Effects of Various Prāṇāyāma on Cardiovascular and Autonomic Variables

Abstract
Cardiovascular functions are controlled by neural factors as well as others such as temperature, hormones, etc., Of these, neural factors primarily concern the autonomic nervous system, which plays a major role in maintaining and regulating cardiac functions, e.g., blood pressure and heart rate. Prāṇāyāma is one of the most important yogic practices. There are various review articles on Yoga and its effects but, though Prāṇāyāma is a part of yoga, there is lack of review articles. To the best of our knowledge there is no known review article on effect of various Prāṇāyāma on cardiovascular and autonomic variables. To provide a general overview about the effect of various prāṇāyāma (breathing techniques) on cardiovascular and autonomic variables. A narrative review was performed based on the available scientific literature. An electronic data search was performed in Medline/PubMed database to review relevant articles, using keywords such as “Prāṇāyāma, Yogic breathing techniques, Unilateral nostril breathing, Alternate nostril breathing, Kapalbhati, Bhastrika and Bhramari Pranayama”. All the relevant articles published from 1988 to 06-04-2016 were included in this review. Slow type of yogic breathing technique was reported to produce beneficial effect on cardiovascular and autonomic variables while fast breathing techniques do not produce such effects. There is lack of consistency in the results of specific nostril yogic breathing techniques and the mechanisms behind the effects of various prāṇāyāma. This review suggests that different types of Prāṇāyāma techniques produce different effects and the mechanisms behind these effects are not fully understood.

Keywords: Autonomic nervous system, cardiovascular, prāṇāyāma

Introduction
Cardiovascular functions are controlled by neural factors as well as others such as temperature, hormones, etc., Of these, neural factors primarily concern the autonomic nervous system (ANS), which plays a major role in maintaining and regulating cardiac functions, e.g., systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR). Imbalances in these lead to cardiovascular disorders such as hypertension, ischemia, infarction, etc., Numerous studies indicate a strong association between compromised ANS (e.g., decreased vagal activity or increased sympathetic activity) and sudden and non-sudden cardiac death.[1] Cardiovascular disease is the leading cause of death for both men and women.[2] Lifestyle modifications are important factors in the treatment, prevention, and rehabilitation of cardiovascular disorders.[1,2] Yoga is one of the best lifestyle modifications and an ancient vedic science thought to have originated in India in 5000 BC which is being applied in the field of therapeutics.[3,4] It includes practice of specific posture (āsana), regulated breathing (Prāṇāyāma) etc., Breath is the dynamic bridge between body and mind and Prāṇāyāma is one of the most important yogic practices.[5]

The word Prāṇāyāma is comprised of two components: ‘prāṇa’ and ‘āyāma’. Prāṇa means ‘vital energy’ or ‘life force’. Āyāma is defined as ‘extension’ or ‘expansion’. Thus, the word Prāṇāyāma means ‘extension or expansion of the dimension of prāṇa’. In the Prāṇāyāma practices, there are four important aspects of breathing such as (1) Pūraka (inhalation), (2) Recaka (exhalation), (3) Antah kumbhaka (internal breath retention), and (4) Bahih kumbhaka (external breath retention). An advanced stage of Prāṇāyāma which occurs during high states of meditation is called as kevala kumbhaka (spontaneous breath retention).[6]

There are various review articles in Yoga and its effects on brain waves,
structural changes and activation, pulmonary function, management of chronic diseases, type 2 diabetes, cerebrovascular attack rehabilitation, cardiovascular disease prevention and its risk factors in general and prevention of coronary heart disease and the management of hypertension in specific.

Though Prāṇāyāma is a part of yoga and different types of Prāṇāyāma were reported to produce different cardiovascular and autonomic responses in healthy individuals and cardiovascular diseases such as hypertension, there is lack of reviews on Prāṇāyāma. To the best of our knowledge there is no known review article on effect of various Prāṇāyāma on cardiovascular and autonomic variables. Hence, in order to provide a general overview, we performed Medline/PubMed search to review relevant articles, using keywords such as: Pranayama, Yogic breathing techniques, Unilateral nostril breathing, Alternate nostril breathing, Kapalabhati, Bhastrikā and Bhramari Pranayama. Articles published from 1988 to 06-04-2016 were included in this review.

