CHAPTER-10

Annexure

ANNEXURE 1

Informed Consent Form

SWAMY VIVEKANANDA YOGA ANUSANDHANA SAMSTHANA UNIVERSITY

Title of the project: Impact of Selected Pranayama on Cerebrovascular Hemodynamics in Healthy Volunteers

Name of Principle Investigator: Dr. L.Nivethitha

Informed Consent form for male and female subjects who are willing to participate in the research study on various selected pranayama techniques

This Informed Consent Form has two parts:
- Information Sheet (to share information about the research with you)
- Certificate of Consent (for signatures if you agree to take part)

You will be given a copy of the full Informed Consent Form

PART I: Information Sheet

Introduction

I am Dr. L.Nivethitha, working as Assist Professor at S-VYASA Yoga University. Pranayama also called yogic breathing technique is an essential part of traditional Yoga. We would like to understand the impact of selected pranayama techniques such as kumbhaka (breath retention), bhastrika (belows breath), Kapalbhati (frontal brain cleansing breath) and bhramari (humming bee breath) on cerebral (brain) hemodynamics such as cerebral blood low (CBF), and its auto-regulation; and cardiovascular changes. I wish to give you information regarding this study and invite you to participate in the same, to help us understand the effects of selected pranayama. You may talk to anyone you feel before giving your consent to participate in the study. There may be some words in the description that you may not understand. Please ask me as we go through the information and I shall clarify the doubts. In case you have any questions later, you could get them cleared anytime by asking me.

Purpose of the research

One or the other cerebral hemodynamic variables such as CBF, cerebro vascular resistance, cerebral perfusion and auto-regulation were reported to impaired in various disease such as hypertension, obesity, metabolic syndrome, stroke, epilepsy, Alzheimer's disease, memory and cognitive functions whereas, yogic practices including pranayama were reported to be effective for the management all the above mentioned diseases/disorders. To the best of our knowledge there is no known previous studies evaluating the impact of different pranayamas (one of the yoga techniques) such as kumbhaka (breath retention), bhastrika (belows breath), Kapalbhati (frontal brain cleansing breath), and bhramari (humming bee breath) on cerebrovascular hemodynamic changes in healthy volunteers.

Type of Research Intervention

You will be receiving all the selected pranayamas such as Kumbhaka, (andhar and bhakir kumbhaka, bhastrika, bhramari, and Kapalbhati. The duration of each pranayama practice would be of 1 minute (3 rounds) with a rest period of 2-3 minutes between each pranayama practice.

Participant selection

We are inviting male and female healthy adults with and without experience in yoga.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You may change your mind later and stop participating even if you agreed earlier.

Procedures and Protocol

If you have experience in doing yoga for minimum of 1 year, to study the effect of selected pranayama on cerebrovascular hemodynamic and cardiovascular changes, you will be receiving all the above mentioned selected pranayama in anyone of the 5 difference orders. All the pranayama will be given for the duration of 1 minute (three rounds) except Bhramari (five minute) with a rest period of 2-3 minutes between each pranayama practice in order to neutralize the effect of the previous pranayama. Assessments will be taken 1 minute before (normal breath), 1 minute during (selected pranayama) and minute after (normal breath) the intervention. All the assessments will be done at our research laboratory. Cerebrovascular haemodynamic changes of the right middle cerebral artery (MCA) will be assessed with the use of Transcranial Doppler (TCD) (Multi Dop X, DWL, Germany.) by using trans 2MHz pulsed-wave. A 4/16 channel polygraph (MP 36, Biopac Student Lab, BIOPAC System Inc, U.S.A.) will be used to record the electrocardiogram (ECG), and respiration.

A beat to beat blood pressure changes will be assessed using non-invasive blood pressure monitoring system (Finapres Continuous Non Invasive Blood Pressure Systems) throughout the assessment duration. A finger cuff will be connected to the left middle finger, in between the interphalangeal joints. Brachial correction will be made at regular intervals as per SOPs of the instrument.

If you have no experience in yoga, you will be assessed only one time for the above mentioned variables using the same equipments without intervention sessions.

We do not anticipate any untoward effect of any of the assessments. You will not feel any sensation during the recordings.

