

Benefits of *Pranayamam* – A discussion with the help of Modern Physiology.

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Abstract:

Background:

Pranayamam – *Prana* + *Ayamam*, which is the regulation technique of breath. It is the fourth limb of eight-limbed yoga system called the *Astanga Yogam*. There are lots of siddha literature that speak about the importance and beneficial effects of *pranayamam*. There are also many clinical trials went and ongoing on the aspect of this concerned yogic breathing thus proving the fruiting effects of *Pranayama*.

Aim:

This study is here to discuss about the beneficial health effects of pranayamam with the possible physiological mechanisms which could be the underlying causes for the fruiting effects of *pranayamam*.

Methods:

Data obtained by searching the online pubmed, Google scholar, science direct by using keywords. Textbook of K. Sembulingam's essential of medical physiology and some siddha literatures are kept for base. Controlled clinical trials which used *pranayamam* as intervention on humans to evaluate the health related outcomes are selected and included.

Conclusion:

Available evidences of clinical trials show the physiological benefits of *pranayama*. Which shows that there should be a proper underlying mechanisms that is aiding the results. However, high quality trials are required for definitive evidence.

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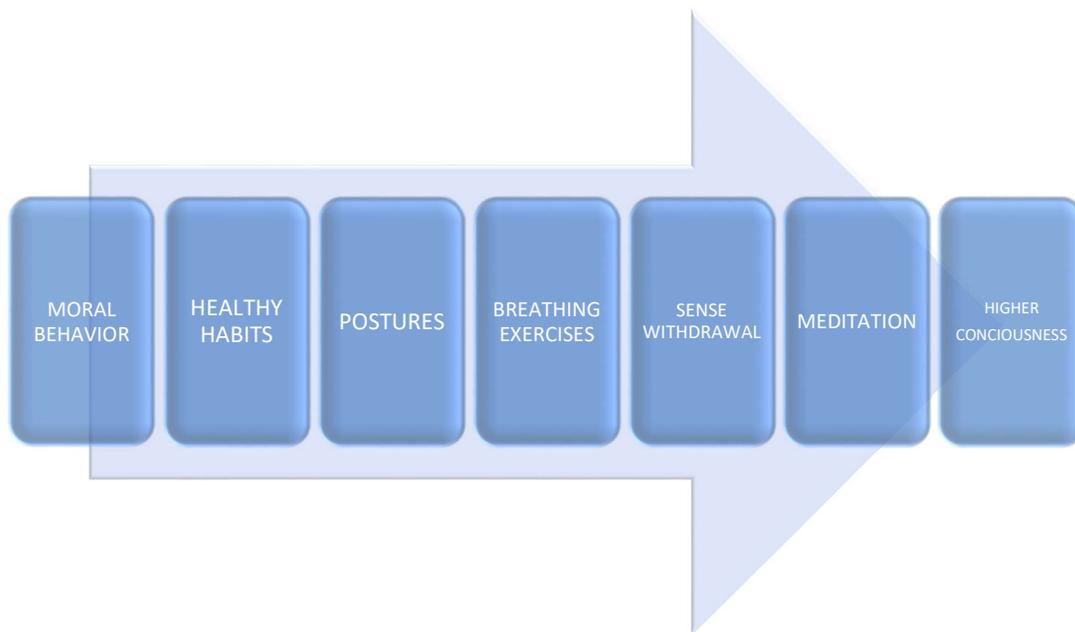
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Introduction:

Siddha system of medicine is a very old and holistic system of medicine, created by sages called '*Siddhars*'. On the path of union of the soul with the eternal being they realise the importance of the Union of body with the mind. Thus created a holistic practice called Yoga, which ultimately means their purpose 'The union'. It is the mind and body fitness which involves a combination of activities such as muscular activity, mindful focus on awareness of the self, the breath and energy. It is the eight – limbed practice they are *Iyamam, niyamam, asananm, pranayamam, prathyagaram, thaaranai, thyaanam*. Pranayama is the fourth among the eight fold yoga practice. (1)

