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# Pranayama: The power of breath

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*Abstract:* Pranayama, the regulation of inhalation and exhalation, is accomplished by eliminating the pause between inhalation and exhalation or expending it by retention. Pranayama regulates the motion of the lungs, resulting into control of heart and vagus nerve. The science of pranayama is thus intimately connected with the autonomic nervous system and brings its functions under conscious control via breathing patterns and movements of the diaphragm and lungs. The nasal tissue is erectile similar to sex organs in men and women, which is very sensitive to breath. Control of breath constitutes an obvious starting point toward attainment of control of autonomic nervous system, which appears to have beneficial effects on the functions of omental adipocytes, brain, heart, lungs, liver, and kidney functions. The left nostril, diaphragm, and stomach are supplied by the vagus nerve, which may influence pituitary function, hypothalamus, pineal gland and suprachiasmatic nucleus. Studies conducted in Italy have shown that verbalization of *mantras* (i.e., *om-mani-padme-om*) can decrease the breathing rate, due to increased vagal activity, resulting into increased nitric oxide release when the breathing rate is brought down to less than six breaths per minute. We have observed in 101 patients of chronic bronchitis or asthma, the role of breathing patterns in their treatment. Common methods for pranayama are discussed. Further studies are necessary to establish the role of pranayama in the management of diseases.

***Keywords:*** Chronic bronchitis, heart disease, hypertension, diabetes, asthama, allergy, sinusitis

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## INTRODUCTION

From ancient times (3000 BCE), pranayama methods *anulome* and *velome*, and *kapalbhati* (Sanskrit) have been used by saints in caves for the prevention of diseases and long-term survival under natural circumstances. Patanjali, (600 BCE), the codifier of yoga science proposed that the control of *prana* (mind) is the regulation of inhalation and exhalation. This is accomplished by eliminating the pause between inhalation and exhalation or expending it by retention. It regulates the motion of the lungs, resulting into control of heart and vagus nerve. In a more recent study, transcendental meditation has been reported to provide beneficial effect on blood pressure and insulin resistance components of the metabolic syndrome (1). In several studies, breathing practices have been found to have protective effects (2-18). Regular practice of pranayams may have beneficial effects on nasobronchial disorders like chronic bronchitis, asthma, rhinitis, and common cold, pharyngitis, obesity, diabetes, hyper-tension, insulin resistance, heart attacks, allergies, memory dysfunction, and aging. In one observation, we described the effects of specific breathing patterns, *anulome* and *velome* and *kapal bhati* on respiratory tract allergic disorders.

The science of pranayama is thus intimately connected with the autonomic nervous system and brings its functions under conscious control via breathing patterns and movements of diaphragm and lungs (15-17). The nasal tissue is erectile similar to sex organs in men and women, which is very sensitive to breath. Control of breath constitutes an obvious starting point toward attainment of control of the autonomic nervous system, and appears to have beneficial effects on the functions of nasal mucosa, pharynx, bronchi, bronchioles, and lungs. These breathing patterns may also benefit the omental adipocytes, brain, heart, liver, and kidney functions. The left nostril, diaphragm, and stomach are supplied by the vagus nerve, which may influence pituitary function, the hypothalamus, the pineal gland, and the suprachiasmatic nucleus. One study conducted in Italy has shown that verbalization of *mantras* like *Oem mani padme oem* can decrease the breathing rate, as well as heart rate, due to increased

Table 1. *Possible indications of pranayamas*

| Indications | |
|---|---|
| **Respiratory system**<br>Chronic bronchitis<br>Asthma<br>Chronic sinusitis<br>Chronic rhinitis | **Neurological problems**<br>Paralysis<br>Motor neuron disease<br>Myopathy |
| **Cardiovascular diseases**<br>Hypertension<br>Heart attack<br>Atherosclerosis<br>Heart failure<br>Vascular variability diseases | **Psychological problems**<br>Depression<br>Neurosis<br>Anxiety<br>Stress<br>Schizophrenia<br>Manic depressive psychosis |
| **Diabetes mellitus** | **Kidney diseases**<br>Chronic renal failure |
| **Liver diseases**<br>Chronic viral hepatitis<br>Cirrhosis liver | **Physical weakness** |

Table 2. *Types of pranayamas.(Patanjali yoga)*

| Types | Definition |
|---|---|
| Nari shodhanam | Three cycles of exhalation through the left nostril and inhalation through right nostril followed by three cycles of exhalation through the right nostril and inhalation through the left, both should be of equal duration. |
| Kapalbhati | Vigorous and forceful expulsion of breath, using the diaphragm and abdominal muscles. It is followed by a relaxation of the abdominal muscles, resulting in a slow passive inhalation. |
| Bhastrika | It means bellows, in which abdominal muscles work like bellows. Here both inhalation and exhalation are vigorous and forceful. The effects are similar to kapalbhati and complication could be hyperventilation. |
| Ujjayi | It means control of victory, arising from a process of expansion, enhancing the ventilation of the lungs. Inhalation and exhalation are slow and deep and take place with partial closure of glottis. It removes the expectoration, calms the sympathetic activity and fills the whole body with wellness. |
| Bhramari | It means a large bee and the sound of a bee is made, during exhalation. Inhale completely through both nostrils and exhale producing a humming sound. |
| Sitali | The tongue is curled lengthwise until it resembles a tube. The tip of the tongue is protruded outside the lips. A hissing sound is produced during inhalation. Exhale completely with both nostrils. |
| Sitkari | The tongue is rolled back towards the soft palate and lips part and clench the teeth. Now inhale through the teeth, making a hissing sound with breath. Exhale completely through both nostrils. |
| Suryabhedana | The breath is inhaled through the right nostril, retained then exhaled, through the nostril. |
| Murccha | There is complete inhalation via both nostrils followed by slow exhalation, applying chin lock. |
| Plavini | The stomach is first filled completely with air and simultaneously the lungs are also filled completely with air by air. The breath is retained and then finally exhaled. It is an advanced mode of pranayam. |

vagal activity, resulting into increased nitric oxide release when the breathing rate is brought down to six per minute (18). In a few subjects, we have demonstrated increased heart rate variability by verbalization of *Rama,Rama,Rama.* The possible indications of prnayamas are given in table 1.

