Effects of yogic breath regulation: A narrative review of scientific evidence

Apar Avinash Saoji*, B.R. Raghavendra, N.K. Manjunath

Swami Vivekananda Yoga Anusandhana Samsthana (S-VYASA Yoga University), Bangalore, India

Pranayama or breath regulation is considered as an essential component of Yoga, which is said to influence the physiological systems. We present a comprehensive overview of scientific literature in the field of yogic breathing. We searched PubMed, PubMed Central and IndMed for citations for keywords “Pranayama” and “Yogic Breathing”. The search yielded a total of 1400 references. Experimental papers, case studies and case series in English, revealing the effects of yogic breathing were included in the review. The preponderance of literature points to beneficial effects of yogic breathing techniques in both physiological and clinical setups. Advantageous effects of yogic breathing on the neurocognitive, psychophysiological, respiratory, biochemical and metabolic functions in healthy individuals were elicited. They were also found useful in management of various clinical conditions. Overall, yogic breathing could be considered safe, when practiced under guidance of a trained teacher. Considering the positive effects of yogic breathing, further large scale studies with rigorous designs to understand the mechanisms involved with yogic breathing are warranted.

1. Introduction

Yoga is a traditional practice from the ancient Indian culture and is considered to be the science of holistic living. Various practices involved in the tradition of Yoga include disciplined lifestyle (Yama and Niyama), cleansing procedures (Kriya), physical postures (Asana), breath regulation (Pranayama), concentration (Dharana) and meditation (Dhyana) [1,2]. In recent years, there has been greater interest in exploring the benefits of various practices described in Yoga [3,4]. There have been scientific studies on the effects of individual Yoga practices or their combinations on healthy individuals as well as in people suffering from various ailments [5]. Pranayama or breath regulation has been greatly emphasized in Yoga and has drawn special attention from the scientific community. Breath regulation includes modulation of the pace of breathing, viz. slowing down or pacing the breath, manipulation of nostrils, chanting of humming sounds, retention of breath etc. Various Yoga breathing practices described in classical text of hathayoga are enlisted in Table 1 [2]. The current review was undertaken with an objective of presenting an overview of the available scientific evidences on Yogic Breathing.

2. Methodology

The online database, PubMed, PubMed Central and IndMed were searched for citations for keywords “Pranayama” and “Yogic Breathing”. The search yielded a total of 1400 references from the date of inception of the databases till July 2017. Experimental papers, case studies and case series in English, revealing the effects of yogic breathing were included in the review. The studies that had used yogic breathing in combination with other Yoga practices were excluded. Studies in languages other than English, and whose abstracts were unavailable were excluded from the review. After applying the inclusion and exclusion criteria and removing the duplicates, a total of 68 studies were selected for the final review.

The studies included in the review were classified into two major categories, physiological and clinical. They were subclassified based on the major findings of the study. The physiological measures assessed with various yogic breathing practices are the neurocognitive assessments, psychophysiological changes,
Thus, evaluating the impact of yogic breathing on neurocognition, the mind, and mind ceases to move as the breath is stopped.

## 3. Results

### 3.1. Neurocognitive effects of yogic breathing

Ancient Indian texts on Yoga describe, “As the breath moves, so does the mind, and mind ceases to move as the breath is stopped.” [2] Thus, evaluating the impact of yogic breathing on neurocognitive abilities has sought special attention from the scientific community. An early review indicates that yogic breathing practices could influence the brain activity in different ways [6].

#### 3.1.1. Changes due to pace of breathing

The earliest studies reported assessing the effects of yogic breathing on neurocognitive abilities evaluated the effect of 15 min of high frequency yogic breathing, described as Kapalabhati on EEG activity [7]. The study demonstrated increased alpha activity during the initial 5 min of Kapalabhati. Theta activity was observed to be enhanced, mostly in the occipital region during later stages of 15 min Kapalabhati compared to the pre-exercise period. Beta 1 activity increased during the first 10 min of Kapalabhati in occipital and to a lesser degree in parietal regions. Another study assessing the cognitive abilities demonstrated increase in the number of errors following 1 and 5 min of practice of Kapalabhati, in a letter cancellation task [8].