Duration

The intervention and the assessment (including preparation) will be around 60 minutes.

Side Effects
As already mentioned, we do not anticipate any untoward effects due to practice of selected pranayama or due to the assessment methods. You may feel discomfort due to placing of electrodes or the head probes while the recordings are conducted. Exposure to the ultrasound might produce mild headache or giddiness. We will stop the recordings in case you feel any of these side effects.

Risks
We do not anticipate any risk due to either intervention or the assessment methods. While the possibility is very low, you may have allergy to the electrode. Exposure to the ultrasound might produce mild headache or giddiness. In any such case, you can report us so that we will provide you first aid in our university hospital and refer you to the nearby hospital if necessary but the expenses towards any untoward effects will not be provided by us in any form.

Benefits
You may not be benefitted directly or may have improved cardio-pulmonary due to the practice, but the findings from the study will help us to understand the physiological changes such as the cerebrovascular hemodynamics (CBF and its auto-regulation) and autonomic variables (heart rate, respiratory rate, blood pressure) along with the relationship between cerebrovascular and autonomic variables.

Reimbursements
You will not be provided any compensation for participating in this study in the form of money or any gifts.

Confidentiality
Your identity will not be disclosed to anyone. The information that we collect from this research will be kept confidential. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone.

Sharing the Results
The information that we collect will be shared with you and reported to relevant research journals or conference. Your name and identity will be kept confidential during any such reporting.

Right to Refuse or Withdraw
You do not have to take part in this research if you do not wish to do so. You may also stop participating in the research at any time you choose. It is your choice and all of your rights will still be respected.

Who to Contact
If you have any questions you may ask them now or later, even after the study has started. If you wish to ask questions later, you may contact

- Dr. L. Nivethitha, Mobile: 8496930190, dr.nivethithathenature@gmail.com

This proposal has been reviewed and approved by Institutional Ethics Committee (IEC), which is a committee whose task it is to make sure that research participants are protected from harm. If you wish to find more about the IEC, contact coordinator, IEC, through iec.svyasa@gmail.com

You can ask me any more questions about any part of the research study, if you wish to. Do you have any questions?

PART II: Certificate of Consent

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction.

I consent voluntarily to participate as a participant in this research.

Name of Participant :

Signature of Participant :

Date :

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done:

1.
2.
3.

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

Name of Researcher/person taking the consent: Dr. L. Nivethitha

Signature of Researcher /person taking the consent___________________________

Date ___________________________

Day/month/year

ANNEXURE-2

List of Publications

Publications from This Thesis

1. **Nivethitha, L.,** Mooventhan, A., & Manjunath, N. K. (2016). Effects of various Prāṇāyāma on cardiovascular and autonomic variables. Ancient Science of Life, 36(2), 72-7.
2. **Nivethitha, L.,** Mooventhan, A., Manjunath, N. K., Bathala, L., & Sharma, V. K. (2017). Cerebrovascular hemodynamics during pranayama techniques. Journal of Neurosciences in Rural Practice, 8(1), 60-63.
3. **Nivethitha, L.,** Manjunath, N. K., & Mooventhan, A.(2017). Heart Rate Variability Changes during and after the Practice of Bhramari Pranayama. International Journal of Yoga, 10(2), 99-102.
4. **Nivethitha, L.,** Mooventhan, A., & Manjunath, N. K. (2017). A Study on Evaluating Cardiovascular Functions during the Practice of *Bahir Kumbhaka* (External breath Retention). Advances in Integrative Medicine,4, 7-9.

Papers under Review:

1. **Nivethitha, L.,** Mooventhan, A., &Manjunath, N. K. Evaluation of cardiovascular functions during the practice of different pranayama techniques. Indian Journal of Physiology and Pharmacology. [Under Review]
2. **Nivethitha, L.,** Mooventhan, A., Manjunath, N. K., Bathala, L., & Sharma, V. K. Cerebrovascular Hemodynamics during the Practice of Bhramari Pranayama, Kapalbhati and Bahir-Kumbhaka: An Exploratory Study. Applied Psychophysiology and Bio-Feedback. [Under Review]

Anc Sci Life. 2016 Oct-Dec; 36(2): 72–77.
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Effects of Various *Prāṇāyāma* on Cardiovascular and Autonomic Variables

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Abstract

Cardiovascular functions are controlled by neural factors, 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] 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) *Antaḥ kumbhaka* (internal breath retention), and (4) *Bahiḥ 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,[7] pulmonary function,[8] management of chronic diseases,[9] type 2 diabetes,[10] cerebrovascular attack rehabilitation,[11] cardiovascular disease prevention[12] and its risk factors in general[13] and prevention of coronary heart disease[14] and the management of hypertension[15,16] in specific.