METHODS

The methods of pranayamas are given in table 2. Both *kapalbhati* and *anulome* and *velome* breathing patterns, have become very popular because of their demonstration and training by Swami Ramdeo, a well known practitioner of yogasans and pranayam, around the world. These patterns should be conducted preferably on an empty stomach for maximum beneficial effects. Pranayams could be practiced either on a bed or while sitting on a chair. Sit straight and do not move the shoulders or neck and do not make any noise during breathing.

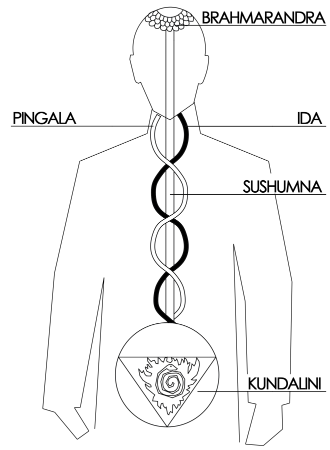
***ANULOME VELOME***

1. Close both the eyes and concentrate on inspiration and expiration, alternately from each nostril, starting from left nostril.
2. Take deep inspiration slowly followed by a pause of few seconds, then do complete expiration from the other nostril, while one nostril is closed by the thumb.
3. All the steps of breathing, "in and out" should be performed very gently without any strain for 100-150 times daily(minimum) in about 10 minutes.

***KAPALBHATI***

1. Exhale or expire the breath by moving diaphragm and abdominal muscles during expiration.
2. During expiration, the muscle of the abdomen moves inside, and during inspiration the abdomen moves up with the movements of the diaphragm.
3. Practice gently, about 400-500 times daily (minimum) in about 20 minutes.

According to Patanjali, having control on pause is called the *pranayama*. This means that to control, eliminate, and expand the pause is the main process in doing *pranayama*. In Sanskrit, the pause is called *kumbhaka*, which is controlled by all the breathing exercises. Hath yoga manual, mention eight varieties of *kumbhaka*, which are practiced by highly adapted yogis, who know the secrets of the nature of the pause. These should be practiced under guidance of experienced yogis. These practices can take us to deeper states of the mind.



IDA, PINGALA, SUSHUMNA

**THE SUPER POWER OF BREATH**

The pause during the breath called *kumbhaka* should be practiced under supervision of an expert not just by reading manuals alone. It is important to apply *bandhas* before practicing *kumbhakas. Bandhas* are locks, which may be of different types; *jalandhara bandha*-the chin lock, *uddiyana bandha*-the abdominal lock, and *mulabandha*-the anal lock.

**Chin Lock *(Jalandhara bandha)***

The blood supply of the brain is provided by the internal carotid arteries, situated on both sides of the neck. If the chin lock is used to apply conscious pressure to these arteries, the nerve impulses traveling to the brain fade the body consciousness and bring about a trance like condition. Such stimulation is associated with decrease in heart rate and conscious control of *vijnani nadi,* the channel of consciousness. It has been mentioned in *sivasamhita* that by the application of pressure on the carotid sinus nerves, a blissful state of mind may be experienced. If the chin lock is practiced both during inhalation and exhalation, the control of the channel of consciousness or *vijnani nadi* turns easy. Long practice for years may be needed to control chin lock. After deep inhalation, the air in the lungs wants to rush out if the chin lock is not applied, after the retention of the breath, despite the glottis being kept closed. The air rushes through the auditory tubes resulting in manipulations in the ears—in the inner ear. It is possible that such manipulations by chin lock in the inner **ear** could be useful for the treatment of ear disorders. The chin lock is properly applied after closing the glottis, for easy practice of *kumbhaka*. Practice of *jalandhara bandha*, yogis bring about conscious control of this phenomenon and thus attain a state of joy before doing meditation. Putting pressure on the carotid arteries may provide yogic anesthesia to the person for minor surgery. The martial art experts, in the schools of Kung Fu also use this technique whenever necessary.

**Abdominal Lift (*Uddiyana bandha*)**
This is an exercise involving the diaphragm, ribs and the abdominal muscles. It can be practiced either in standing or sitting in one of meditation postures. If it is practiced in standing position, the feet are kept two feet apart and spine straight, then the knees are bend slightly and lean forward from the waist far enough to place the palms of the hands just above the knees. After achieving this posture, exhale completely and place the chin on the hollow of the throat, then suck the abdominal muscles in and up without inhaling, pulling the novel toward the spine. These procedures pull the diaphragm up and create a cavity in the front side of the abdomen under the rib cage. There would be slight curving in the back and this position is maintained as long as it remains comfortable and tolerable. Now slowly inhale and relax.