The impact of another rapid paced Pranayama called Bhashrika, described in Hathayoga as bellow’s breath, on reaction time was studied by Telles et al. They found a reduction in anticipatory responses following 18 min of practice of Bhashrika [9]. Auditory (ART) and visual reaction time (VRT) reduced significantly in school children following just 9 rounds of Mukha Bhashrika, in 22 healthy school children [10]. This phenomenon was further exploited clinically in mentally challenged adolescents, who have higher reaction time. A study done by same authors has shown immediate reduction in VRT and ART among 34 mentally challenged adolescents [11]. A study comparing the effects of slow and fast paced Pranayama reported effects of 35 min/day of fast and slow Pranayama practiced for 10 weeks. Executive functions, perceived stress scale (PSS) and reaction time improved significantly in both fast and slow Pranayama groups, except reverse digit span, which showed an improvement only in fast Pranayama group [12].

#### 3.1.2. Changes with Bhramari Pranayama

A form of yogic breathing called Bhramari (female honeybee humming breath), which is said to modify the brain responses through resonance produced by the humming sound, has shown to cause non-epileptic paroxysmal gamma waves in the EEG [13]. A study has shown that the practice of Bhramari for 10 min enhances inhibition and reaction time in the stop signal task that involves cognitive inhibition, in 31 healthy male individuals [14].

#### 3.1.3. Changes due to manipulation of nostrils

Un nostril and alternate nostril breathing has been of special significance in Yoga, since the nostrils are said to represent the subtle energy channels known as Nadis [2,15]. Right nostril corresponds to Pingala Nadi, and the left to Ida, respectively. Breathing through a single specific nostril is said to affect the human system differently. A study involving 51 volunteers demonstrated that the performance in a spatial task was significantly enhanced during left nostril breathing in both males and females, whereas non-significant increase was noted in the verbal task performance [16]. Another study compared alternate nostril breathing with breath awareness. A significant increase was noted in the P300 peak amplitudes at different scalp sites along with a decrease in the peak latency at frontal scalp region, following alternate nostril Yoga breathing. Following breath awareness there was a significant increase in the peak amplitude of P300 at vertex region alone [17].

Healthy experienced Yoga practitioners demonstrated an increase in Na-wave amplitude and decrease in latency during the period of Pranayama practice, whereas no alterations were observed in the Pa-wave. The Pranayama practice in the study involved consciously controlled rhythmic breathing with breath holding [18]. A three arm randomized controlled trial done on patients with essential hypertension, comparing the effects of Nadishuddhi Pranayama and

| Name of the practice | Method of practice |
|----------------------|--------------------|
| Kapalabhati           | Sitting with back and neck erect, one should inhale through both nostrils and exhale rapidly by flapping the abdomen during each exhalation at a pace of 60–120 breaths/min. |
| Bastrika (Bellow's breath) | One should inhale and exhale quickly and forcefully without straining by flapping the abdomen. This should be practiced for up to 100 breaths. |
| Nadishodhana/Nadishuddhi (Alternate nostril breathing) | With the right thumb, close the right nostril and inhale through left nostril. Closing the left nostril, exhale through right, following which inhalation should be done through right nostril. Closing the right nostril, breath out through left nostril. This is one round. The procedure is repeated for desired number of rounds. |
| Suryanuloma Viloma (Right unnostril breathing) | Closing the left nostril, both inhalation and exhalation should be done through right nostril, without altering the normal pace of breathing. |
| Chandranuloma Viloma (Left unnostril breathing) | Procedure similar to Suryanuloma Viloma, breathing is done through left nostril alone, by closing the right nostril. |
| Suryabhedana (Right nostril initiated breathing) | Closing the left nostril, inhalation should be done through right nostril. At the end of inhalation, close the right nostril and exhale through the left nostril. This is one round. The procedure is repeated for desired number of rounds. |
| Ujjiy (Psychic Breath) | Inhalation and exhalation are done through the nose at normal pace, with partial contraction of glottis, which produce light snoring sound. One should be aware of the passage of breath through the throat during the practice. |
| Bhramari (Female honeybee humming breath) | After a full inhalation, closing the ears using the index fingers, one should exhale making a soft humming sound similar to that of a female honeybee. |
breath awareness with control session for 10 min elucidated reduction in systolic and diastolic blood pressure following Nadishuddhi and improvement in Purdue pegboard task performance with both hands and right hand. The Purdue pegboard task assesses manual dexterity and eye-hand co-ordination. Breath awareness group demonstrated reduction in systolic blood pressure when compared with control activity like reading magazine [19]. The practice of uninostril breathing was also used clinically in cases of stroke, where practice of uninostril breathing for 10 weeks reduced anxiety in 11 post stroke cases and improved language measures in individuals with aphasia due to stroke [20]. Another case series on the use of forced uninostril breathing along with speech therapy for post stroke aphasia showed improvement in correct information unit and word productivity [21].