Effects of Various Prāṇāyāmas in General

The effects of physical or mental leads to cardiovascular morbidity. In a study, a 2 month practice of various Prāṇāyāma was shown to reduce stress level; low frequency (LF) of heart rate variability (HRV) spectrum (indicative of reduction in sympathetic drive to heart); and increase in high frequency (HF) of HRV spectrum (indicative of increase in parasympathetic output to the heart) along with reduction in LF/HF ratio (indicative of a better sympatho-vagal balance).[19] Hence, Prāṇāyāma produces relaxed state and in this state, parasympathetic activity overrides sympathetic activity.[18]

Regular practice of Prāṇāyāma was shown to produce reduction in the sympathetic tone within a period as short as 7 days.[20] Another study reported that the alteration in autonomic responses to breath holding is probably because of an increase in vagal tone and decreasing sympathetic discharges.[21] In patients with hypertension, arrhythmia.[22] practice of Prāṇāyāma has shown to produce better control of blood pressure (BP),[18] and significant reduction in the indices of ventricular repolarization dispersion,[22] respectively.

Effects of Slow and Fast Prāṇāyāmas

In a previous study on slow Prāṇāyāma such as Nādi śuddhi, Mukhabhastrikā, Pranava and Sāvitrī Prāṇāyāma practiced for 20 minutes daily for a duration of 3 months had shown to modulate ventricular performance by increasing parasympathetic activity and decreasing sympathetic activity.[23]

Different types of Prāṇāyāmas were shown to produce different physiological responses such as practice of Sāvitrī Prāṇāyāma (slow, rhythmic, and deep breathing) reported to produce reduction in heart rate (HR), rate pressure product (RPP) and double product (DoP), whereas Bhastrikā Prāṇāyāma (bellows type rapid and deep breathing) reported to increase it.[24]

In the other studies though both fast (Kapālabhāti, Bhastrikā and Kukkurīya Prāṇāyāma) and slow Prāṇāyāma (Nādi śodhana, Sāvitrī and Pranava Pranāyama) were shown to be beneficial in reducing stress level,[25] the beneficial effects on cardiovascular parameters was seen only after practicing slow Prāṇāyāma[25]breathing[26] but not after fast prāṇāyāma[25]/breathing[26] techniques.

Effects of Individual Prāṇāyāma (Breathing Technique)

Breath awareness

Breath awareness is being aware of or concentrating one’s own breath. In a previous study on 30 minutes of breath awareness, no significant changes in either SBP or DBP were observed in healthy male volunteers. However, another study on 10 minutes of breath awareness showed a significant decrease in SBP in patients with hypertension.[27]

Slow breathing/slow deep breathing

Slow deep breathing has a therapeutic effect on autonomic tone. Repeated practice of Prāṇāyāma was shown to strengthen cardio-respiratory coupling,[28] increases in the parasympathetic activity in healthy individuals,[29] and reduction in BP and enhancement in baroreflex sensitivity in hypertensive patients.[30] There is a class II-A, level of evidence B recommendation for BP lowering efficacy conferred on slow breathing.[31] Hence, these effects appear potentially beneficial in the management of hypertension.[30]

The best technique for improving baroreflex sensitivity and reduce BP in yoga-naive subjects is doing the slow breathing with equal inspiration and expiration.[32] Whereas, another study reported that the increase in baroreflex sensitivity depends on the slow breathing rate and not on the regularization obtained by controlling the breathing because controlled breathing at a fixed and faster frequency (15/min) did not produce such effect.[31]

Fast breathing

Kapālabhāti

It involves forceful exhalation followed by passive inhalation.[8] A previous study reported a decrease in cardiac vagal tone during Kapālabhāti due to changes in respiratory pattern and decreased sensitivity of arterial baroreflex; and decrease in respiratory rate (RR) and increased in SBP and low frequency BP oscillations after Kapālabhāti which suggested a differentiated pattern of vegetative activation and inhibition associated with Kapālabhāti exercise.[33] In a case study, a case of spontaneous pneumo-thorax caused by Kapālabhāti Prāṇāyāma was reported.[34] Hence,
Prāṇāyāma especially fast Prāṇāyāma should be practiced under the supervision of qualified yoga practitioners.