It is important not to force the abdominal muscles outward. The use of force should be gentle, pulling the muscles in and upward. Contraindications for not practicing this exercise are hypertension, hiatal hernia, ulcers, heart diseases, menstruation, or pregnancy. This exercise is the best for disease of the abdominal organs.

**Anus Lock(*mulabandha*)**
In this exercise both the internal or external muscles of the sphincters of the anus are contracted and then held. This anal lock may be practiced during panorama and meditation.

**POSSIBLE MECHANISMS**
It should be noted that diaphragmatic breathing is the basis of all the breathing exercises and pranayamas. The western field of medicine addressing breathing and the human condition is called respiratory psychophysiology. Pranayamas is in its infancy and it has much to learn from the ancient eastern practices. Joseph Campbell uncovered consistent personality archetypes that due to *chakra* insights, imply generic ways of breathing (16), but there are cultural and functional biases in the way we use the breathing (6,16).


In addition to the vital role of breathing as a mechanism of gas exchange, a key aspect of breathing is the interaction between breathing and emotions, cognition and behavior. It is possible that breathing may well be the link between psychology and physiology, which is referred by other experts, as the link for the mind/body/spirit connection. Much of the need for psychotherapy stems from stress and trauma. The unbalanced breathing patterns set during chronic stress and intense trauma needs to be disorganized in a gentle and replicated manner. Breathing affects and reflects much of what we think and do. There is a direct relation between breathing and aliveness. If we hold our breath and try to feel angry or happy, we can not. Too little breath is correlated with passivity, sadness and depression. The breath can be purposefully utilized to alter mental and emotional states. Postures, tensions, environment, all have effect on breath.

It is unfortunate that with urbanization and an increase in environmental stress, chest breathing has now been considered natural and involuntary for the majority of the population. It seems to be a part of the fight/flight syndrome, aroused when the organism is challenged by some external stress or danger. Chest breathing gives rise to tensions and anxiety, in association with the above syndrome due to reciprocity between breath and mind. The breath becomes shallow, jerky and unsteady, resulting in similar state of the mind. It is important to replace chest breathing with deep, even and steady diaphragmatic breathing to achieve beneficial effects of the relaxation technique. Since chest breathing is rapid, shallow and irregular, hence the lower lobes of the lungs, which receive an abundant supply of blood, are not adequately ventilated. The gas exchange, which takes place between air in the lungs and the blood, is inadequate resulting in a ventilation-perfusion abnormality. These disturbances can be minimized by diaphragmatic breathing. This breathing pattern appears to be beneficial because it increases the suction pressure created in the thoracic cavity and improves the venous return of blood. These changes decrease the load on the heart, which enhances the circulatory functions such as heart rate, blood pressure, left ventricular pressures and coronary artery diameter.

Breathing between 15-18 times per minute is considered normal in adults. Rhythmic diaphragmatic breathing can bring more air and oxygen into the air sacs of the lungs and hence into the blood circulation. There is an increase in venous return to the lungs causing greater blood supply to the alveoli. As the process of inhalation is under the influence of the nerve centers, the diaphragm, the intercostals, and the abdominal muscles, therefore inhalation should be slowed first. Inhalation is associated with an oozing of plasma into the alveolar space, which returns again into the circulation during exhalation. Therefore, during inhalation, nutrients and enzymes from the blood ooze out into the air sacs, which interact and protect the lungs. Thus, the longer the process of inspiration, the greater the metabolic functions within the alveoli. These metabolic products enhance our capability to further slow down the breathing rate, resulting in increased parasympathetic activity and causing greater release of acetylcholine and nitric oxide, which are protective to various tissues and organs like heart, arteries, brain, lungs, liver, bone marrow, and spleen.

**RESPIRATORY TRACT DISORDERS**

It is possible that manipulations in the breathing patterns may constitute an obvious starting point toward the attainment of control of the autonomic nervous system via movements of the diaphragm and sensitization of nasal tissue, which may have beneficial effects on the functions of nasal mucosa, pharynx, bronchi, bronchioles, and lungs, resulting in an improvement in the clinical manifestations of nasobronchial allergies and infections.

We selected 201 subjects aged 15 to 75 years suffering from various clinical disorders (3-4 times or more in one year) for the last year or more, persisting each time for a minimum of seven days or more despite conventional treatment (15). The clinical diagnosis was based on history, clinical manifestations, radiography of chest and sinus with electrocardiography if indicated, and blood counts, total and differential blood cell counts, ESR, and hemoglobin. Only patients with a clinical diagnosis of chronic bronchitis and asthma (n= 101), rhinitis (n=21), sinusitis (n=40), pharyngitis (n =39) due to a possible allergic reaction, were included in this observation.(see table 3 and 4). Patients suffering from pulmonary tuberculosis, pneumonia and other chronic lung diseases were excluded.

All patients were advised to do regular breathing, *kapalbhati* and *anulome* and *velome* (breathing exercises), which were demonstrated to patients on each visit and during follow-up. The period of follow-up was 12-48 weeks. The effects of treatment were assessed by asking the patients, good, best, no benefit or worse in the symptoms such as coughing, dyspnea, nasal discharge, headache etc. Only those patients mentioning good or very good benefit were considered to have beneficial effects. Results showed that clinical mani-festations were cough, dyspnea, sputum on coughing, headache, and nasal discharge. The majority of the patients had either good or very good beneficial effects on clinical manifestations.