Though *Prāṇāyāma* is a part of yoga and different types of *Prāṇāyāma* were reported to produce different cardiovascular[3] and autonomic responses[17] in healthy individuals[3,17] and cardiovascular diseases such as hypertension,[18] 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, *Kapalbhati*, *Bhastrikā* and *Bhramari Pranayama*. Articles published from 1988 to 06-04-2016 were included in this review.

Effects of Various *Prāṇāyāmas* in General

The stress either 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[18] and 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 *Nāḍi śuddhi*, *Mukhabhastrikā*, *Praṇava* and *Sāvitrī Prāṇāyāmas* 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* (*Nāḍi śodhana, Sāvitrī and Praṇava Pranāyāma*) 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.[17] 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-naïve 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.[6] 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.

Bhastrikā *Bhastrikā*, 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 hypertension. 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*.[39,40,41] 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[41,42,43] 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 DSP 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.[39] 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;[27] and significant increase in parasympathetic activity during[53] and after ANYB[53,54] were reported. In contrast, the previous studies showed a significant increase in HR;[55] 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.

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Cerebrovascular hemodynamics during pranayama techniques

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Abstract

Background:

Pranayama techniques are known to produce variable physiological effects on the body. We evaluated the effect of the two commonly practiced Pranayama techniques on cerebral hemodynamics.

Materials and Methods:

Fifteen healthy male volunteers, trained in Yoga and Pranayama, were included in the study. Mean age was 24 years (range 22–32 years). Study participants performed 2 Pranayamas in 2 different orders. Order 1 (n = 7) performed Bhastrika (bellows breaths) followed by Kumbhaka (breath retention) while order 2 (n = 8) performed Kumbhaka followed by Bhastrika. Both breathing techniques were performed for 1 min each. Continuous transcranial Doppler (TCD) monitoring was performed during the breathing techniques. TCD parameters that were recorded included peak systolic velocity (PSV), end-diastolic velocity (EDV), mean flow velocity (MFV), and pulsatility index (PI) of the right middle cerebral artery at baseline, 15, 30, 45, and 60 s.

Results:

Significant reductions in EDV (3.67 ± 6.48; $P < 0.001$) and MFV (22.00 ± 7.30; $P < 0.001$) with a significant increase in PI (2.43 ± 0.76; $P < 0.001$) were observed during Bhastrika. On the contrary, a significant increase in PSV (65.27 ± 13.75; $P < 0.001$), EDV (28.67 ± 12.03; $P < 0.001$), and MFV (43.67 ± 12.85; $P < 0.001$) with a significant reduction in PI (0.89 ± 0.28; $P < 0.01$) was observed only during Kumbhaka.

Conclusion:

Bhastrika and Kumbhaka practices of Pranayama produce considerable and opposing effects on cerebral hemodynamic parameters. Our findings may play a potential role in designing the Pranayama techniques according to patients' requirements.

KEYWORDS: Bhastrika, cerebrovascular hemodynamics, Kumbhaka, Pranayama

Introduction

Cerebral autoregulation represents the brain's ability of maintaining cerebral perfusion over a wide range of physiological challenges.[1] Maintenance of cerebral blood flow (CBF) ensures constant supply of nutrients and oxygen to the brain.[2] Blood flow velocities in the major arteries of the circle of Willis can be monitored noninvasively with continuous Transcranial Doppler (TCD) and represent relative changes in CBF during short periods of physiological challenges.[1] TCD, aptly called as the stethoscope of the brain is the only diagnostic tool, provides real-time monitoring of cerebrovascular hemodynamics in the major intracranial arteries.[3]