Bhaṣṭrikā

Bhaṣṭrikā, which comprises of rapid forced expirations followed by inspiration through the right nostril, inspiratory apnoea with generation of intrathoracic negative pressure, and expiration through the left nostril showed a significant decrease in the LF component (a marker of cardiac sympathetic modulation) of HRV in elderly healthy population.[35]

Yogic breathing techniques

In a study on 2:1 yogic breathing technique (exhalation is twice of inhalation), maintaining RR of around 6 breaths/min for a duration of 5-7 minutes twice a day for 3 months was shown to reduce SBP, DBP, HR and RR in patients with essential hypetension. Hence, it is suggested as an effective modality for management of essential hypertension.[36] According to a previous study report, a yogic breathing technique that consists of 1 breath/minute (inspiration = 20 seconds, breath retention = 20 seconds, and expiration = 20 seconds) for 31 consecutive minutes appears to have a unique effect on the brain stem cardio-respiratory center regulating the Mayer wave (0.1-0.01 Hz) patterns of the cardiovascular system.[37]

Specific nostril yogic breathing

Right, left uninostril yogic breathing and alternate nostril yogic breathing (ANYB) techniques have differential physiological effects that are in tune with the traditional svara yoga concept.[38] The science of svara (nasal cycle) is an ultradian rhythm and a marker for psycho-physiological states which had been analyzed extensively by Indian yogis.[39-41] It is dependent upon tonic activity of the limbic ANS with hypothalamus as the control centre, as well as levels of circulating catecholamines and other neuro-hormones.[39] and characterized by alternating patency of the left and right nostrils, with a periodicity of two to eight hours.[40]

Sympathetic activity is induced by left brain hemisphere stimulation and parasympathetic activity by right hemisphere stimulation.[42] Previous studies had shown that forced unilateral nostril breathing/specific nostril yogic breathing induces selective contra-lateral hemispheric stimulation[41,43] as measured by relative increases in the electroencephalographic amplitude in the contra-lateral hemisphere as well as alternating lateralization of plasma catecholamines.[42] Forced alternate nostril breathing has a balancing effect on the functional activity of the left and right hemispheres.[44] Hence, the left nostril dominance is associated with parasympathetic response and the right nostril dominance is associated with sympathetic response. If, due to some reason the nostril switching is not proper, that will lead to autonomic imbalance resulting in some somatic or psychosomatic problems such as hypertension.[45]

Results of a previous study suggest that breathing selectively through either nostril could have a marked activating effect or a relaxing effect on the sympathetic nervous system.[46] In contrast, another study reported no significant changes in HR, pulse amplitude, temperature, skin conductance response, and respiration force.[47]

Right nostril yogic breathing

It involves both inhalation and exhalation through right nostril. A previous study reported that the air flow through right nostril (sūrya nāḍi/piṅgalā svara) is activatory in nature.[38] The practice of RNYB is shown to produce increase in oxygen consumption (which could be due to increased sympathetic discharge to the adrenal medulla)[46] and SBP[48,49] and HR[49,50] along with significant decrease in digit pulse volume. Hence it is reported to have a sympathetic stimulating effect.[48] In contrast, previous studies on RNYB showed, no significant changes in either SBP or DBP in healthy males volunteers,[17] and a significant change in HR along with a significant reduction in SBP and DBP in healthy male subjects with no significant changes in female subjects.[51]

Left nostril yogic breathing

It involves both inhalation and exhalation through left nostril. A previous study reported that the air flow through left nostril (candra nāḍi/iḍā svara) is relaxatory in nature.[38] Previous studies on LNYB had shown to produce significant reduction in RR, HR, SBP and DBP in healthy subjects[51] and significant reduction in HR and SBP in hypertensive patients on regular standard medical management.[49] In another study, increase in volar galvanic skin resistance was observed following LNYB which was interpreted as a reduction in sympathetic nervous system activity supplying the sweat glands.[46] In contrast, previous studies on LNYB was shown to produce no significant changes in either SBP or DBP,[17] and significant increase in SBP and HR in healthy men.[49]