About half (n = 103, 51.2%) of the patients felt benefit from the breathing changes and one quarter (n = 52, 25.8%) felt optimal benefit of practicing breathing patterns (see table 2). In majority of the patients, benefit started within 3 days to 7 days. The proportion of patients feeling benefit in symptoms was significantly ($P < .05$) higher among patients with chronic bronchitis or asthma (76.1%), sinusitis (82.5%) and pharyngitis (79.3%) compared with patients with rhinitis or the common cold (65.8%). This clinical observation indicated that pranayama appeared to be an important method in the management of respiratory tract disorders. Our observations showed that by practicing *anulome* and *velome* in conjunction with *kapal bhati*, beneficial effects may occur in various symptoms of chronic bronchitis and asthma, chronic rhinitis, common cold, sinusitis, and pharyngitis. In brief, our observations indicate that pranayama breathing appears to be beneficial in respiratory disorders. However, a randomized, single blind trial is necessary to provide stringent scientific evidence that breathing patterns could be useful in the treatment and prevention of naso-bronchial allergic problems. Only a few studies have examined the role of breathing patterns pranayama in the treatment of asthma.

In a randomized, double-blind, placebo-controlled, crossover trial, the effects of two pranayama yoga breathing exercises on airway reactivity, airway calibre, symptom scores, and medication used in patients with mild asthma were assessed (7). After baseline assessment occurring over one week, 18 patients with mild asthma practiced slow deep breathing for 15 minutes twice a day for two consecutive two week periods. During the active period, subjects were asked to breathe through a Pink City lung (PCL) exerciser, a device that 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 FEV1, PEFR, symptom score, and inhaler use over the last three days of each treatment period were assessed in comparison with the baseline assess-ment period. All patients improved more with the PCL exerciser than with the placebo device, but the differences were not statistically significant. There was, however, a statistically significant increase in the dose of histamine needed to provoke a 20% reduction in FEV1 (PD20) during pranayama breathing, but not with the placebo device. Further studies are needed to confirm the usefulness of controlled ventilation exercises in the control of asthma. This breathing method is different from ours and hence we cannot compare our results with these conclusions.

In another study, 53 patients with asthma underwent training for two weeks in an integrated set of yoga exercises, including breathing exercises, *suryanamaskar*, *yogasana* (physical postures), *pranayama* (breath slowing techniques), *dhyana* (meditation), and a devotional session, and were told to practice these exercises for 65 minutes daily (8). They were then compared with a control group of 53 patients with asthma matched for age, gender, and type and severity of asthma, who continued to take their usual drugs. There was a significantly greater improvement in the group, who practiced yoga in the weekly number of attacks of asthma, scores for drug treatment and peak flow rate. This study showed the efficacy of yoga in the long term management of bronchial asthma, but the physiological basis for this beneficial effect needs to be examined in more detail.

In a further study, the effects of breathing exercises (BE) or yoga (Y) on the course of bronchial asthma were studied among 36 subjects with a mild disease (9). The patients were randomly divided into three groups. Two groups participated in a three weeks training program of BE or Y, whereas the third group rested without any additional treatment (control group C). At the end of the training period, the patients were asked to practice BE or Y on their own. Drug therapy and lung function parameters before and after a beta 2-agonist metered dose inhaler (albuterol, ALB) were recorded before the training program and in four weeks intervals for four months thereafter. The response to the beta 2-agonist was documented continuously in 28 patients. The mental state of the patients was elucidated by questionnaires. Before the study a significant effect of inhaled ALB on the FEV1 was shown without any significant group differences. Both, BE and Y, caused a significant amelioration of the mental state, but only the BE induced a significant improvement of lung function parameters compared with the individual baseline values. The FEV1 increased significantly by 356.3 +/- 146.2 ml ($p < .05$) and the VC by 225.0 +/- 65.5 ml ($p < .01$). These long-term changes were not significantly different from the actual response to ALB. BE decreased the RV significantly by 306.3 +/- 111.6 ml ($p < .05$), an effect significantly higher compared with the beta 2-agonist ($p < .01$). BE in combination with ALB caused an additive effect

In one double blind study, the effects of breathing exercises focusing on shallow nasal breathing were compared with those of non-specific upper body exercises on asthma symptoms, QOL (quality of life), other measures of disease control, and inhaled corticosteroid (ICS) dose (10). This study also assessed the effect of peak flow monitoring on outcomes in patients using breathing techniques. After a two week period, 57 subjects were randomized to receive one of two breathing techniques learned from instructional videos. During the following 30 weeks, subjects practiced their exercises twice daily and as needed for relief of symptoms. After week 16, two successive ICS down titration steps were attempted. The primary outcome variables were QOL score and daily symptom score at week 12. Overall there were no clinically important differences between the groups in primary or secondary outcomes at weeks 12 or 28. The QOL score remained unchanged (0.7 at baseline v 0.5 at week 28, $p = .11$ both groups combined), as did lung function and airway responsiveness. Across both groups, however, reliever use decreased by 86% ($p< .0001$) and ICS dose was reduced by 50% ($p< .0001$; $p> .10$ between groups). Peak flow monitoring did not have a detrimental effect on asthma outcomes. Breathing techniques may be useful in the management of patients with mild asthma symptoms who use a reliever frequently, but there is no evidence to favor shallow nasal breathing over non-specific upper body exercises. This breathing pattern appears to be different from those used in our study.