Figure no. 1: Eight fold yoga practice (*Astanga Yogam*)



Prana means – breath of life or vital energy. *Ayamam* means control or regulation. There are many types of modification of breathing process they are, rapid diaphragmatic breathing – *kapalpathi*, alternative nostril breathing – *naadisuthi*, slow and deep breathing – breathing/ holding / retention in the ratio of 16:64:32. Important aspect of such breathing is,

- **Poorakam** – inhalation – 16
- **Kumbagam** – holding – 64 (there is two types of *kumbagam* one is *Antahkumbagam*– internal breath holding, *bahihkumbagam* – external breath holding)
- **Resakam**–exhalation – 32

Table. No. 1: Types of *pranayamam* (*pathanjali yoga suthram*)[36]

1	<i>Nadisodhana pranayamam</i>	Seated in a cross legged position, spine stretched and back straight, with the thumb on the right nostril use the left nostril to breathe. Hold the breath for a beat and switch the thumb to the left nostril. Now exhale via the right nostril.
2	<i>Shitali pranayamam</i>	Seated in a cross legged position, take deep breath for 6 times. After the body gets adjusts, make a O with the mouth and breathe in deeply via the mouth. Always exhale via the nose.
3	<i>Ujjayi pranayamam</i>	Seated in a cross legged position and begin to breathe via the mouth during that make sure to constrict the throat and try to produce ocean waves like sound. In the second phase, do the same with the nose.
4	<i>Kapalpathi pranayamam</i>	In a seated position breathe in and out normally for 2-3 times. After the body gets adjusted, inhale deeply and exhale with force. In such a manner, that should suck the belly in while expelling the air out.
5	<i>Dirga pranayamam</i>	Lie down inhale a lot of air that makes your belly bulge. Remain in this position for a while then exhale while drawing your belly in.

6	<i>Viloma pranayamam</i>	<p>A) <u>Paused inhalation:</u> Lie down inhale in intervals, until the lungs are filled with air and exhale slowly and gently until completely exhaling the air.</p> <p>B) <u>Paused exhalation:</u> Lie down inhale deeply in one go. Exhale with periodical intervals.</p>
7	<i>Anuloma pranayamam</i>	Inhaling and exhaling is done with one nostril but the other one is not completely blocked.
8	<i>Bhramari pranayamam</i>	Close the ears with the thumbs; close the eyes with the fingers. Take a deep breath and exhale with a chant of OM.
9	<i>Bhastrica pranayamam</i>	Seated in a cross legged position, start to inhale and exhale at a very fast rate continuously.
10	<i>Sheethali pranayamam</i>	Inhaling through your mouth but keep the tongue rolled inside of the mouth. Tilt the chin forward and hold it for a moment.
11	<i>Moorcha pranayamam</i>	For advanced yogis to practice.
12	<i>Palawani pranayamam</i>	For advanced yogis to practice and etc.

Benefits:

Breath awareness:

In the day to day life people are distracted by their needs of money, food, shelter, good job etc. In order to prove oneself, a person had to participate in these competitive world. In such a pushing environment people tends to disconnect from their bodies and experiences. That will ultimately result in uncoordination, unknown fatigue and depression. Guiding the attention towards self can only bring out the desired mindfulness, improved cognition, meta awareness, less mind wandering and better mood. Breath awareness will help in this aspect. In breath awareness, one will concentrate on their own breath. The study of Telles S, et al said that 10 minutes of breath awareness decrease SBP in hypertensive patients.[26]

In stress control:

Stress in this pandemic situations – COVID-19.