Alternate nostril yogic breathing

It involves inhalation through left nostril followed by exhalation through right nostril and vice versa. In previous studies a significant reduction in HR, SBP in healthy;[52] significant reduction in both SBP and DBP in patients with hypertension;[17] and significant increase in parasympathetic activity during[52] and after ANYB[53,54] were reported. In contrast, the previous studies showed a significant increase in HR,[53] no effect in HRV,[56] and a significant increase in LF and LF/HF ratio along with significant reduction in HF spectrum of HRV immediately after 6 and 12 minutes of ANYB in non practitioners of yogic breathing.[57]
Bhrāmarī prāṇāyāma

It involves inhalation through both nostrils and producing humming sound of a bee while exhaling.[5] Five minutes of slow paced Bhrāmarī Prāṇāyāma have been reported to influence parasympathetic dominance on cardiovascular system due to its effects in reducing SBP, DBP, mean arterial BP and HR.[58]

Praṇava prāṇāyāma

Praṇava Prāṇāyāma is a slow and deep yogic breathing techniques which was shown to be effective in reducing HR, SBP, pulse pressure, RRP and DoP in hypertensive patients within five minutes of the practice. The result was said to 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 along with an augmentation of endogenous nitric oxide production.[59]

Sukha prāṇāyāma

Sukha Prāṇāyāma consists of a conscious, slow and deep breathing with equal duration of inhalation and exhalation at the rate of 6 breaths/minute which was shown to reduce the HR and BP in hypertensive patients within 5 minutes of practice.[60]

Mukha bhastrikā

It involves inhalation and exhalation quickly for ten times like the bellows of the blacksmith i.e., with a hissing sound. Starting with rapid expulsion of breath following one another in rapid succession, after ten expulsions, the final expulsion is followed by the deepest possible inhalation. Breath is suspended as long as it can be done with comfort. Deepest possible exhalation is done very slowly. This Prāṇāyāma technique has shown to increase the parasympathetic activity (i.e., reduce basal HR, increase Valsalva ratio and deep breathing difference in HR) and reduce sympathetic activity (i.e., reduction in fall of SBP on posture variation). Hence, Mukha Bhastrikā was reported as having beneficial effect on cardiac autonomic reactivity, when practiced for a longer duration.[61]

Slow pace bhastrikā

It involves inhalation through both nostrils slowly up to the maximum for about 4 seconds and then exhalation slowly up to the maximum through both nostrils for about 6 seconds (at the rate of 6 breaths/min). The breathing must not be abdominal. These steps complete one cycle of Slow Pace Bhastrikā Prāṇāyāma. Five minutes practice of slow bhastrikā was shown to produce significant reduction in both SBP and DBP with a slight fall in HR unlike volunteers who performed the same breathing exercise for the same duration following oral intake of hyoscine-N-butylbromide (Parasympathetic blocker). Hence, Slow Pace Bhastrikā Prāṇāyāma is effective in improving ANS through enhanced activation of the parasympathetic system.[62]

Prāṇāyāma with meditation

Short term (15 days) practice of regular Prāṇāyāma and meditation practice was shown to improve cardiovascular functions, irrespective of age, gender, and BMI in normal healthy individuals.[3]

The hypothesis and the possible mechanism

The mechanism of how Prāṇāyamic breathing interacts with the nervous system affecting metabolic and autonomic functions was hypothesized by Jerath et al. it is their hypothesis that the voluntary slow deep breathing functionally resets the ANS through stretch induced inhibitory signals and hyperpolarization currents propagated through both neural and non-neural tissue which synchronizes neural elements in the heart, lungs, limbic system and cortex. During inspiration, stretching of lung tissue produces inhibitory signals by action of slowly adapting stretch receptors (SARs) and hyperpolarization current by action of fibroblasts. Both inhibitory impulses and hyperpolarization current are known to synchronize neural elements leading to the modulation of the nervous system and decreased metabolic activity indicative of the parasympathetic state.[63]