The majority of the patients with asthma and chronic bronchitis are interested in the use of breathing exercises, but their role is uncertain. The effects of the *Buteyko* breathing technique, a device that mimics pranayama (a yoga breathing technique), and a dummy pranayama device on bronchial responsiveness and symptoms were compared over six months in a parallel group study (11). Ninety patients with asthma taking an inhaled corticosteroid were randomized after a two week period to *Eucapnic Buteyko* breathing, use of a Pink City Lung Exerciser (PCLE) to mimic pranayama, or a PCLE placebo device. Subjects practiced 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) (PD(20)) during the first six months. Sixty nine patients (78%) completed the study. There was no significant difference in PD(20) between the three groups at three or six months. Symptoms remained relatively stable in the PCLE and placebo groups, but were reduced in the *Buteyko* group. Median change in symptom scores at six months was 0 (interquartile range -1 to 1) in the placebo group, -1 (-2 to 0.75) in the PCLE group, and -3 (-4 to 0) in the *Buteyko* group ($p= .003$ for difference between groups). Bronchodilator use was reduced in the *Buteyko* group by two puffs/day at six months; there was no change in the other two groups ($p= .005$). No difference was seen between the groups in FEV(1), exacerbations, or ability to reduce inhaled corticosteroids. It is possible that, the *Buteyko* breathing technique can improve symptoms and reduce bronchodilator use but does not appear to change bronchial responsiveness or lung function in patients with asthma. No benefit was shown for the Pink City Lung Exerciser. It is possible that breathing exercises may be complemented by *yogasans* (12).

Apart from conventional medical care, breathing retraining is used increasingly throughout the world by many patients with asthma in addition to their usual medical care. One systematic review of the literature (13) to determine the effectiveness of breathing retraining in the management of asthma found six randomized-controlled trials that involved breathing retraining in asthma. Due to the variation in reported trial outcomes, limited reporting of study data and small number of included trials, it was not possible to draw any firm conclusions as to its effectiveness. However, outcomes that were reported from individual trials did show that breathing retraining may have a role in the treatment and management of asthma. Further large-scale trials using breathing retraining techniques in asthma are required to address this important issue.

The Eastern and Western literature based on anecdotal evidence propose considerable benefits for patients with asthma, when treated with breathing interventions. The term “breathing exercise, training and retraining” has numerous interpretations depending on the nature of the therapy, the therapist, and the cultural background. To assess the evidence for the efficacy of breathing retraining in the treatment of patients with asthma, trials were searched for in the Cochrane Airways Group trials register, Cochrane Complementary Medicine Field trials register, EMBASE: Physical Medicine and Rehabilitation Field, and Databases of the physiotherapy library of current research (13,14), World Congress of Physical Therapy Proceedings, and AMED (Allied and Complementary Medicine Database 1985-2003/4) (13). Hand searching of the Association of Chartered Physiotherapists in Respiratory Care Journals was also undertaken. Known physiotherapists in the field of respiratory medicine were contacted and appeals made in the 'Physiotherapy' Journal and the Physiotherapy Respiratory Care magazine. Searches were undertaken of bibliographies from the included studies and other appropriate papers. Authors of the included studies were contacted for information concerning other relevant trials.

The selection criteria were randomized or quasi-randomized controlled trials of breathing retraining in patients of all ages with a diagnosis of asthma. Breathing retraining should be a major component of the treatment intervention. Two reviewers (EH and FR) independently assessed trial quality and extracted data. Authors of included trials were contacted for additional data. Adverse effects were noted. Abstracts were identified and 42 full text papers were obtained for assessment and possible inclusion. Thirty five studies were excluded. A total of five studies were included in the original review. Two further studies have been added to this update. Most studies were of small size. Two studies demonstrated significant reductions in rescue bronchodilator use and three studies showed reductions in acute exacerbations, although these were measured in different ways. Two single studies showed significant improvements in quality of life measures. Overall, benefits of breathing exercises were found in isolated outcome measures in single studies. Five studies compared breathing retraining with no active control and two with asthma education control groups. Comparisons and conclusions were difficult to evaluate as treatment interventions and outcome measurements from the seven trials varied considerably.

In brief, our observations and review of studies indicated that randomized, controlled trials in a large number of patients and a long-term follow-up are necessary to demonstrate the role pranayama breathing has in patients with respiratory tract disorders. At present therefore no reliable conclusions can be drawn concerning the use of breathing exercises for asthma or chronic bronchitis in clinical practice. However trends for improvement, notably in quality of life measurements, are encouraging and further studies including full descriptions of treatment methods and outcome measurements are required (19).