The novel covid-19 virus emerged and spread all over the world. It is a highly contagious virus with +ss RNA and nucleocapsid caused significant morbidity and mortality rate. In this critical situation, people from all over the world suffering physically, psychologically, economically etc. The social distancing, locked down situation, threads of unemployment and fear of death like reasons caused a newly found psychosis called 'coronaphobia'. [18] There is also some suicide cases have been recorded after healing. There are abundant studies which could act as proof for *pranayamam* on the aspect of the emotional state of mind. [19] So, *pranayamam* can be prescribed as an adjuvant treatment against covid-19 burden.

Stress due to malignant diseases:

Chakrabharthyvidyasakar conducted 3 trials on cancer patients undergoing chemotherapy in the aspect of short-term effectiveness of *pranayamam* on fatigue, emotional state of mind and antioxidant state. [7]

At the Shirdi Sai Baba cancer hospital and research centre, he conducted his first study on 160 cancer patients. The fatigue scale shows that the patients done *pranayamam* experienced lesser fatigue [5]

The patients ongoing the therapies of cancer and suffering chronic pain tends to develop fear, anxiety, and other negative emotions. The second trial was conducted on 160 eligible participants with breast cancer. Among them, 80 members are instructed to do pranayama along with regular radiation therapy. Other set of 80 members instructed to follow their radiation therapy with routine care. Both of their emotional aspects were checked using the Mann – U – test. The pranayama practicing group shows lesser mean score for this negative emotions. [6]

Stress due to other factors:

Beck depression university conducted a study on verbally physically and sexually harassed participants (n=40) after practicing *pranayamam* they show abrupt fall in the post test levels. [8]

Asthma:

Saxena et al, evaluate the effect of *pranayamam* in mild to moderate bronchial asthmatic patients. 50 participants are divided into two groups as group A (n=25) group B (n= 25). A significant reduction in symptoms and improvement in FEV1 and PEFr was observed in group

A, that practiced breathing exercise, *pranayamam* for 20 minutes, two times per day for 12 days. [2]

Bhatt and Rampillavare evaluated the impact of *pranayamam* on ventilatory functions in patients with bronchial asthma. 80 patients are divided into two groups as 40 in each. One group made to practice *pranayamam* along with medication for 3 months another group made to take only medicines. The vitals and pulmonary functions are significantly raised in the group that practiced *pranayamam*. [3]

Pranayamam is also useful in patients with pleural effusion. Patients those practiced *pranayamam* shows quicker re expansion of the lung [4]

Hypertension:

Goyal et al, conducted test to measure the effectiveness of *pranayamam* on rate pressure product and shows significant reduction in the groups undertaking than the control group. [9]

Mouriya et al, performed hospital based investigation about blood pressure and automatic functions on patients with the essential hypertension. On the intervention of fast and slow yogic breathing exercises. Around 20 – 60-year-old patients both male and female (n = 60) participates in this investigation. Among them one group kept for control second group asked to perform slow breathing exercise, the third group advised to perform fast breathing exercise for three months. The results show that the people practiced breathing exercise had decreased blood pressure. But the people who practiced slow breathing had greater significant effects. [20]

Arrhythmias:

Abhijeet Madhukar Dabhade et Al, conducted a study to determine the effects of *pranayamam* in QT dispersion (QTdis the difference between maximal and minimal intervals between QT intervals in ECG) on 15 patients with Arrhythmias. Those patients showed marked improvement after practicing *pranayamam*. [27]

Table. No. 2: Methods of *pranayamam* that used as an intervention in some clinical trials.

1	Bronchial asthma	Saxena et al,	Deep breathing, Brahmari, OM kara.	20 mins for 2 times per day. For 12 days.
2	Bronchial asthma	Bhatt & Rampillavare,	a) Bhastrica, b) Kapalathi, c) Anuloma- viloma d) Bhramari e) Ujjayi	a) 3-5 mins b) 3-5 mins c) 3-10 mins d) 10-20 times e) 10- 20 times
3	Pleural effusion	M. Prakasamma et al,	Alternate nostril breathing	After the aspiration instructed to practice for 20 days
4	Malignancy • Fatigue • Stress • Antioxidant	Chakrabharthi et al,	a) Nadishodhana, b) Sheethali,	a) 21-25 cycle b) 50-60 cycle
5	Pressure product	Goyal et al,	c) Bramari,	c) 10 cycles twice in a day for 5 days in a week, for 6 weeks
6	Blood pressure	Mouriya et al,	Slow and fast breathing.	3 months.