Thus, most yogic breathing techniques are found to influence the neuro-cognitive abilities positively and some of which were even used in clinical settings with beneficial effects. The neuro-cognitive effects of yogic breathing are summarized in Table 2.

### 3.2. Psychophysiological effects of yogic breathing

Human respiration is the only physiological system that is under both autonomic and voluntary nervous control and thus it is also given special emphasis in yogic texts. The effects of yogic breath regulation on modulation of autonomic functions (AFT) have been studied extensively. The studies on yogic breathing assessing the AFT include various assessment measures like blood pressure (BP) – systolic (SBP) and diastolic (DBP), heart rate (HR), heart rate variability (HRV), respiratory rate (RR), galvanic skin resistance (GSR), pulse rate (PR), etc. Both short and long term effects of yogic breathing have been assessed using AFT.

#### 3.2.1. Changes due to nostril manipulation

A study performed on 8 healthy volunteers demonstrated an increase in HR following right forced uninostril breathing (UNB) indicating the sympathetic activation following right UNB [22]. A three-arm RCT using HRV as the measure of autonomic activity, showed sympathovagal arousal in the right UNB group, whereas indices representing parasympathetic activity were increased in left UNB group following 6-week nostril breathing [23]. A pilot RCT performed on 12 individuals found that 20 min of alternate nostril breathing increased GSR, which denotes parasympathetic activity. Though there was no significant change in the BP or pulmonary function tests, the study demonstrated efficacy of the yogic breathing in bringing a parasympathetic shift in the autonomic functions within a short span of one week [24]. Another study illustrating the ability of ANB in bringing the parasympathetic shift in the autonomic functions uses 30:15 ratio and expiration-inspiration ratio as measures of autonomic functions [25]. Nadishuddhi Pranayama at the rate of one breath per min was found to enhance sinus arrhythmia and reduction in low frequency component of HRV [26]. It also decreased the average breath rate, confirming the