Pranayama is an ancient art of breath control,[4] which involves breathing through one or the other nostril, holding the breath in inspiration, expiration, etc.[5] It is one of the most important yogic practices,[4] consists of long, sustained inhalation (Puraka), exhalation (Rechaka), and holding breath (Kumbhaka).[6] Kumbhaka constitutes the most important part of Pranayama[7] during which carbon dioxide (CO_2) level rises.[8] The increase in CO_2 level provides a potent vasodilatory challenge to increase CBF.[9] On the contrary, reduction in $CO_{2,}$ induced by hyperventilation, produces vasoconstriction and reduces CBF in the intracranial arteries.[1]

Different types of Pranayama produce different physiological responses.[10] For example, slow Pranayama results in reduction in heart rate and blood pressure,[11] whereas Bhastrika Pranayama (bellows type rapid and deep breathing) increases the heart rate and blood pressure.[10] To the best of our knowledge, information regarding cerebral hemodynamic alterations during various Pranayama techniques is lacking. In this study, we evaluated the cerebrovascular hemodynamic responses during the two Pranayama techniques - Bhastrika and Kumbhaka.

Materials and Methods

Subjects

Initially, 16 healthy male volunteers, trained in Yoga and Pranayama, were recruited. However, one of them was later excluded due to insufficient experience. The 15 final participants (mean age 24 years, range 22–32 years) belonged to one of the reputed residential Yoga University in South India.

Inclusion criteria Healthy male volunteers, aged 18 years and above, body mass index 18.5–24.99 kg/m^2, and practicing regular Yoga and Pranayama techniques for more than 1 year were the inclusion criteria.

Exclusion criteria Participants with a history of any active systemic and mental illness, on regular medication for any diseases, chronic substance abuse, and not trained in Yoga and Pranayama were excluded from the study. The study protocol was approved by the Institutional Ethics Committee and a signed written informed consent was obtained from each participant.

Study design

A single group repeated measures design was used and each participant performed two Pranayama techniques (Bhastrika and Kumbhaka) in two different orders. The order of the sessions was randomized using 7 papers with the word “Bhastrika” and 8 with the word “Kumbhaka” put in an envelope and each participant drew a paper to determine their order.[4] In the first order (n = 7), participants performed Bhastrika followed by Kumbhaka while in the second order (n = 8), performance of Kumbhaka was followed by Bhastrika. Figure 1 summarizes the study design and workflow.

Assessment

Cerebrovascular hemodynamic changes Cerebrovascular hemodynamic changes were monitored in the right middle cerebral artery (MCA) with TCD (Multi-Dop X, DWL, Germany). A 2-MHz TCD ultrasound transducer probe was placed with the use of head frame in the right temporal area just above the zygomatic arch and in front of the tragus of the ear. The transducer was adjusted to get consistent flow spectra between 45 and 60 mm. The right MCA was chosen only for consistency and technique of fixing the head frame and monitoring transducer. TCD parameters recorded during the monitoring included peak systolic velocity (PSV), end-diastolic velocity (EDV), mean flow velocities (MFV) in cm/s, and pulsatility index (PI).[3] These measurements were recorded at baseline, 15, 30, 45, and 60 s during each Pranayama technique.

Intervention Interventions were given in two different orders as described above. Each Pranayama technique was performed for 1 min with a rest period of 5 min to allow the cerebral hemodynamic patterns to settle at their baseline values.

Bhastrika (bellows breath for 1 min): Participants were asked to perform voluntary forceful inhalation and forceful exhalation through both nostrils for 60 s followed by gentle and normal breathing.

Kumbhaka (Internal breath retention for 1 min): Participants were asked to perform voluntary breath holding for 60 s followed by gentle and normal breathing.[7]

Normal breathing (1 min): TCD monitoring was performed for 1 min during normal breathing pattern before and after Bhastrika and Kumbhaka.

Data analysis

Statistical analysis was performed by Student's paired samples *t*-test with the use of Statistical Package for the Social Sciences (SPSS) for Windows, Version 16.0. Chicago, SPSS Inc.