Discussion:

From the above evidences we come to understand that there is indeed numerous health benefits are attained by *pranayamam*, then there should have been some underlying physiological mechanisms responsible for that. They might be,

- Strengthening both the inspiratory as well as the expiratory muscles. "*Valiyinaivaangivayatrihadakkilpalingotthukaayampazhukkinumpinjaam*". The word *kumbagam* is originated from '*kumbi*' which means abdomen. The rapid

breathing technique *kapalpathi* and holding breath – *kumbagam* both stretches and strengthens the abdominal muscles as well as the diaphragmatic muscles. Thus, pranayama helps in the improvement of respiratory functions, reaction time and respiratory endurance.

- It may correct the altered patterns [21] of breathing by properly toning the respiratory muscles of the respiratory system.

Table. No. 3: Altered patterns of breathing

1	Tachypnea	Rapid rate of respiration
2	Bradypnea	Low rate of respiration
3	Polypnea	Rapid, shallow breathing. Despite of the high respiration rate, the force does not increase.
4	Apnea	Short – term arrest of breathing
5	Hyperpnea	High pulmonary ventilation. Increased rate and force of respiration.
6	Hyperventilation	Unusually high rate and force of respiration which leads to dizziness and chest pain.
7	Hypoventilation	Low rate and force of respiration.
8	Dyspnea	Difficulty in breathing.
9	Periodic breathing	Unusual rate of rhythm.

Because appropriate muscle tone is important for a muscle to react quickly to aexternal stimuli. The *pranayamam* exercises the scalene muscle as well as the stylohyoid muscle that could also stimulates the vagal nerve.

- Lung surfactant is the most needed thing to maintain our lung compliance. And prevents from lung collapsing, stabilizing the alveoli and defencing the lung from infection and inflammation. Maintains the appropriate thickness of the respiratory membrane and facilitates the gaseous exchange[11]. There are two types of cells which secrets surfactant. They are,

1. Type - 2 alveolar cells = presents in the microvilli and the alveolar surface,
2. Clara cells of the bronchioles.

When we do the step *kumbagam* – holding the breath, the lung inflation becomes almost near to the total lung capacity that makes the ventilation of the lung to be much higher. Which is the major stimulus for surfactant to get released.[10]

- Due to inflammations, there occur injury of airway epithelial cells that results in hyper secretion of mucus. This kind of hyper secretion is common in asthma. On the other hand, mucus clearance is altered, contributing to an excessive mucus accumulation, implicated in airway obstruction.[12] And *pranayamam* likely to remove the secretions of bronchial tree and alveoli thus paves a path for free air flow. By Releasing surfactant and improving parasympathetic dominance in the autonomic nervous system.[13] The slow breathing exercises reduces the frictional stress and reduces the mast cell degranulation. It reduces the mast cell related inflammations.[14]
- Nitric oxide is a relaxing factor, derived from endothelium. It gets synthesized endogenously by our own body mechanisms from semi essential amino acids, molecular oxygen, L- arginine, and various nitric oxide synthase. [22] This nitric oxide has anti- inflammatory effects. It will provide nonspecificdefence againsttheinfections produced by viral, bacterial, fungal, and other parasites to our body. Bronchial tree smooth muscles tend to relax on the contact of nitric oxide. It tends to improve the ventilation perfusion ratio in the lung. Nitric oxide has anti- viral activity. It has the ability to inhibit viral proteins along with their nuclear material. Nitric oxide may also have the ability to stimulate ciliary motility.[23] Nitric oxide therapy for neonates with persistent pulmonary hypertension is clinically approved one.[24]There are studies which provides evidence that shows the humming increases the nitric oxide formation in the body dramatically.[25]
- ARDS is an important crisis in Covid-19.As ARDS progresses, vascular permeability in the lung will be increased. If the surfactant deactivates at the time, it will make the lung even more unstable [26]. Pranayama stimulates surfactant secretion. So, pranayama could make up a great adjuvant treatment for Covid-19.