Another study reported that the Prāṇāyāma practices increase the frequency and duration of inhibitory neural impulses by activating pulmonary stretch receptors during above tidal volume inhalation as in Hering Bruer 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 BP. After hyoscine-N-butylbromide, the parasympathetic blocker, it was observed that blood pressure was not decreased significantly as a result of Prāṇāyāma, as it was observed when no drug was administered. Thus this indicates the parasympathetic activation during the practice of prāṇāyāma.[62]

Advantage

Prāṇāyāma is known since ancient times to relieve stress and stabilize autonomic function of the body.[19] It is easy to learn, practice and follow in our daily life. It can be learned and practiced by patients. Its potential in reducing BP makes this technique a promising non-pharmacologic tool for BP reduction in pre-hypertensive patients.

Conclusion

Prāṇāyāma is one of the most important parts of the ancient traditional Yoga practices. Different types of prāṇāyāma techniques were shown to produce different effects, in which slow type of yogic breathing techniques were reported to improve cardiovascular and autonomic
variables which might be useful for the prevention and the management of cardiovascular disorders. There is lack of consistency in the results of specific nostril yogic breathing and the mechanisms behind the effects of various prāṇāyāma. Hence, future studies are required in the field of Prāṇāyāma to explore its precise effect with the underlying mechanisms.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References
1. Muralikrishnan K, Balakrishnan B, Balasubramanian K, Visnegarwala F. Measurement of the effect of Isha Yoga on cardiac autonomic nervous system using short-term heart rate variability. J Ayurveda Integr Med 2012;3:91-6.
2. Chaddha A. Slow breathing and cardiovascular disease. Int J Yoga 2015;8:142-3.
3. Ankad RB, Henur A, Patil S, Shashikala GV, Chinnagudi S. Effect of short-term pranayama and meditation on cardiovascular functions in healthy individuals. Heart Views 2011;12:58-62.
4. Singh S, Kyziom T, Singh KP, Tandon OP, Madhu SV. Influence of pranayam and yoga-asanas on serum insulin, blood glucose and lipid profile in type 2 diabetes. Indian J Clin Biochem 2008;23:365-8.
5. Mooventhan A, Khode V. Effect of Bhramari pranayama and OM chanting on pulmonary function in healthy individuals: A prospective randomized control trial. Int J Yoga 2014;7:104-10.
6. Saraswati S. Asana Pranayama Madra Bandha. Fourth Revised Edition. Munger, Bihar, India: Yoga Publications Trust; 2008.
7. Desai R, Tailor A, Bhatt T. Effects of yoga on brain waves and structural activation: A review. Complement Ther Clin Pract 2015;21:112-8.
8. Abel AN, Lloyd LK, Williams JS. The effects of regular yoga practice on pulmonary function in healthy individuals: A literature review. J Altern Complement Med 2013;19:185-90.
9. Desveaux L, Lee A, Goldstein R, Brooks D. Yoga in the management of chronic disease: A systematic review and meta-analysis. Med Care 2015;53:653-61.
10. Innes KE, Selfe TK. Yoga for adults with type 2 diabetes: A systematic review of controlled trials. J Diabetes Res 2016;2016:6979370.
11. Lynton H, Kligler B, Shiflett S. Yoga in stroke rehabilitation: A systematic review and results of a pilot study. Top Stroke Rehabil 2007;14:1-8.
12. Hartley L, Dyakova M, Holmes J, Clarke A, Lee MS, Ernst E, et al. Yoga for the primary prevention of cardiovascular disease. Cochrane Database Syst Rev 2014;5:CD010072.
13. Cramer H, Lauche R, Haller H, Steckhan N, Michalsen A, Dobos G. Effects of yoga on cardiovascular disease risk factors: A systematic review and meta-analysis. Int J Cardiol 2014;173:170-83.