Results

All study participants demonstrated stable cerebral hemodynamic parameters during normal breathing. No significant changes were observed in PSV, EDV, MFV, and PI during normal breathing sessions. Bhastrika resulted in a significant reduction in EDV and MFV with a significant increase in PI between 15 and 60 s of the technique [Table 1]. Briefly, considerable reductions in EDV (3.67 ± 6.48; $P < 0.001$) and MFV (22.00 ± 7.30; $P < 0.001$) with a significant change in PI (2.43 ± 0.76; $P < 0.001$) were observed during Bhastrika. During Kumbhaka [Table 2], a significant increase in PSV, EDV, and MFV with a significant reduction in PI was observed between 30 and 60 s of the breathing technique. Accordingly, a considerable increase in PSV (65.27 ± 13.75; $P < 0.001$), EDV (28.67 ± 12.03; $P < 0.001$), and MFV (43.67 ± 12.85; $P < 0.001$) with a significant reduction in PI (0.89 ± 0.28; $P < 0.01$) was observed only during Kumbhaka.

Discussion

Our study shows that Bhastrika and Kumbhaka practices of Pranayama produce considerable effects on cerebral hemodynamic parameters. CBF is regulated by the autonomic nervous system (ANS) by altering the tone of arteriolar sphincters. Some of the important determinants of CBF include partial pressure of arterial CO_2 ($PaCO_2$), mean arterial pressure (MAP), and cerebral metabolism. $PaCO_2$ is the strongest regulator of arteriolar tone and an increase of 1 mm of Mercury (Hg) increases CBF by 3–6% while a 1 mmHg reduction decreases CBF by 1–3%.[2]

We did not observe any significant change in the cerebral hemodynamic parameters during normal breath sessions, probably related to the maintenance of $PaCO_2$, MAP, cerebral metabolism, and the balanced state of ANS within a very narrow and stable range.[12]

Hyperventilation reduces the end-tidal partial pressure of CO_2 by 15.5 ± 1.9 mmHg[1] by washing out CO_2. The resultant hypocapnea increases cerebrovascular resistance and decreases the CBF.[2] We strongly believe that a similar mechanism operates during Bhastrika, resulting in a significant reduction in

EDV and MFV and an increased PI between 15 and 60 s. Our hypothesis is supported by a previous study on Bhastrika, where the sympathetic activation was reported indirectly by means of the increase in heart rate, rate pressure product, and double product.[10] Since the arteriolar sphincters reduce the blood flow mainly by vasoconstriction-induced reduction of EDV, the effect of hyperventilation (also applicable to Bhastrika) on PSV remains poorly understood. We observed a significant reduction in PSV only after 45 s of rapid breathing. The cerebral hemodynamic parameters gradually returned to their baseline values within 1 min of cessation of Bhastrika, most probably related to the normalization of PaCO2 during the normal breathing.

During Kumbhaka, a significant increase in PSV, EDV, and MFV was observed during 30–60 s, accompanied by a significant reduction in PI. Kumbhaka might lead to the development of hypercapnia and hypoxia because previous studies on breath-holding maneuver reported a reduction of end-tidal partial pressure of oxygen below its normal level of ~100 mmHg while end-tidal $PaCO_2$ rises above its normal level of ~40 mmHg during breath holding.[13] Hence, we assume that the same phenomenon might have been responsible for an increase in CBF and reduction in cerebrovascular resistance in this present study.[2] However, lack of the objective measures such as end-tidal $PaCO_2$ is limiting the claim for the support of the result.

The mechanism by which hypercapnia and hypoxia affect cerebrovascular resistance remains poorly understood. Cerebrovascular smooth muscles are believed to be sensitive to changes in $PaCO_2$ and hydrogen ion (H^+) concentration. Increase in CO_2[12] and hypoxia[2] leads to increased H^+ concentration, which activates voltage-gated potassium (K^+) channels. The resultant hyperpolarization of endothelial cells reduces intracellular calcium, leading to cerebrovascular relaxation and vasodilatation.[2,12] Other proposed mechanisms include the release of vasoactive agents such as nitric oxide and prostaglandins in response to the velocity-induced shear stress[12] and adenosine-induced vasodilation.[2]

Certain limitations of the study need to be acknowledged. First, we did not monitor the partial pressures of oxygen and CO_2 during various Pranayama techniques to delineate the underlying physiological mechanisms for the observed changes in cerebral hemodynamic parameters. Second, we feel that monitoring of some of the autonomic variables, specifically blood pressure might have helped in a better understanding of the changes in PSV during the recovery periods of both practices. Third, our study might appear to have a small number of participants. One of the reasons for this is due to inclusion of trained professionals in Yogic Pranayama techniques. Hence, further study is required with the large sample size and more objective measurements for the better understanding.

