that included studies on humans were included. Non-English papers and those studies without abstracts were excluded.

Data synthesis

Pranayama in health: The studies (both reviews and clinical trials) which included healthy participants as study subjects were categorized under theme 'health'.

Pranayama in disease: The studies (both reviews and clinical trials) which included diseased participants and patients as study subjects were categorized under theme 'health'.

Results-main findings

The first-level search yielded 92 citations. After elimination of duplicate citations, we got 49 potentially eligible citations. Of the final total 49 citations, 7 were non-English papers, 9 were on other types of breathing and they were excluded. The final list of 33 selected studies was then descriptively summarized as below.

There were 19 studies on its effects on various systems in healthy subjects (cardiovascular=8, metabolic=1, autonomic nervous system=4, central nervous system=5, psychological=1). There were 14 studies on its efficacy in patients with various disorders (cardiovascular=2, immunological=1, metabolic=2, pulmonary=3, neurological=2, psychological=3, adverse events=1).

Effects of pranayama on hemodynamics and cardiovascular system

Malshe[3] opined with evidence that Nisshesharechaka pranayama might offer therapeutic benefits through inducing brief intermittent hypoxia.

Pramanik *et al*[4] evaluated the immediate effect Bhramari pranayama, a slow breathing exercise for 5 minutes on heart rate and blood pressure in healthy volunteers. The systolic and diastolic blood pressures were found to be decreased with a slight fall in heart rate. Fall of diastolic pressure and mean pressure were significant. The result indicated that slow pace Bhramari pranayama for 5 minutes, induced parasympathetic dominance on cardiovascular system.

Pramanik *et al*[5] evaluated the immediate effect of slow pace bhastrika pranayama (respiratory rate 6/min) for 5 minutes on heart rate and blood pressure versus a parasympathetic blocker drug in 39 healthy volunteers. It was noted that after slow bhastrikapranayamic breathing (respiratory rate 6/min) for 5 minutes, both the systolic and diastolic blood pressure decreased significantly with a slight fall in heart rate.

Upadhyay *et al*[6] studied the responses of Alternate Nostril Breathing (ANB) the Nadisudhi Pranayama on some cardio-respiratory functions in healthy young adults. The subjects performed ANB exercise (15

minutes everyday in the morning) for four weeks. Cardio-respiratory parameters were recorded before and after 4-weeks training period. A significant increment in Peak expiratory flow rate (PEFR L/min) and Pulse pressure (PP) was noted.

Shannahoff-Khalsa *et al*[7] studied 3 males and 1 female were recorded. Fourteen beat-to-beat parameters were measured noninvasively and calculated for body surface area to yield: stroke index (SI), heart rate (HR), cardiac index, end diastolic index, peak flow, ejection fraction, thoracic fluid index, index of contractility, ejection ratio, systolic time ratio, acceleration index, and systolic, diastolic, and mean arterial pressures (MAPs). Left stroke work index (LSWI) and stroke systemic vascular resistance index (SSVRI) were calculated.

Ankad *et al*[8] studied short-term effects of pranayama and meditation on cardiovascular functions in 50 healthy individuals with respect to age, gender, and body mass index (BMI). Pre and post yoga cardiovascular functions were assessed by recording pulse rate, systolic blood pressure, diastolic blood pressure, and mean blood pressure. There was significant reduction in resting pulse rate, systolic blood pressure, diastolic blood pressure, and mean arterial blood pressure after practicing pranayama and meditation for 15 days.

Srivastava *et al*[9] studied the effects of ANB on 40 healthy subjects where respiratory rate (RR/min), heart rate (HR/min), systolic blood pressure (SBP; mm Hg), diastolic blood pressure (DBP; mm Hg), peak expiratory flow rate (PEFR; L/min) and galvanic skin resistance (GSR; microV) were recorded thrice; once as control and then after 15 min (acute exposure) and following 8 wks of training in ANB (15 min daily). The authors found decreases in RR and HR with increases in PEFR. SBP and DBP also decreased but GSR was unaffected by ANB in both males and females.

Pratap *et al*[10] studied the effects of pranayama on arterial blood gases in 10 trained individuals. On the contrary to authors' expectations, there was no significance changes in arterial blood gases noted after Pranayama.