- Vagal afferents from peripheral receptors connected with "nucleus tractus solitarius" from which they ascend to the higher centres thalamus and 'limbic areas' which is responsible for mood swings and emotions called as emotional brain and anterior cortical areas resulting in positive changes in cardio - vagal function and associated neuroendocrine, hemodynamic, and inflammatory profiles, in sleep and affect, and in related downstream metabolic parameters [15]. During *pranayamam* inhibitory signals are produced by vagal nerve due to parasympathetic dominance. Relax and stable mind attained by us. The inhibitory response is due to mechanical stretching of the stretch receptors in the muscles during *pranayamam*. Which initiate synchronization of neural elements of CNS and PNS and other related tissues, causing automatic balance in other words sympathetic- parasympathetic shift [16]. Because of the parasympathetic shift, there will be reduction in the catecholamine, cortisol levels and cardiovascular response to stress etc.
- Psychological benefits are due to breath holding *kumbagam* induce theta wave in EEG [17]. Theta rhythm is a neural oscillation frequency found in the brain. Which will be helpful in our cognition and behaviour. For example, learning capacity, memory capacity etc. There are two types of Theta rhythms have been described. One is hippocampal Theta rhythm another one is cortical theta rhythm. They can be measured by quantitative EEG.
- While holding the breath it ventilates even the apical portion of lungs and prevent it from infection.
- The respiratory and the cardiovascular systems are closely related. Each of these systems can affect each other. This is known as the cardio respiratory coupling. That's why ventilatory patterns have significant effects on blood pressure and heart rate. Practicing pranayama reported to be strengthening this CRC. CRC is an indicator of good health it is decreased in sepsis conditions, stressful and depressed conditions and increased in athletes, relaxed conditions and during slow wave sleep [28].
- There are many homeostatic mechanisms present in the body in order to maintain the normal physiology. One such homeostatic mechanism is the baro reflex or baroreceptor reflex. It will help to maintain blood pressure at nearly constant levels. It is maintained by the autonomic nervous system. This baro reflex sensitivity is increased in the

hypertensive patients who are practiced pranayama. The point, 'Baro reflex mechanism is the reason for sinus Arrhythmias' is mentioned in the Karemaker, 2009 [29].

Discussion on adverse reactions of *pranayamam*:

It is important to know the possible positive and negative outcome of a therapy in order to expect a successful cure. To attain the wholeness, we have look into the other side of this valuable coin.

- As mentioned above, there are lot of *pranayamam* methods and breathing techniques are being practiced. But sometimes people experience the undesirable results.
- Many articles, studies say that only slow breathing practices brings the previously discussed, 'parasympathetic shift', while the fast breathing practices like kapalpathy, *Bhastrika* and other forceful expiratory exercises tends to act opposite from the previous [30]. *Bhastrika pranayamam* that comes under, rapid and deep breathing exercise reported to increase the HR, RPP, and DoP.
- Controlled breathing at a fixed and faster frequency did not produce beneficial effects.
- Some articles report that *kapalpathi* decreases cardiac vagal toning, decrease the sensitivity of arterial baroreflex[31]. In a case study spontaneous pneumothorax caused by *kapalpathi* gotten reported [32].
- *Bhastrika pranayamam* showed significant decrease in the LF component of HRV which is an indicator of cardiac 'sympathetic' modulation. Increase in sympathetic activity can cause sudden and non-sudden cardiac death [33].
- It has been said that in our brain, sympathetic activity is induced by left brain hemisphere, parasympathetic activity is related to right brain hemisphere. Thus left nostril dominance is associated with parasympathetic response while right nostril gets vice versa [34].
- If the nostril switching is not proper it will lead to autonomic imbalance resulting in some somatic and psycho - somatic problems like hypertension. [35]
- We have to hold these things in our mind. That is necessary. But there is no need to fear or developing a bad impression on pranayama. And ofcourse our litterateurs also mentioned the adverse effects via some stories, songs, etc. [1]
- These all things pressing some important points