**CARDIORESPIRATORY ASPECTS**

In healthy individuals pranayama can produce different physiological responses (20), and the responses of alternate nostril breathing (ANB), the *Nadisudhi* pranayama on some cardiorespiratory functions were investigated in healthy young adults. The subjects performed ANB exercise (15 minutes everyday in the morning) for 4 weeks. Cardiorespiratory parameters were recorded before and after a four-weeks training period. A significant increment in PEFR (L/min) and pulse pressure (PP) was noted. Although systolic blood pressure (SBP) decreased insignificantly, the decrease in pulse rate (PR), respiratory rate (RR), diastolic blood pressure (DBP) was significant. The results indicated that regular practice of ANB (*Nadisudhi*) may increase para-sympathetic activity, resulting in to decrease in SBP and PP. Alternate nostril breathing (ANB) may modulate cardiorespiratory and autonomic functions. However, the studies are scarce and results highly conflicting. One study (21) was conducted in healthy young volunteers comprising males (n=20) and females (n=20) in an age range of 17-22 years. In both groups, the RR/min, HR/min, SBP (mm Hg), DBP (mm Hg), PEFR (L/min), and galvanic skin resistance (GSR; microV) were recorded thrice; once as control and then after 15 min (acute exposure) and again following 8 wks of training in ANB (15 min daily). In males the control RR was 16.60 +/- 2.01, HR 75.75 +/- 11.07, SBP-115.9 +/- 7.33, DBP 70.4 +/- 6.28 and PEFR 550.00 +/- 51.50. After 15 min of ANB-RR (14.75 +/- 1.41, P< .001), HR (68.45 +/- 12.41, P< .01) and SBP (113.6 +/- 6.04, P<0.05) fell significantly. After 8 wks of ANB training RR (12.35 +/- 1.35, P< .0001), HR (63.20 +/- 11.11, P< .001), SBP (109.5 +/- 5.61, P< .001), declined to much greater extent and PEFR (571.50 +/- 46.26, P < .01) rose significantly. In females the control RR was 17.25 +/- 1.89, HR-74.90 +/- 12.85, SBP-106.70 +/- 6.91, DBP-68.70 +/- 5.52 and PEFR-394.50 +/- 44.89. After 15 minutes, of ANB RR (15.05 +/- 1.54, P< .001) and HR (64.75 +/- 9.80, P< .001) there was significant decline with concomitant rise in PEFR (407.00 +/- 2.31, P<0.05). Following eight weeks of training the decrement in RR (12.60 +/-1.50, P< .0001) and HR (63.30 +/- 8.65, P< .001) was maintained. SBP (103.10 +/- 4.92, P< .001) and DBP (65.8 +/- 5.54, P< .001) decreased further and PEFR (421.00 +/- 38.51 P< .001) rose, GSR was unaffected by ANB in both males and females. The results suggested that in general, there is a tilt toward parasympathetic dominance by alternate nostril breathing. This breathing may be a useful adjuvant to medical therapy of hypertension and COPD.

The responses of right nostril breathing (RNB) and left nostril breathing (LNB) on cardiorespiratory and autonomic functions were investigated in healthy student volunteers of both sexes (22). The RNB and LNB groups comprised 10 males and 10 females in each in age range of 17-22 years. Initially, in both groups control values of RR, HR, SBP, DBF, PEFR, and GSR were recorded. The same parameters were recorded after 15 min (acute exposure) and following 8 wks of training in RNB and LNB. In males RR (P< .0001), SBP (P <0.05) and DBF (P<.05) fell significantly after 15 min of RNB. After 8 wks training in RNB, HR (P < .01) decreased, SBP (P < .001) declined more profoundly and RR (P < .0001) and DBP (P < .05) decrement was maintained. After 15 min of LNB, RR (P < .01), HR (P < .01), SBP (P < .001), and DBP (P < .01) declined significantly; upon 8 wks training, RR (P < .0001) and HR ( P< .001) decreased further, the decrement in SBP (P < .001) and DBP (P < .01) was the same. In females, RR alone fell significantly (P < .05) after 15 min RNB. After 8 weeks, the RR decrement was more profound (P < .0001) and DBP also declined significantly (P < .01). Similarly, 15 min LNB resulted in a significant reduction in RR

(P < .001) and HR (P < .05) only. Following 8 weeks, of training in LNB, in addition to RR (P < .0001) and HR (P < .05) decrement, SBP (P < .01) and DBP (P < .05) also fell significantly. Both in males and females, GSR did not change significantly (P > .05) either after RNB or LNB (15 min/8 wk). PEFR rose significantly (P < .05) only in females after 8 wks of LNB. The results suggest that there are no sharp distinctions between the effects of RNB and LNB either after acute exposure (15 min) or after training (8 wk). However, a general parasympathetic dominance is evoked by both breathing patterns.

In a pilot study, on the prevention of heart attack, the effects of breathing patterns were studied (23). This study investigated the hemodynamics of a yogic breathing technique claimed "*to help eliminate and prevent heart attacks due to abnormal electrical events to the heart,*" and to generally "*enhance performance of the central nervous system (CNS) and to help eliminate the effects of traumatic shock and stress to the CNS*." Parameters for subjects during a pre-exercise resting period, a 31-minute exercise period, and a post-exercise resting period were recorded in a laboratory at the University of California, San Diego. Parameters for three males (ages 44, 45, 67 years) and one female (age 41 years) were recorded. One subject (male age 45 years) had extensive training in this technique. This yogic technique is a one 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. Fourteen beat-to-beat parameters were measured non-invasively and calculated for body surface area to yield stroke index (SI), 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. The effects were observed on SI, HR, MAP, LSWI, and SSVRI and how they can help to describe hemodynamic state changes. This technique induces dramatic shifts in all hemodynamic variables during the one BPM exercise and can produce unique changes in the post-exercise resting period after long-term practice that appears to have a unique effect on the brain stem cardiorespiratory center regulating the Mayer wave (0.1-0.01 Hz) patterns of the cardiovascular system. Preclinical studies are warranted to examine the possible long-term effects of this technique that appear to reset a cardiorespiratory brain-stem pacemaker. We postulate that this effect may be the basis for the purported yogic health claim.