Cardiovascular disorders

Dabhade *et al*[11] aimed to determine the effects of Pranayama (breathing exercise) on Q-T duration (QTd) in 15 patients with arrhythmia who were on a stable medical regimen.Standardized 12-lead surface ECGs were obtained at the beginning and end of the Pranayama session, and QT and JT intervals were measured manually and corrected for heart rate by using Bazett's formula. QTd, heart rate-corrected QTd (QTc-d), JT dispersion (JTd), and heart rate corrected JTd (JTc-d) were measured in at least eight ECG leads in each patient. Following the Pranayama session, patients with arrhythmia had only slight improvements in exercise capacity (results were not significant). However, these patients had marked improvements in QTd, QTc-d, JTd and JTc-d following the Pranayama session.

Bhavanani *et al*[12] determined the immediate cardiovascular effects of sukha pranayama in 23 hypertensive patients attending the Yoga OPD at JIPMER who were instructed to perform sukha pranayama for 5 minutes at the rate of 6 breaths/min. Post-intervention statistical analysis revealed a significant reduction in HR and a highly significant reduction in systolic pressure, pulse pressure, mean arterial pressure, rate-pressure product, and double product with an insignificant fall in diastolic pressure.

Immunological disorders

Brazier *et al*[13] in their randomized controlled trial evaluated the effectiveness of a group program aimed at improving well-being among individuals living with HIV/AIDS. Their intervention consisted of a residential program designed to teach breathing, movement, and meditation techniques on 47 study participants. Standardized measures used were the Mental Health Index (MHI), the MOS-HIV Health

Survey (MOS), and the Daily Stress Inventory (DSI), along with qualitative interviews. They found positive changes in well-being on the MHI and the MOS, where the effect was primarily seen immediately following the program and disappeared at later data points.

Metabolic effects

Bhattacharya *et al*[14] assessed the effect of yogic breathing exercises (pranayama) on the oxidatives stress in 30 young male volunteers, trained for the purpose of this study and an equal number of controls were used. The free radicals and Super oxide dismutase (SOD) levels were measured before the study and at the end of the study. The authors found that free radicals were decreased significantly in the study group but the SOD was increased insignificantly as compared to the control group.

Metabolic disorders

Jyotsna *et al*[15] assessed the effect of a comprehensive yogic breathing program (Sudarshan Kriya Yoga and Pranayam) versus standard treatment on glycemic control and quality of life (QoL) in patients with diabetes in a prospective randomized controlled intervention trial. Change in fasting and post-prandial blood sugars, glycated hemoglobin and QoL as assessed by the World Health Organization Quality of Life-BREF (WHOQOL-BREF) questionnaire were assessed.There was a trend toward improvement in glycemic control in the group practicing the comprehensive yogic breathing program compared with the group following standard treatment alone, although this was not significant.

Electrophysiological evidence of delayed cognition as measured by P300, an evoked potential is observed in Diabetes mellitus. P300 (or P3) is a component of endogenous cerebral evoked response that assesses higher functions of the brain. Kyizom *et al*[16] aimed to see the role of pranayama and yoga-asana on P300 latency and amplitude in 60 type 2 diabetic patients into two groups - control group on only conventional medical therapy and yoga-group on conventional medical therapy along with pranayama and yoga-asana. Statistically significant improvement in the latency and the amplitude of N200, P300 was observed in the yoga group as compared to the control group.

Effects of pranayama on autonomic nervous system

Ghiya and Lee[17] compared the immediate effects of ANB on autonomic control compared to paced breathing (PB) at the same rate in 20 healthy individuals who are inexperienced with yogic breathing. Their data suggested that there was an immediate increase in cardiac autonomic modulation following ANB and PB without a shift in autonomic balance in individuals inexperienced with yogic breathing.

Jovanov[18] presented the results of eight sessions of Nadi Shodhana Pranayama practiced at rate of one breath per minute. They characterized statistic and spectral measures of heart rate variability before, during, and after exercises. Significant changes include increase of VLF frequencies caused by slow breathing and decrease in average interbeat interval.