14. Kwong JS, Lau HL, Yeung F, Chau PH, Woo J. Yoga for secondary prevention of coronary heart disease. Cochrane Database Syst Rev 2015;6:CD009506.
15. Posadzki P, Cramer H, Kuzdzal A, Lee MS, Ernst E. Yoga for hypertension: A systematic review of randomized clinical trials. Complement Ther Med 2014;22:511-22.
16. Tyagi A, Cohen M. Yoga and hypertension: A systematic review. Altern Ther Health Med 2014;20:32-59.
17. Raghuraj P, Telles S. Immediate effect of specific nostril manipulating yoga breathing practices on autonomic and respiratory variables. Appl Psychophysiol Biofeedback 2008;33:65-75.
18. 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.
19. Bhimani NT, Kulkarni NB, Kowale A, Salvi S. Effect of pranayama on stress and cardiovascular autonomic function. Indian J Physiol Pharmacol 2011;55:370-7.
20. Turanakar AV, Jain S, Patel SB, Sinha SR, Joshi AD, Vallish BN, et al. Effects of slow breathing exercise on cardiovascular functions, pulmonary functions and galvanic skin resistance in healthy human volunteers – A pilot study. Indian J Med Res 2013;137:916-21.
21. Bhargava R, Gogate MG, Mascarenhas JF. Autonomic responses to breath holding and its variations following pranayama. Indian J Physiol Pharmacol 1988;32:257-64.
22. Dabhide AM, Pawar BH, Ghusane MS, Ghusane VM. Effect of pranayama (breathing exercise) on arrhythmias in the human heart. Explore (NY) 2012;8:12-5.
23. Udupa K, Madanmohan, Bhavanani AB, Vijayalakshmi P, Krishnamurthy N. Effect of pranayam training on cardiac function in normal young volunteers. Indian J Physiol Pharmacol 2003;47:27-33.
24. Madanmohan, Udupa K, Bhavanani AB, Vijayalakshmi P, Surendiran A. Effect of slow and fast pranayams on reaction time and cardiorespiratory variables. Indian J Physiol Pharmacol 2005;49:313-8.
25. Sharma VK, Trakroo M, Subramaniam V, Rajajeyakumar M, Bhavanani AB, Sahai A. Effect of fast and slow pranayama on perceived stress and cardiovascular parameters in young health-care students. Int J Yoga 2013;6:104-10.
26. Pal GK, Velkumary S, Madanmohan. Effect of short-term practice of breathing exercises on autonomic functions in normal human volunteers. Indian J Med Res 2004;120:115-21.
27. 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 Sci Monit 2013;19:61-6.
28. Dick TE, Mims JR, Hsieh YH, Morris KE, Wehrwein EA. Increased cardio-respiratory coupling evoked by slow deep breathing can persist in normal humans. Respir Physiol Neurobiol 2014;204:99-111.
29. Chandla SS, Sood S, Dogra R, Das S, Shukla SK, Gupta S. Effect of short-term practice of pranayamic breathing exercises on cognition, anxiety, general well being and heart rate variability. J Indian Med Assoc 2013;111:662-5.
30. Joseph CN, Porta C, Casucci G, Casiraghi N, Maffeiis M, Rossi M, et al. Slow breathing improves arterial baroreflex sensitivity and decreases blood pressure in essential hypertension. Hypertension 2005;46:714-8.
31. Cernes R, Zimlichman R. RESPERATE: The role of paced breathing in hypertension treatment. J Am Soc Hypertens 2015;9:38-47.
32. Mason H, Vandoni M, Debarbieri G, Codrons E, Ugargol V, Bernardi L. Cardiovascular and respiratory effect of yogic slow breathing in the yoga beginner: What is the best approach? Evid Based Complement Alternat Med 2013;2013:743504.
33. Stancák A Jr., Kuna M, Srinivasan, Vishnudevanda S, Dostálek C. Kapalabhati – yogic cleansing exercise. I. Cardiovascular and respiratory changes. Homeost Health Dis 1991;33:126-34.

34. Johnson DB, Tierney MJ, Sadighi PJ. Kapalabhati pranayama: Breath of fire or cause of pneumothorax? A case report. Chest 2004;125:1951-2.