1. 'The need of mentor while practicing pranayama'. Doing a very good thing in a bad way may ultimately results in a bad ending.
2. The importance of knowing the underlying mechanism and being aware of them.

Then only we can avoid the short comings and use it in a fruitful way.

Conclusion:

Pranayamam stimulates the neurohumoral mechanisms; strengthens the respiratory muscles; and balances the autonomic nervous system to give benefits to the body physiologically as well as psychologically. There are enough clinical trials to prove this fact. Also *pranayamam* is economically cheap and easy to practice. For well-being of society, practicing *pranayamam* is important. During the practice, in order to avoid undesirable outcomes, knowing the underlying mechanism of *pranayamam* is necessary. The possible mechanisms are listed above. But high quality researches are need to get the definitive evidence.

Annexure - 1

Abbreviations:

SBP	Systolic blood pressure
FEV1 PEFR	Forced expiratory volume measured on the first second Peak expiratory flow rate.
Mann U Test	Mann Whitney U test. A non parametric test for null hypothesis used to compare the dependent variables between the concerned two groups
+ ss RNA virus	Positively coiled single stranded ribo nucleic Acid containing virus
QTd	QT dispersion. (In ECG)
ECG	Electro cardio gram
Mins	Minutes

Et Al	Et, alias (Latin word) and others
ARDS CoVid – 19	Acute Respiratory Distress Syndrome/ Adult Respiratory Distress Syndrome Corona Virus Disease 2019
CNS	Central Nervous System
PNS	Peripheral Nervous System
EEG	Electro Encephalo Gram
CRC	Cardio Respiratory Coupling
HR	Heart Rate
RPP	Respiratory pressure product (HR* SBP)
DoP	Double Product [indicator of myocardial oxygen consumption (SBP* Pulse Rate)
HRV	Heart Rate Variability
LF	Low Frequency

Annexure – 2

Tamil versus:

1	இயம நியமமே எண்ணிலா ஆதனம் நயமுறு பிராணாயா மம்பிரத்தி யாகாரம் சயமிகு தாரணை தியானஞ் சமாதி அயமுறும் அட்டாங்க மாவது மாமே – திருமந்திரம்	Notes about eight limbs system of astanga yoga in thirumanthiram
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2	<p>ஏறுதல் பூரகம் ஈரெட்டு வாமத்தால் ஆறுதல் கும்பகம் அறுபத்து நாலதில் உறுத்தல் முப்பத் திறந்ததில் ரேசகம் மாறுதல் ஒன்றின்கண் வஞ்சக மாமே - திருமந்திரம்</p>	<p>Notes about important aspects of pranayama in thirumanthiram with breathing/holding ratios.</p>
3	<p>வளியினை வாங்கி வயத்தில் அடக்கில் பளிங்கொத்துக் காயம் பழுக்கினும் பிஞ்சாம் தெளியக் குருவின் திருவருள் பெற்றால் வளியி னும்வேட்டு அளியனும் ஆமே. - திருமந்திரம்</p>	<p>Notes about the involvement of abdominal muscles in the practice of pranayama in thirumanthiram.</p>

References:

1. *Thirumoolar Thirumanthiram - moolamum vilakka urayum (pattham thirumurai), uma pathippagam.*
2. 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;2:22–5. [PMC free article]
3. Bhatt A, Rampallivar S. Effect of pranayam on ventilatory functions in patients of bronchial asthma. J Evol Med Dent Sci. 2016;5:1453–55. [Google Scholar]
4. Prakasamma M, Bhaduri A. A study of yoga as a nursing intervention in the care of patients with pleural effusion. J AdvNurs. 1984;9:127–33. [PubMed]
5. Chakrabarty J, Vidyasagar M, Fernandes D, Joisa G, Varghese P, Mayya S. Effectiveness of pranayama on cancer-related fatigue in breast cancer patients undergoing radiation therapy: A randomized controlled trial. Int J Yoga. 2015;8:47–53. [PMC free article]
6. Chakrabarty J, Vidyasagar MS, Fernandes D, Mayya S. Emotional aspects and pranayama in breast cancer patients undergoing radiation therapy: A randomized controlled trial. Asia Pac J OncolNurs. 2016;3:199–204. [PMC free article]

7. Chakrabarty J, Vidyasagar MS, Fernandes D, Bhat V, Nagalakshmi, Joisa G, et al. Effectiveness of pranayama on the levels of serum protein thiols and glutathione in breast cancer patients undergoing radiation therapy: A randomized controlled trial. *Indian J PhysiolPharmacol.* 2013;57:225–32. [[Google Scholar](#)]
8. 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;23:1800–8. [[PubMed](#)]
9. Goyal R, Lata H, Walia L, Narula MK. Effect of pranayama on rate pressure product in mild hypertensives. *Int J Appl Basic Med Res.* 2014;4:67–71. [[PMC free article](#)]
10. A Chander et al. Regulation of lung surfactant secretion. *Am J Physiol.* 1990 Jun.
11. Dr.K.Sembulingam. *Textbook of essential medical physiology*, JAYPEE brothers medical publishers. Eighth edition.
12. Duncan F Rogers. Airway mucus hypersecretion in asthma: an undervalued pathology? *Curr Opin Pharmacol.* 2004 Jun.
13. Subbalakshmi NK, Saxena SK, Urmimala JA. Immediate effect of nadi -shodhana pranayama on some selected parameters of cardiovascular, pulmo-nary and higher functions of brain. *Thai J Physiol Sci.* 2005;18:10–6. [[Google Scholar](#)]
14. Karthik PS, Chandrasekhar M, Ambareesha K, Nikhil C. Effect of pranayama and suryanamaskar on pulmonary functions in medical students. *J ClinDiagn Res.* 2014;8:BC04–6. [[PMC free article](#)]
15. Innes KE, Selfe TK. Yoga for adults with type 2 diabetes: A systematic review of controlled trials. *J Diabetes Res.* 2016;2016:6979370. [[PMC free article](#)]
16. Jerath R, Edry JW, Barnes VA, Jerath V. Physiology of long pranayamic breathing: Neural respiratory elements may provide a mechanism that explains how slow deep breathing shifts the autonomic nervous system. *Med Hypotheses.* 2006;67:566–71. [[PubMed](#)]
17. Harinath K, Malhotra AS, Pal K, Prasad R, Kumar R, Kain TC, et al. Effects of Hatha yoga and Omkar meditation on cardiorespiratory performance, psychologic profile, and melatonin secretion. *J Altern Complement Med.* 2004;10:261–8. [[PubMed](#)]
18. Asmundson G.J., Taylor S. Coronaphobia: fear and the 2019-nCoV outbreak. *J. Anxiety Disord.* 2020;70:102196. [[PMC free article](#)]