| Sl No. | Author                  | Year | Sample size | Variables studied                                      | Findings                                                                 |
|-------|-------------------------|------|-------------|--------------------------------------------------------|-------------------------------------------------------------------------|
| 1     | Stancak et al.          | 1991 | 11          | EEG                                                    | Alpha activity was increased during the initial 5 min of Kapalabhati (KPB). Theta activity was increased during later stages of 15 min KPB mostly in the occipital region, compared to the pre-exercise period. Beta 1 activity increased during the first 10 min of KPB in occipital and to a lesser degree in parietal regions. |
| 2     | Telles et al.           | 1993 | 11          | Middle Latency Auditory Evoked Potential              | Na-wave amplitude increased and latency decreased during the period of pranayamic practice, whereas the Pa-wave was not significantly altered.                   |
| 3     | Jella & Shannahoff-Khalsa | 1993 | 51          | Spatial and verbal task performance                  | Spatial task performance was significantly enhanced during left nostril breathing. Verbal task performance non-significantly increased during right nostril breathing. |
| 4     | Bhavanani et al.        | 2003 | 22          | Visual reaction time (VRT) and auditory reaction time (ART) | VRT and ART reduced significantly in school children following 9 rounds of Mukha Bhastrika. Non-epileptic paroxysmal gamma waves were generated during the practice of Bhramari Pranayama. There was reduction in VRT and ART following 9 rounds of Mukha Bhastrika among mentally challenged children. |
| 5     | Vialatte et al.         | 2008 | 8           | EEG                                                   | Non-epileptic paroxysmal gamma waves were generated during the practice of Bhramari Pranayama. There was reduction in VRT and ART following 9 rounds of Mukha Bhastrika among mentally challenged children. |
| 6     | Bhavanani et al.        | 2012 | 34          | VRT and ART                                          | There was reduction in systolic (SBP) and diastolic blood pressure (DBP) following Nadishuddhi and improvement in Purdue pegboard task performance with both hands and right hand. Breath awareness group demonstrated reduction in SBP. There was a significant increase in the P300 peak amplitudes at different scalp sites and a significant decrease in the peak latency at frontal scalp region, following alternate nostril Yoga breathing. Following breath awareness there was a significant increase in the peak amplitude of P300 at Vertex region. KPB practice for 1 min and 5 min had no significant impact on SLCT and DLST scores, but there was increase in errors following the practice. Following 18 min of Bhastrika Pranayama there was a statistically significant reduction in number of anticipatory responses compared to before the practice. Reduction in stop signal reaction time was found with 10 min of practice of Bhramari Pranayama. There was increase in go Reaction time in Bhramari group when compared to deep breathing group for equal duration. |
| 7     | Telles et al.           | 2013 | 90          | Blood pressure (BP) and Purdue pegboard task         | There was reduction in systolic (SBP) and diastolic blood pressure (DBP) following Nadishuddhi and improvement in Purdue pegboard task performance with both hands and right hand. Breath awareness group demonstrated reduction in SBP. There was a significant increase in the P300 peak amplitudes at different scalp sites and a significant decrease in the peak latency at frontal scalp region, following alternate nostril Yoga breathing. Following breath awareness there was a significant increase in the peak amplitude of P300 at Vertex region. KPB practice for 1 min and 5 min had no significant impact on SLCT and DLST scores, but there was increase in errors following the practice. Following 18 min of Bhastrika Pranayama there was a statistically significant reduction in number of anticipatory responses compared to before the practice. Reduction in stop signal reaction time was found with 10 min of practice of Bhramari Pranayama. There was increase in go Reaction time in Bhramari group when compared to deep breathing group for equal duration. |
| 8     | Telles et al.           | 2013 | 20          | P300                                                  | There was a significant increase in the P300 peak amplitudes at different scalp sites and a significant decrease in the peak latency at frontal scalp region, following alternate nostril Yoga breathing. Following breath awareness there was a significant increase in the peak amplitude of P300 at Vertex region. KPB practice for 1 min and 5 min had no significant impact on SLCT and DLST scores, but there was increase in errors following the practice. Following 18 min of Bhastrika Pranayama there was a statistically significant reduction in number of anticipatory responses compared to before the practice. Reduction in stop signal reaction time was found with 10 min of practice of Bhramari Pranayama. There was increase in go Reaction time in Bhramari group when compared to deep breathing group for equal duration. |
| 9     | Pradhan                 | 2013 | 36          | Digit Letter Substitution Task (DLST), Six Letter Cancellation Test (SLCT) | Following 18 min of Bhastrika Pranayama there was a statistically significant reduction in number of anticipatory responses compared to before the practice. Reduction in stop signal reaction time was found with 10 min of practice of Bhramari Pranayama. There was increase in go Reaction time in Bhramari group when compared to deep breathing group for equal duration. |
| 10    | Telles et al.           | 2013 | 70          | Reaction time                                         | Following 18 min of Bhastrika Pranayama there was a statistically significant reduction in number of anticipatory responses compared to before the practice. Reduction in stop signal reaction time was found with 10 min of practice of Bhramari Pranayama. There was increase in go Reaction time in Bhramari group when compared to deep breathing group for equal duration. |
| 11    | Rajesh et al.           | 2014 | 31          | Stop Signal Task                                      | Following 18 min of Bhastrika Pranayama there was a statistically significant reduction in number of anticipatory responses compared to before the practice. Reduction in stop signal reaction time was found with 10 min of practice of Bhramari Pranayama. There was increase in go Reaction time in Bhramari group when compared to deep breathing group for equal duration. |
parasympathetic shift of ANS. Another study demonstrated that Nadishuddhi Pranayama for 15 min/day for 4 weeks increased PEFR and pulse pressure and decrease in PR, RR, DBP in healthy subjects [27]. Training in Nadishuddhi Pranayama along with breath holding for 4 weeks elucidated reductions in baseline HR, SBP and DBP, which was attributed to increased vagal tone and reduced sympathetic discharge [28]. 6 variations of nostril breathings on cardiovascular parameters and reaction time in 20 experienced subjects demonstrated that 9 rounds of Nadishuddhi, left nostril breathing and left initiated breathing lead to reduction in BP and HR, whereas right nostril breathing and right initiated breathing showed an increase in the same. There were no changes found with normal breathing. The reaction time was lowered following the practice of right nostril breathing and right initiated breathing. The changes were attributed to the nostril used for inspiration than that for expiration [29].