A further study (24) evaluated the effects of *hatha* yoga and *omkar* meditation on cardiorespiratory performance, psychological profile, and melatonin secretion. Thirty healthy men in the age group of 25-35 years volunteered for the study and were randomly divided in two groups of 15 each. Group 1 subjects served as controls and performed body flexibility exercises for 40 minutes and slow running for 20 minutes during morning hours and played games for 60 minutes during evening hours daily for three months. Group 2 subjects practiced selected yogic *asanas* (postures) for 45 minutes and pranayama for 15 minutes during the morning, whereas during the evening hours these subjects performed preparatory yogic postures for 15 minutes, pranayama for 15 minutes, and meditation for 30 minutes daily, for 3 months. Orthostatic tolerance, heart rate, blood pressure, respiratory rate, dynamic lung function (such as forced vital capacity, FEV1, forced expiratory volume percentage, PEFR, and maximum voluntary ventilation), and psychological profile were measured before and after three months of yogic practices. Serial blood samples were drawn at various time intervals to study effects of these yogic practices and *Omkar* meditation on melatonin levels. Yogic practices for three months resulted in an improvement in cardiorespiratory performance and psychological profile. The plasma melatonin also showed an increase after three months of yogic practices. The SBP, DBP, MAP, and orthostatic tolerance did not show any significant correlation with plasma melatonin. However, the maximum night time melatonin levels in the yoga group showed a significant correlation (r = .71, p < .05) with the well-being score. These observations suggest that yogic practices can be used as psycho-physiologic stimuli to increase the endogenous secretion of melatonin, which, in turn, might be responsible for the improved sense of well-being.

*Surya Namaskar* (SN) is a group of yogic exercises consisting of a set of 12 postures that is practiced by some yoga practitioners. A study was undertaken to observe critically the energy cost and different cardio-respiratory changes during the practice of SN (25). Twenty-one male volunteers from the Indian Army practiced selected yogic exercises for six days in a week for three months duration. The yogic practice schedule consisted of *Hatha Yogic Asanas* (28 min), Pranayama (10.5 min) and Meditation (5 min). In the yogic practice schedule, the participants first practiced *Kapal Bhathi* (breathing maneuvers) for 2 minutes, then *Yogamudra* (yogic postural exercise) for two minutes, after which they rested until oxygen consumption and HR returned to the resting value. Subsequently, the subjects performed SN for 3 min 40 sec on average. After three months of training, namely, at the beginning of the fourth month, the subjects performed an entire yogic practice schedule in the laboratory as they practiced during their training session and experiments were carried out. Their pulmonary ventilation, carbon dioxide output, oxygen consumption, HR, and other cardio-respiratory parameters were measured during the actual practice of SN. Oxygen consumption was highest in the eighth posture ($1.22 \pm 0.073$ 1 $min^{-1}$) and lowest in the first posture ($0.35 \pm -0.02$ 1 $min^{-1}$). Total energy cost throughout the practice of SN was 13.91 kcal and at an average of 3.79 kcal/min. During its practice highest HR was $101 \pm -13.5$ bpm. As an aerobic exercise SN seemed to be ideal as it involves both static stretching and slow dynamic component of exercise with optimal stress on the cardiorespiratory system.

We studied cardiovascular and respiratory changes during the yogic breathing exercise *kapalabhati* (KB) in 17 advanced yoga practitioners (26). The exercise consisted of fast shallow abdominal respiratory movements at about 2 Hz frequency. Blood pressure, electrocardiogram (ECG), and respiration were recorded continuously during three 5 min periods of KB and during pre- and post-KB resting periods. The beat-to-beat series of SBP and DBP, R-R intervals, and respiration were analyzed by spectral analysis of time series. The mean absolute power was calculated in three frequency bands, band of spontaneous respiration, band of 0.1 Hz rhythm, and the low-frequency band > 15 s in all spectra. The mean modulus calculated between SBP and R-R intervals was used as a parameter of the baro-receptor-cardiac reflex sensitivity (BRS). The HR increased by nine beats per min during KB. The SBP and DBP increased during KB by 15 and 6 mm Hg respectively. All frequency bands of R-R interval variability were reduced in KB. Also the BRS parameter was reduced in KB. The amplitude of the high-frequency oscillations in SBP and DBP increased during KB. The low-frequency blood pressure oscillations were increased after KB. The results point to decreased cardiac vagal tone during KB, which was due to changes in respiratory pattern and due to decreased sensitivity of arterial baroreflex. Decreased respiratory rate and increased SBP and low-frequency blood pressure oscillations after KB suggest a differentiated pattern of vegetative activation and inhibition associated with KB exercise.

To study the effect of 40 days of yogic exercises on cardiac functions in type 2 diabetics (27), 24 patients provided metabolic and clinical evidence of improvement in glycemic control and autonomic functions. The patients were on an antihyperglycemic and dietary regimen, and their baseline fasting and postprandial blood glucose and glycosylated hemoglobin (HbA1C) were monitored along with autonomic function studies. The patients were trained in yoga *asanas* , which they pursued for 30-40 min/day for 40 days under guidance. The *asanas* consisted of 13 well known postures, done in a sequence. After 40 days of the yoga *asanas* regimen, the parameters were repeated.