Raghuraj *et al*[19] studied the HRV in two yoga practices which have been previously reported to have opposite effects, viz, sympathetic stimulation (kapalabhati, breathing at high frequency, i.e., 2.0 Hz) and reduced sympathetic activity (nadisuddhi, alternate nostril breathing) on twelve male volunteers who were assessed before and after each practice on separate days. The electrocardiogram (lead I) was digitized on-line and off-line analysis was done. The results showed a significant increase in low frequency (LF) power and LF/HF ratio while high frequency (HF) power was significantly lower following kapalabhati. There were no significant changes following nadisuddhi.

Bhargava *et al*[20] studied the autonomic responses to breath-holding in 20 healthy young men when breath was held at different phases of respiration and parameters recorded

were Breath holding time, heart rate systolic and diastolic blood pressure and galvanic skin resistance (GSR). After taking initial recordings all the subjects practised Nadi-Shodhana Pranayama for a period of 4 weeks. At the end of 4 weeks same parameters were again recorded and the results compared. Baseline heart rate and blood pressure (systolic and diastolic) showed a rendency to decrease and both these autonomic parameters were significantly decreased at breaking point after pranayamic breathing.

Effects of pranayama on central nervous system

Vialette *et al*[21] reported paroxysmal gamma waves (PGW) that were observed in eight subjects practicing a yoga technique of breathing control called Bhramari Pranayama (BhPr). To obtain new insights into the nature of the EEG during BhPr, they analyzed EEG signals using time-frequency representations (TFR), independent component analysis (ICA), and EEG tomography (LORETA). They found that the PGW consists of high-frequency biphasic ripples.

Bhavanani *et al*[22] determined if mukh bhastrika has any effect on central neural processing by studying its effect on visual reaction time (VRT) and auditory reaction time (ART) in 22 healthy schoolboys (a yogic technique in which breath is actively blasted out in 'whooshes' following a deep inspiration). VRT and ART were recorded before and after nine rounds of mukh bhastrika. Mukh bhastrika produced a significant decrease in VRT as well as ART.

Raghuraj *et al*[23] studied 130 right hand dominant, school children between 11 and 18 yrs of age who 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: (1) right-, (2) left-, (3) alternate- nostril breathing (4), breath awareness and (5) 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%, at the end of the camp though without any lateralization effect suggesting a central neural mechanism of effect.

Srinivasan[24] reported on some of the recent observations of EEG changes during different types of Pranayama and their significance in health and diseases. The proposed effects of forced ANB on EEG topography were studied later by Stancak and Kuna[2] in 18 trained subjects. Mean power in the beta bands and partially in the alpha band increased during FANB irrespective of the type of nostril breathing. In addition, hemisphere asymmetry in the beta 1 band decreased in the second half of FANB suggesting that FANB has a balancing effect on the functional activity of the left and right hemisphere.

Telles *et al*[26] studied the effects of pranayama on Middle latency auditory-evoked potentials (AEP-MLRs) of 10 healthy male subjects. The results revealed that the Na-wave amplitude increased and latency decreased during the period of pranayamic practice, whereas the Pa-wave was not significantly altered.

Neurological disorders

Sendhilkumar *et al*[27] studied the add-on effects of pranayama and meditation in rehabilitation of patients with Guillain-Barré syndrome (GBS) in their randomized control pilot study of twenty-two GBS patients, who were randomly assigned to yoga and control groups. The yoga group received 15 sessions in total over a period of 3 weeks (1 h/session), one session per day on 5 days per week that consisted of relaxation, Pranayama (breathing practices) and Guided meditation in addition to conventional rehabilitation therapeutics. The control group received usual rehabilitation care. There was reduction of pain scores, anxiety and depression in both the groups without statistical significance between groups. Overall functional status improved in

both groups without significant difference.