35. Santealla 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.

36. Adhana R, Gupta R, Dvivedi J, Ahmad S. The influence of the 2:1 yogic breathing technique on essential hypertension. Indian J Physiol Pharmacol 2013;57:38-44.

37. Shannahoff-Khalsa DS, Sramek BB, Kennel MB, Jamieson SW. The effects of unilateral forced nostril breathing (FUNB) on the autonomic nervous system: An unsupported claim. Med Hypotheses 1993;41:367-9.

38. Johnson DB, Tierney MJ, Sadighi PJ. Kapalabhati pranayama: Breath of fire or cause of pneumothorax? A case report. Chest 2004;125:1951-2.

39. Bhavanani AB, Ramanathan M, Balaji R, Pushpa D. Differential effects of uninostril and alternate nostril pranayamas on cardiovascular parameters and reaction time. Int J Yoga 2014;7:60-5.

40. Bhavanani AB, Madanmohan, Sanjay Z. Immediate effect of Chandra Nadi pranayama (left unilateral forced nostril breathing) on cardiovascular parameters in hypertensive patients. Int J Yoga 2012;5:108-11.

41. Samantaray S, Telles S. Nostril dominance at rest associated with performance of a left hemisphere-specific cancellation task. Int J Yoga 2008;1:56-9.

42. 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 intracranial pressure in open and closed angle glaucoma. Br J Ophthalmol 1990;74:607-9.

43. Sinha AN, Deepak D, Gusain VS. Assessment of the effects of pranayama/alternate nostril breathing on the parasympathetic nervous system in young adults. J Clin Diagn Res 2013;7:821-3.

44. Stancák A Jr., Kuna M. EEG changes during forced alternate nostril breathing. Int J Psychophysiol 1994;18:75-9.

45. Telles S, Nagarathna R, Nayendra HR. Breathing through a particular nostril can alter metabolism and autonomic activities. Indian J Physiol Pharmacol 1994;38:133-7.

46. Larson G, Zaichickovsky LD, Mostofsky DL. Forced unilateral nostril breathing (FUNB) effects on the autonomic nervous system: An unsupported claim. Med Hypotheses 1993;41:367-9.

47. Telles S, Nagarathna R, Nagendra HR. Physiological measures of right nostril breathing. J Altern Complement Med 1996;2:479-84.

48. Bhavanani AB, Madanmohan, Sanjay Z, Basavaraddi IV. Immediate cardiovascular effects of pranava pranayama in the heart rate variability in non-practitioners of yogic breathing. J Altern Complement Med 2004;10:757-66.

49. Upadhyay Dhungel K, Mallotra V, Sarker D, Prajapati R. The effects of unilateral forced nostril breathing exercise on cardiorespiratory functions. Nepal Med Coll J 2008;10:25-7.

50. Ghiya S, Lee CM. Influence of alternate nostril breathing on heart rate variability in non-practitioners of yogic breathing. Int J Yoga 2012;5:66-9.

51. Subramanian RK, Devaki PR, Saikumar P. Alternate nostril breathing at different rates and its influence on heart rate variability in non-practitioners of yoga. J Clin Diagn Res 2016;10:CM01-2.

52. 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;12:154-7.

53. Bhavanani AB, Madanmohan, Sanjay Z, Basavaraddi IV. Immediate cardiovascular effects of pranava pranayama in hypertensive patients. Indian J Physiol Pharmacol 2012;56:273-8.

54. Upadhyay Dhungel K, Mallotra V, Sarker D, Prajapati R. The effects of unilateral forced nostril breathing exercise on cardiorespiratory functions. Nepal Med Coll J 2008;10:25-7.

55. Veerabhadrappa SG, Baljoshi VS, Khanapure S, Herur A, Patil S, Ankad RB, et al. Effect of yogic bellows on cardiovascular autonomic reactivity. J Cardiovasc Dis Res 2011;2:223-7.

56. Upadhyay Dhungel K, Mallotra V, Sarker D, Prajapati R. The effects of unilateral forced nostril breathing exercise on cardiorespiratory functions. Nepal Med Coll J 2008;10:25-7.

57. 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.