3.2.2. Changes due to modulation of pace of breathing

The pace of breathing also modifies psychophysiological responses. A pilot study evaluating the effect of very slow breathing at 1 breath/min for 20 min on cardiovascular risk factors showed dramatic changes in hemodynamic variables like stroke index, HR, cardiac index, end diastolic index, peak flow, ejection fraction, thoracic fluid index, index of contractility, ejection ratio, systolic time ratio, acceleration index, and systolic, diastolic, and mean arterial pressures, left stroke work index and stroke systemic vascular resistance index. These changes indicate that breathing at a slow pace with internal breath hold could influence brainstem cardiorespiratory center regulating the Mayer wave patterns [30].

Another study done on 17 naïve subjects demonstrated an increase in baroreflex sensitivity (BRS) following slow breathing with or without Ujjayi Pranayama. The decrease in the BP and increase in the BRS was maximal when the subjects practiced slow breathing with equal inspiration and expiration at the rate of 6 breaths/minutes [31]. A study comparing the training in fast and slow Pranayama for 3 months elucidated increased parasympathetic activity and decreased sympathetic activity in the slow breathing group at the end of intervention period, whereas no significant change in autonomic functions was observed in the fast breathing group [32]. A three armed RCT involving 90 young healthcare students, which compared the effects of training in slow and fast Pranayama for 3 months, showed reduction in perceived stress in both fast and slow Pranayama group. The cardiovascular variables viz. HR, SBP and DBP reduced only in slow Pranayama group. The fast Pranayama group did not show significant changes in the cardiovascular variables [33]. Hand grip strength (HGS) and hand grip endurance (HGE) increased with the training of fast Pranayama, whereas only HGS increased following slow Pranayama training for 12 weeks [34].

Fast paced Kapalabhati was shown to increase the LF power and LF:HF ratio and lower the HF power in HRV, indicating the sympathetic arousal [35]. A concurrent result was found in another study that demonstrated an increase in HR, SBP and DBP following Kapalabhati. The study performed on 17 individuals also elucidated reduced BRS during practice of Kapalabhati [36]. A study demonstrated the effect of training in Mukha Bhastrika, involving rapid breathing for 12 weeks, reduced basal HR, increase in vasa valva ratio and deep breathing difference in HR. It was also found to reduce the fall in BP on variation of posture. All the findings were indicative of increased parasympathetic activity following long term training in the practice of Mukha Bhastrika [37]. To understand the underlying pathways for the modulation of cardiovascular parameters following slow paced Bhastrika Pranayama, a study compared the effect of 5 min of Bhastrika on HR and BP, with and without oral administration of hyoscine-N-butylbromide (Buscopan), a parasympathetic blocker drug. Fall in SBP, DBP and HR were noted in the group which practiced Bhastrika for 5 min without administration of the drug whereas subjects following the administration of the drug did not show significant changes in BP or HR. Thus the study concluded that the modulation of ANS due to practice of slow pace Bhastrika is attributed to the enhanced parasympathetic activity [38].

3.2.3. Changes due to other yogic breathing techniques

A recent study using HRV demonstrated parasympathetic withdrawal during the practice of Bhramari Pranayama, which reverted back to normalcy after the completion of practice [39]. Medical students showed reduced stress levels following practice of a combination of Pranayama practices for 1 h a day, 5 days per week for 2 months. HRV demonstrated reduction in VLF and LF and increase in HF component, indicative of a parasympathetic shift of the autonomic activity [38]. The relaxation attained through practice of Pranayama was exploited to ease the test anxiety and improve test scores in 107 postgraduate students. An RCT demonstrated that following the practice of Pranayama for a semester, only 33% participants experienced high test anxiety, compared to 66.67% among the control group. Participants in the Pranayama group also had higher scores in the test performance than controls [40].