Pulmonary disorders

Saxena and Saxena[28] studied the effects of 12-weeks breathing exercises (pranayama) in 50 patients with bronchial asthma of mild to moderate severity(Forced Expiratory Volume in one second (FEV1) > 70%). Patients were allocated to two groups: group A and group B (control group). Patients in group A were treated with breathing exercises (deep breathing,Brahmari, and Omkara, etc.) for 20 minutes twice daily for a period of 12 weeks. Patients were trained to perform Omkara at high pitch (forceful) with prolonged exhalation as compared to normal Omkara. Group B was treated with meditation for 20 minutes twice daily for a period of 12 weeks. Subjective assessment, FEV1%, and Peak Expiratory Flow Rate (PEFR) were done in each case initially and after 12 weeks. After 12 weeks, group A subjects had significant improvement in symptoms, FEV1, and PEFR as compared to group B subjects.

The authors found that breathing exercises (pranayama), mainly expiratory exercises, improved lung function subjectively and objectively.

Cooper *et al*[29] studied 90 patients with asthma taking an inhaled corticosteroid were randomised after a 2 week run in period to Eucapnic Buteyko breathing, use of a Pink City Lung Exerciser (PCLE) to mimic pranayama, or a PCLE placebo device. Subjects practised the techniques at home twice daily for 6 months followed by an optional steroid reduction phase. Primary outcome measures were symptom scores and change in the dose of methacholine provoking a 20% fall in FEV (1) during the first 6 months. The authors found that Buteyko breathing technique improved symptoms and reduced bronchodilator use but did not appear to change bronchial responsiveness or lung function in patients with asthma.

Singh *et al*[30] in their randomised, double-blind, placebo-controlled, crossover trial studied the effects of two pranayama yoga breathing exercises on airway reactivity, airway calibre, symptom scores, and medication use in patients with mild asthma. During the active period, subjects were asked to breathe through a Pink City lung (PCL) exerciser—a device which imposes slowing of breathing and a 1:2 inspiration:expiration duration ratio equivalent to pranayama breathing methods; during the control period, subjects breathed through a matched placebo device. Mean forced expiratory volume in 1 s (FEV1), peak expiratory flow rate, symptom score, and inhaler use over the last 3 days of each treatment period were assessed in comparison with the baseline assessment period; all improved more with the PCL exerciser than with the placebo device, but the differences were not significant.

Adverse pulmonary events of pranayama

Johnson *et al*[31] reported a case of 29-year old woman who presented to the emergency department with a spontaneous pneumothorax caused by a yoga breathing technique called Kapalabhati pranayama, or breath of fire, which was supposed to push the body to physiologic extremes.

Psychological effects

Kjellgren *et al*[32] studied the effects of Sudarshan Kriya and related practices (SK & P) on feeling of wellness in healthy volunteers. Participants were recruited in a small university city in Sweden and were instructed in a 6-day intensive program of SK & P which they practiced daily for six weeks. The control group was instructed to relax in an armchair each day during the same period. Subjects included a total of 103 adults, 55 in the intervention (SK & P) group and 48 in the control group.The data suggest that participants in the SK & P group, but not the control group, lowered their degree of anxiety, depression and stress, and also increased their degree of optimism. The participants in the yoga group experienced the practices as a positive event that induced beneficial effects.

Psychological disorders

Franzblau *et al*[33] studied whether abused women who give testimony about their experiences of intimate partner violence and learn how to use yogic breathing techniques have reduced feelings of depression. Their results indicated that learning yogic breathing techniques alone and combined with giving testimony significantly reduces feelings of depression.

Brown and Gerbarg[34] explained the neurophysiologic model of yogic breathing proposes to integrate research on yoga with polyvagal theory, vagal stimulation, hyperventilation, and clinical observations. Yogic breathing is a unique method for balancing the autonomic nervous system and influencing psychologic and stress-related disorders. They explained hat Sudarshan Kriya yoga (SKY), which combines pranayama (yogic breathing) asanas (yoga postures), and meditation, a sequence of specific breathing techniques (ujjayi, bhastrika, and Sudarshan Kriya) can alleviate anxiety, depression, everyday stress, post-traumatic stress, and stress-related medical illnesses.[35]

Techniques of pranayama

There were different techniques of pranayama studied by various authors in different subject populations creating a huge heterogeneity in the very definition of the term and its subsequent derivatives. For example, the various described techniques are outlined as follows;

Alternate nostril breathing (ANB) or Nadisudhi pranayama: Six studies reported effects of ANB.[6,9,17,20,23,24[