Conclusion

Our study suggests that Bhastrika and Kumbhaka practices produced different cerebral hemodynamic changes which are almost opposite to each other. The changes were uniform among the study participants. We hypothesize that our findings may play a potential role in designing the Pranayama techniques according to patients' requirements. We recommend further studies with all the relevant parameters in larger sample sizes for better understanding of cerebrovascular hemodynamic changes during various Pranayama techniques.

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Conflicts of interest

There are no conflicts of interest.

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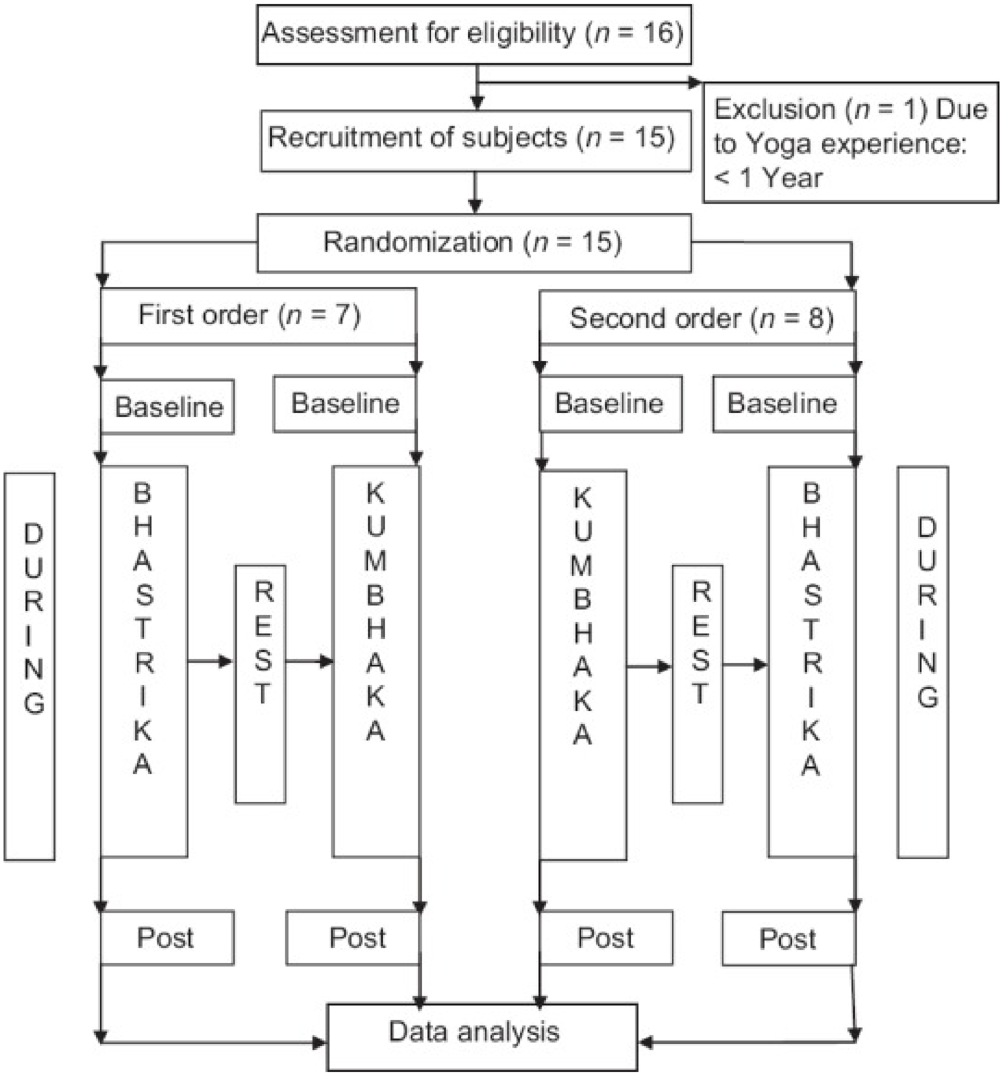
Figures and Tables