The results indicated a significant decrease in fasting blood glucose levels from basal $190.08 \pm 18.54$ in mg/dl to $141.5 \pm 16.3$ in mg/dl after yoga regimen. The post prandial blood glucose levels decreased from $276.54 \pm 20.62$ in mg/dl to $201.75 \pm 21.24$ in mg/dl, glycosylated hemoglobin showed a decrease from 9.03 $\pm$ 0.29% to $7.83 \pm 0.53$% after yoga regimen. The pulse rate, SBP, and DBP decreased significantly (from 86.45 $\pm$ 2.0 to $77.65 \pm 2.5$ pulse/min, from $142.0 \pm 3.9$ to $126.0 \pm 3.2$ mm of Hg and from $86.7 \pm 2.5$ mm of Hg to $75.5 \pm 2.1$ mm of Hg after yoga regimen respectively). Corrected QT interval (QTc) decreased from $0.42 \pm 0.0$ to $0.40 \pm 0.0$. The findings suggest that better glycemic control and stable autonomic functions can be obtained in type 2 diabetes with yoga *asanas* and pranayama. The exact mechanism of how these postures and controlled breathing interact with somato-neuro-endocrine mechanisms affecting metabolic and autonomic functions remains to be worked out.

**NEURO-PSYCHOLOGICAL FUNCTIONS, PHYSICAL PERFORMANCE AND OTHER FUNCTIONS**

One study (28) was conducted to determine whether breathing through a particular nostril has a lateralized effect on hand grip strength. 130 right hand dominant, school children between 11 and 18 years of age were randomly assigned to five groups (28). 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 five 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. The breath awareness and mudra groups showed no change. Hence the results suggested that yoga breathing through a particular nostril, or through alternate nostrils increases hand grip strength of both hands without lateralization.

The effect of right, left, and alternate nostril yoga breathing (RNYB, LNYB, ANYB, respectively) were compared with breath awareness (BAW) and normal breathing (CTL) (29). Autonomic and respiratory variables were studied in 21 male volunteers with ages between 18 and 45 years and experience in the yoga breathing practices between 3 and 48 months. Subjects were assessed in five experimental sessions on five separate days. The sessions were in fixed possible sequences and subjects were assigned to a sequence randomly. Each session was for 40 min; 30 min for the breathing practice, preceded and followed by 5 min of quiet sitting. Assessments included heart rate variability, skin conductance, finger plethysmogram amplitude, breath rate, and blood pressure. Following RNYB there was a significant increase in systolic, diastolic and mean pressure. In contrast, the systolic and diastolic pressure decreased after ANYB and the systolic and mean pressure were lower after LNYB. Hence, unilateral nostril yoga breathing practices appear to influence the blood pressure in different ways. These effects suggest possible therapeutic applications.

Reports on the effect of yogic exercises on aerobic capacity are few, and we could not find literature available on the effect of yogic exercise on perceived exertion (PE) after maximal exercise. In one study (30) the effect of training in Hatha yogic exercises on aerobic capacity and PE after maximal exercise was observed. Forty men from the Indian army (aged 19-23 years) were administered maximal exercise on a bicycle ergometer in a graded work load protocol. The oxygen consumption, carbon dioxide output, pulmonary ventilation, respiratory rate, heart rate (HR) at maximal exercise and PE score immediately thereafter were recorded. The subjects were divided into two equal groups. Twelve subjects dropped out during the course of study. One group (yoga, n = 17) practiced Hatha yogic exercises for one hour every morning (six days in a week) for six months. The other group (PT, n = 11) underwent conventional physical exercise training during the same period. Both groups participated daily in different games for one hour in the afternoon. In the 7th month, tests for maximal oxygen consumption (VO2Max) and PE were repeated on both groups of subjects. Absolute value of VO2Max increased significantly ($P < 0.05$) in the yoga group after six months of training. The PE score after maximal exercise decreased significantly ($P < 0.001$) in the yoga group after 6 months, but the PT group showed no change. The practice of Hatha yogic exercises along with games helped to improve aerobic capacity like the practice of conventional exercises (PT) along with games. The yoga group performed better than the PT group in terms of lower PE after exhaustive exercise.

There is increasing interest in the finding that breathing exclusively through one nostril may alter autonomic functions (31). Male subjects (n=48), with ages ranging from 25 to 48 years were randomly assigned to different groups (31). Each group was asked to practice one out of three pranayamas (viz. right nostril breathing, left nostril breathing or alternate nostril breathing). These practices were carried out as 27 respiratory cycles, repeated four times a day for one month. Parameters were assessed at the beginning and end of the month, but not during the practice. The “right nostril pranayama” group showed a significant increase, of 37% in baseline oxygen consumption. The “alternate nostril” pranayama group showed an 18% increase, and the “left nostril pranayama” group also showed an increase, of 24%. This increase in metabolism could be due to increased sympathetic discharge to the adrenal medulla. The left nostril Pranayama group showed an increase in volar galvanic skin resistance, interpreted as a reduction in sympathetic nervous system activity supplying the sweat glands. The results suggest that breathing selectively through either nostril could have a marked activating effect or a relaxing effect on the sympathetic nervous system. The therapeutic implications of being able to alter metabolism by changing the breathing pattern have been mentioned.

The effects of three yoga breathing practices were evaluated on performance on a letter-cancellation task, which is a left-hemisphere dominant task (32). The three yoga breathing practices (RNYB, LNYB, ANYB) were selected because unilateral forced nostril breathing stimulates the contralateral hemisphere. The participants comprised 20 male volunteers whose ages ranged from 20 to 45 years (M age = 28.4 yr, SD = 5.7). All subjects were assessed before and after four sessions, i.e., RNYB, LNYB, ANYB, and BAW as a control. The letter-cancellation task scores significantly improved, i.e., fewer errors following RNYB and ANYB (Wilcoxon paired signed-ranks test). The improved performance could be related to the enhance-ment of contralateral hemisphere function found with selective nostril breathing.

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