Four studies that did not adequately explain the type or the procedure of pranayama were classified under *Non-specific/undescribed pranayama.*[8,11,16,27]

Three studies reported use of *Bhramari pranayama[4,21,28]:* The subject was directed to inhale slowly up to the maximum for about 5 seconds and then to exhale slowly up to the maximum for about 15 sec keeping two thumbs on two external auditory canal, index and middle finger together on two closed eyes and ring finger on the two sides of the nose. During exhalation the subject must chant the word "O-U-Mmmma" with a humming nasal sound mimicking the sound of a humming wasp, so that the laryngeal walls and the inner walls of the nostril mildly vibrate (Bhramari pranayama, respiratory rate 3/min).

There were two studies each on *Kapalbhati pranayama,*[19,31] *Sudarshan Kriya Yoga[15,32]* and *Yogic breathing.*[13,33]

There was one study each on *Nisshesha rechaka pranayama* (breath holding at residual volume),[3] *Bhastrika pranayama* (First, subjects had to sit comfortably in an easy and steady posture (sukhasana) on a fairly soft seat placed on the floor keeping head, neck, and trunk erect, eyes closed, and the other muscles reasonably loose. The subject is directed to inhale through both nostrils slowly up to the maximum for about 4 seconds and then exhale slowly up to the maximum through both nostrils for about 6 seconds. The breathing must not be abdominal. These steps complete one cycle of slow pace bhastrika pranayama (respiratory rate 6/min). During the practice the subject is asked not to think much about the inhalation and exhalation time, but rather was requested to imagine the open blue sky),[5] *Mukha Bhastrika pranayama[22], Nadisodhana pranayama[18], Sukha pranayama* (conscious, slow and deep breathing with equal duration for inhalation and exhalation),[12] *Specific Yogic breathing* (1 breath per minute (BPM) respiratory exercise with slow inspiration for 20 seconds, breath retention for 20 seconds, and slow expiration for 20 seconds, for 31 consecutive minutes),[7] *Yogic pranayama* (exercise of consciously-controlled rhythmic breathing involving timed breath-holding in each cycle of breathing, while the subject holds utmost attention and experiences the touch of inhaled air in the nasal passage.[26]

Discussion

This is the first review of its kind, aimed to

establish current evidence for pranayama by studying its effects on various bodily systems in both healthy subjects and in diseased patients.

Pramanik *et al*[5] outlined the mechanistic role of Pranayama in the following physiological effects: "It increases frequency and duration of inhibitory neural impulses by activating pulmonary stretch receptors during above tidal volume inhalation as in HeringBruer reflex, which bring about withdrawal of sympathetic tone in the skeletal muscle blood vessels, leading to widespread vasodilatation, thus causing decrease in peripheral resistance and thus decreasing the diastolic blood pressure. After hyoscine-N-butylbromide, the parasympathetic blocker, it was observed that blood pressure was not decreased significantly as a result of pranayama, as it was observed when no drug was administered.Vagal cardiac and pulmonary mechanisms are linked, and improvement in one vagal limb might spill over into the other. Baroreceptor sensitivity can be enhanced significantly by slow breathing (supported by a small reduction in the heart rate observed during slow breathing and by reduction in both systolic and diastolic pressure). Slow pace bhastrika pranayama (respiratory rate 6/min) exercise thus shows a strong tendency to improving the autonomic nervous system through enhanced activation of the parasympathetic system."

Amongst the studies, more studies were on ANB and many authors had recommended it use since regular practice of ANB (Nadisudhi) increases parasympathetic activity.[6,9] Bhavanani *et al*[12] explained the positive effects of pranayama which may be due to a normalization of autonomic cardiovascular rhythms as a result of increased vagal modulation and/or decreased sympathetic activity and improved baroreflex sensitivity.

Bhavanani *et al*[22] also added, "greater arousal, faster rate of information processing, improved concentration and/ or an ability to ignore extraneous stimuli to be seen with yogic breathing and Raghuraj *et al*[19] said that kapalabhati modifies the autonomic status by increasing sympathetic activity with reduced vagal activity.