Figure 1



Study design and workflow

Table 1

Parameter	Baseline	15 s	30 s	45 s	60 s
PSV (cm/s)	52.53±15.39	51.87±15.02	56.13±18.62	52.53±18.21	50.87±15.71
EDV (cm/s)	21.67±7.53	4.67±6.85*	3.80±6.57*	3.67±6.48*	5.07±6.67*
MFV (cm/s)	34.20±10.81	22.87±7.93*	22.80±8.02*	22.00±7.30*	22.27±6.52*
PI	0.91±0.16	2.26±0.88*	2.43±0.76*	2.34±0.79*	2.16±0.68*

All values are in mean±SD. **P*<0.05. PSV: Peak systolic velocity, EDV: End-diastolic velocity, MV: Mean flow velocity, PI: Pulsatility index, SD: Standard deviation

Cerebral hemodynamic parameters during Bhastrika (*n*=15)

Table 2

Parameter	Baseline	15 s	30 s	45 s	60 s
PSV (cm/s)	50.73±12.41	50.60±11.84	55.20±12.53*	58.60±12.57*	65.27±13.75*
EDV (cm/s)	17.27±7.33	18.47±7.24	22.67±8.24*	25.73±9.84*	28.67±12.03*
MFV (cm/s)	30.00±7.67	28.93±7.04	33.87±8.77*	38.80±10.25*	43.67±12.85*
PI	1.20±0.38	1.11±0.34	0.99±0.25*	0.89±0.28*	0.90±0.31*

All values are in mean±SD. **P*<0.05. PSV: Peak systolic velocity, EDV: End-diastolic velocity, MV: Mean flow velocity, PI: Pulsatility index, SD: Standard deviation

Cerebral hemodynamic parameters during Kumbhaka (*n*=15)

ANNEXURE 3: Journal Club Presentations

Sl.No	Date	Time	Place	Title of the Study
1	23.4.2016	2.00 – 4.00 pm	Anvesana	Right Dorsolateral Frontal Lobe N-Acetyl Aspartate and Myoinositol Concentration Estimation in Type 2 Diabetes with Magnetic Resonance Spectroscopy
2	30.4.2016	2.00 – 4.00 pm	Anvesana	Comparative immediate effect of different yoga asanas on heart rate and blood pressure in healthy young volunteers
3	11.6.2016	2.00 – 4.00 pm	Anvesana	Increased Grey Matter Associated with Long- Term Sahaja Yoga Meditation: A Voxel-Based Morphometry Study
4	18.6.2016	2.00 – 4.00 pm	Anvesana	Transcranial Doppler: Technique and common findings
5	25.6.2016	2.00 – 4.00 pm	Anvesana	Breath Holding Index and Arterial Stiffness as Markers of Vascular Aging
6	27.8.2016	2.00 – 4.00 pm	Anvesana	Cognition and Hemodynamics
7	10.9.2016	2.00 – 4.00 pm	Anvesana	Breath Holding Index and Arterial Stiffness as Markers of Vascular Aging
8	17.9.2016	2.00 – 4.00 pm	Anvesana	Cerebral Blood Flow–Related Signal Changes during Breath-Holding
9	24.9.2016	2.00 – 4.00 pm	Anvesana	Age and Sex Differences in Cerebral Hemodynamics
10	1.10.2016	2.00 – 4.00 pm	Anvesana	EEG paroxysmal gamma waves during Bhramari Pranayama: A yoga breathing technique
11	15.10.2016	2.00 – 4.00 pm	Anvesana	Yoga as a Therapeutic Intervention: A Bibliometric Analysis of Published Research Studies from 1967 to 2013
12	05.11.2016	2.00 – 4.00 pm	Anvesana	Effect of high-frequency yoga breathing on pulmonary functions in patients with asthma A randomized clinical trial