19. Kirkwood G, Rampes H, Tuffrey V, Richardson J, Pilkington K, Ramaratnam S. Yoga for anxiety: A systematic review of the research evidence. *Br J Sports Med.* 2005;39:884–91. [[PMC free article](#)]
20. Mourya M, Mahajan AS, Singh NP, Jain AK. Effect of slow- and fast-breathing exercises on autonomic functions in patients with essential hypertension. *J Altern Complement Med.* 2009;15:711–7. [[PubMed](#)]
21. Jaworski J., Bates J.H. Sources of breathing pattern variability in the respiratory feedback control loop. *J. Theor. Biol.* 2019;469:148–162. [[PubMed](#)]
22. Taneja MK (2016) Nitric oxide BhramariPranayam, and deafness. *Indian J Otol* 22:1–3. Available from https://www.youtube/9rOnhM_WO6s.
23. Jain B, Rubinstein I, Robbins RA, Leise KL, Sisson JH. Modulation of air way Epithelial cell ciliary beat frequency by nitric oxide. *BiochemBiophysCommun.* 1993;191:83–86. doi: 10.1006/bbrc.1993.1187. [[PubMed](#)]
24. Robbert DJ Jr, Fineman JR, Morin FC, 3rd Sahul PW, Rimer S (1997) Inhaled nitric oxide and persistent pulmonary hypertension of the new born. The inhaled nitric oxide study group. *New Engl J Med* 336:605–610 [[PubMed](#)]
25. Weitzberg E, Lundberg JO. Humming greatly increases nasal nitric oxide. *Am J RespirCrit Care Med.* 2002;166:144–145. doi: 10.1164/rccm.200202-138BC. [[PubMed](#)]
26. Telles S, Yadav A, Kumar N, Sharma S, Visweshwaraiah NK, Balkrishna A. Blood pressure and Purdue pegboard scores in individuals with hypertension after alternate nostril breathing, breath awareness, and no intervention. *Med SciMonit.* 2013;19:61–6. [[PMC free article](#)] [[PubMed](#)]
27. Dabhade AM, Pawar BH, Ghunage MS, Ghunage VM. Effect of pranayama (breathing exercise) on arrhythmias In the human heart. *Explore (NY)* 2012;8:12–5. [[PubMed](#)]
28. Dick TE, Mims JR, Hsieh YH, Morris KF, Wehrwein EA. Increased cardio-respiratory coupling evoked by slow deep breathing can persist in normal humans. *RespirPhysiolNeurobiol.* 2014;204:99–111. [[PMC free article](#)] [[PubMed](#)]
29. Joseph CN, Porta C, Casucci G, Casiraghi N, Maffei M, Rossi M, et al. Slow breathing improves arterial baroreflex sensitivity and decreases blood pressure in essential hypertension. *Hypertension.* 2005;46:714–8. [[PubMed](#)]

30. Madanmohan, Udupa K, Bhavanani AB, Vijayalakshmi P, Surendiran A. Effect of slow and fast pranayams on reaction time and cardiorespiratory variables. *Indian J PhysiolPharmacol.* 2005;49:313–8. [PubMed]
31. Stancák A, Jr, Kuna M, Srinivasan, Vishnudevananda S, Dostálek C. Kapalabhati – yogic cleansing exercise. I. Cardiovascular and respiratory changes. *Homeost Health Dis.* 1991;33:126–34. [PubMed]
32. Johnson DB, Tierney MJ, Sadighi PJ. Kapalabhati pranayama: Breath of fire or cause of pneumothorax? A case report. *Chest.* 2004;125:1951–2. [PubMed]
33. Santaella DF, Devesa CR, Rojo MR, Amato MB, Drager LF, Casali KR, et al. Yoga respiratory training improves respiratory function and cardiac sympathovagal balance in elderly subjects: A randomised controlled trial. *BMJ Open.* 2011;1:e000085. [PMC free article] [PubMed]
34. Backon J, Matamoros N, Ramirez M, Sanchez RM, Ferrer J, Brown A, et al. A functional vagotomy induced by unilateral forced right nostril breathing decreases intraocular pressure in open and closed angle glaucoma. *Br J Ophthalmol.* 1990;74:607–9. [PMC free article] [PubMed]
35. Srinivasan TM. Pranayama and brain correlates. *AncSci Life.* 1991;11:2–6. [PMC free article] [PubMed]
36. Swami. *Pathanjali yoga suthram* – vilakka urai. Sri indhu publications.