Telles *et al*[26] mentioned that alteration caused in information processing at the primary thalamo-cortical level during the concentrated mental exercise of inducing modifications in neural mechanisms regulating a different functional system (respiratory).

This study had its own limitations-lack of meta-analytic approach to data synthesis and descriptive approach was used to summarize the existing findings in terms of direction to answer our research question rather than the magnitude of the effect. Future large scale population-based pragmatic clinical trials are needed to provide strong recommendations on its effectiveness.

Conclusion

From the reviewed evidence, it is recommended that Pranayama is effective in treatment of most disease conditions and could thus be a viable and affordable treatment option for both patients with diseases and for normal individuals towards health promotion and fitness.

However, future large scale population-based pragmatic clinical trials are needed to provide strong recommendations on its effectiveness.

References

1. Wikipedia. Pranayama. Accessed at: http://en.wikipedia.org/wiki/Pranayama
2. Posadzki P, Glass N. Mind-body medicine: a conceptual (re)synthesis? *Adv Mind Body Med.* 2009; 24(3): 8-14.
3. Malshe PC. Nisshesharechaka pranayama offers benefits through brief intermittent hypoxia. *Ayu.* 2011; 32(4): 451-7.
4. Pramanik T, Pudasaini B, Prajapati R. Immediate effect of a slow pace breathing exercise Bhramari pranayama on blood pressure and heart rate. *Nepal Med Coll J.* 2010; 12(3): 154-7.

5. Pramanik T, Sharma HO, Mishra S, Mishra A, Prajapati R, Singh S. Immediate effect of slow pace bhastrika pranayama on blood pressure and heart rate. *J Altern Complement Med.* 2009; 15(3): 293-5.
6. Upadhyay Dhungel K, Malhotra V, Sarkar D, Prajapati R. Effect of alternate nostril breathing exercise on cardiorespiratory functions. *Nepal Med Coll J.* 2008; 10(1): 25-7.
7. Shannahoff-Khalsa DS, Sramek BB, Kennel MB, Jamieson SW. Hemodynamic observations on a yogic breathing technique claimed to help eliminate and prevent heart attacks: a pilot study. *J Altern Complement Med.* 2004; 10(5): 757-66.
8. Ankad RB, Herur A, Patil S, Shashikala GV, Chinagudi S. Effect of short-term pranayama and meditation on cardiovascular functions in healthy individuals. *Heart Views.* 2011; 12(2): 58-62.
9. Srivastava RD, Jain N, Singhal A. Influence of alternate nostril breathing on cardiorespiratory and autonomic functions in healthy young adults. *Indian J Physiol Pharmacol.* 2005; 49(4): 475-83.
10. Pratap V, Berrettini WH, Smith C. Arterial blood gases in Pranayama practice. *Percept Mot Skills.* 1978; 46(1): 171-4.
11. Dabhade AM, Pawar BH, Ghunage MS, Ghunage VM. Effect of pranayama (breathing exercise) on arrhythmias in the human heart. *Explore (NY).* 2012; 8(1): 12-5.
12. Bhavanani AB, Sanjay Z, Madanmohan. Immediate effect of sukha pranayama on cardiovascular variables in patients of hypertension. *Int J Yoga Therap.* 2011; (21): 73-6.
13. Brazier A, Mulkins A, Verhoef M. Evaluating a yogic breathing and meditation intervention for individuals living with HIV/AIDS. *Am J Health Promot.* 2006; 20(3): 192-5.
14. Bhattacharya S, Pandey US, Verma NS. Improvement in oxidative status with yogic breathing in young healthy males. *Indian J Physiol Pharmacol.* 2002; 46(3): 349-54.
15. Jyotsna VP, Joshi A, Ambekar S, Kumar N, Dhawan A, Sreenivas V. Comprehensive yogic breathing program improves quality of life in patients with diabetes. *Indian J Endocrinol Metab.* 2012; 16(3): 423-8.
16. Kyizom T, Singh S, Singh KP, Tandon OP, Kumar R. Effect of pranayama & yoga-asana on cognitive brain functions in type 2 diabetes-P3 event related evoked potential (ERP). *Indian J Med Res.* 2010; 131: 636-40.
17. Ghiya S, Lee CM. Influence of alternate nostril breathing on heart rate variability in non-practitioners of yogic breathing. *Int J Yoga.* 2012; 5(1): 66-9.
18. Jovanov E. On Spectral Analysis of Heart Rate Variability during Very Slow Yogic Breathing. *ConfProc IEEE Eng Med Biol Soc.* 2005; 3: 2467-70.
19. Raghuraj P, Ramakrishnan AG, Nagendra HR, Telles S. Effect of two selected yogic breathing techniques of heart rate variability. *Indian J Physiol Pharmacol.* 1998; 42(4): 467-72.
20. Bhargava R, Gogate MG, Mascarenhas JF. Autonomic responses to breath holding and its variations following pranayama. *Indian J Physiol Pharmacol.* 1988; 32(4): 257-64.
21. Vialatte FB, Bakardjian H, Prasad R, Cichocki A. EEG paroxysmal gamma waves during Bhramari Pranayama: a yoga breathing technique. *Conscious Cogn.* 2009; 18(4): 977-88.
22. Bhavanani AB, Madanmohan, Udupa K. Acute effect of Mukhbhastrika(a yogic bellows type breathing) on reaction time. *Indian J Physiol Pharmacol.* 2003; 47(3): 297-300.
23. Raghuraj P, Nagarathna R, Nagendra HR, Telles S. Pranayama increases grip strength without lateralized effects. *Indian J Physiol Pharmacol.* 1997; 41(2): 129-33.
24. Srinivasan TM. Pranayama and brain correlates. *Anc Sci Life.* 1991;11(1-2): 2-6.
25. Stancák A Jr, Kuna M. EEG changes during forced alternate nostril breathing. *Int J Psychophysiol.* 1994; 18(1): 75-9.
26. Telles S, Joseph C, Venkatesh S, Desiraju T. Alterations of auditory middle latency evoked potentials during yogic consciously regulated breathing and attentive state of mind. *Int J Psychophysiol.* 1993; 14(3): 189-98.
27. Sendhilkumar R, Gupta A, Nagarathna R, Taly AB. Effect of pranayama and meditation as an add-on therapy in rehabilitation of patients with Guillain-Barré syndrome-a randomized control pilot study. *Disabil Rehabil.* 2012 May 24. [Epub ahead of print]
28. Saxena T, Saxena M. The effect of various breathing exercises (pranayama) in patients with bronchial asthma of mild to moderate

severity. *Int J Yoga*. 2009; 2(1): 22-5.

29. Cooper S, Oborne J, Newton S, Harrison V, Thompson Coon J, Lewis S, Tattersfield A. Effect of two breathing exercises (Buteyko and pranayama) in asthma: a randomised controlled trial. *Thorax*. 2003; 58(8): 674-9.
30. Singh V, Wisniewski A, Britton J, Tattersfield A. Effect of yoga breathing exercises (pranayama) on airway reactivity in subjects with asthma. *Lancet*. 1990; 335(8702): 1381-3.
31. Johnson DB, Tierney MJ, Sadighi PJ. Kapalabhati pranayama: breath of fire or cause of pneumothorax? A case report. *Chest*. 2004; 125(5): 1951-2.
32. Kjellgren A, Bood SA, Axelsson K, Norlander T, Saatcioglu F. Wellness through a comprehensive yogic breathing program - a controlled pilot trial. *BMC Complement Altern Med*. 2007; 7: 43.
33. Franzblau SH, Echevarria S, Smith M, Van Cantfort TE. A preliminary investigation of the effects of giving testimony and learning yogic breathing techniques on battered women's feelings of depression. *J Interpers Violence*. 2008; 23(12): 1800-8.
34. Brown RP, Gerbarg PL. SudarshanKriya yogic breathing in the treatment of stress, anxiety, and depression: part I-neurophysiologic model. *JAltern Complement Med*. 2005; 11(1): 189-201.
35. Brown RP, Gerbarg PL. SudarshanKriya Yogic breathing in the treatment of stress, anxiety, and depression. Part II—clinical applications and guidelines. *J Altern Complement Med*. 2005; 11(4): 711-7.