We observed that, most yogic breathing techniques are found to have profound effects on autonomic functions. Most yogic breathing practices lead to parasympathetic shift of the ANS activity, except high frequency Yoga breathing (Kapalabhati) [41]. The effects of yogic breathing on psychophysiological variables are summarized in Table 3.

3.3. Effects of yogic breathing on respiratory system

The training in yogic breathing is found to be an effective means of enhancing the pulmonary functions. Slow breathing at 6 breaths/min showed an increase in vital capacity (VC) after 2 and 5 min, and increase in forced vital capacity after 2 min, and increase in forced inspiratory vital capacity and peak inspiratory flow rate after 2, 5 and 10 min [42]. Another study where the effects of 12 week training in slow and fast Pranayama on PFT were compared, revealed that slow Pranayama group, PEFR and FEV25 improved significantly, whereas in the fast Pranayama group, FEV1/FVC, PEFR, FEF25–75 improved significantly [43]. A recent study demonstrated beneficial effect of one month training in combination of yogic breathing on pulmonary functions in competitive swimmers [44]. Thus, the limited available evidence on effects of yogic breathing on respiratory system indicates a positive trend of change in the respiratory physiology.

3.4. Effects of yogic breathing on biochemical and metabolic variables

Curiosity of what causes the changes that are observed following the practice of yogic breathing, led to a study which examined the changes in arterial blood gas levels following the practice of Pranayama. No significant changes were observed in arterial blood oxygenation following Pranayama, thus speculating neural mechanisms for changes due to Pranayama [45]. Another study observed a decrease in blood urea, and an increase in creatinine and tyrosine after 1 min of Kapalabhati. It was attributed to decarboxylation and oxidation mechanisms, which may be responsible for a reduction in the activity of respiratory centers [46].
3.4.1. Changes in oxygen consumption with yogic breathing

Oxygen consumption is used as a means to understand the metabolic activity of the body. A study exploring the effects of Ujjayi Pranayama along with short and prolonged Kumbhaka (breath hold) elucidated an increase in oxygen consumption with short Kumbhaka and reduction with prolonged breath hold [47]. Breathing through right nostril was observed to increase the oxygen consumption and thereby the overall metabolic status, when compared to the left nostril and alternate nostril breathing for the same duration [48,49]. These studies have indicated right nostril breathing in conditions with lower metabolic rates, like obesity, though caution must be taken, as the practice of right unnostril breathing was found to increase the BP [50].

3.4.2. Yogic breathing and oxidative stress

Yogic breathing was also found to be an effective means to combat oxidative stress. It was found to lower the free radical load and increase the superoxide dismutase (SOD) among healthy volunteers, when compared to a control population [51]. Athletes often suffer from fatigue due to oxidative stress following the bouts

Table 3
Summary of the psychophysiological changes following yogic breathing.

| Sl No. | Author          | Year | Sample size | Variables studied                    | Findings                                                                 |
|--------|-----------------|------|-------------|--------------------------------------|--------------------------------------------------------------------------|
| 1      | Stancak et al.  | 1991 | 17          | BP, ECG and respiration               | Increase of Heart rate (HR), SBP and DBP during Kapalabhati. BRS reduced during Kapalabhati. |
| 2      | Raghuraj et al. | 1998 | 12          | HRV                                  | Increase in low frequency (LF) power and LF/HF ratio while high frequency (HF) power was significantly lower following KBP. There were no significant changes following Nadishuddhi. |
| 3      | Pal et al.      | 2004 | 60          | Autonomic Function tests             | The increased parasympathetic activity and decreased sympathetic activity were observed in slow breathing group after 3 months, whereas no significant change in autonomic functions was observed in the fast breathing group. |
| 4      | Shannahoff-Khalsa et al. | 2004 | 4          | Cardiovascular variables            | Following breathing at 1 breath/min with ratio of 20:20:20 s, there are dramatic variations in hemodynamic variables. |
| 5      | Bhimani et al.  | 2011 | 59          | HRV, Stress questionnaire            | Makh Bhastrika training showed an increase in parasympathetic activity i.e., reduced baseline HR, increase in Valsalva ratio and deep breathing difference in HR; and reduction in sympathetic activity i.e., reduction in fall of SBP on posture variation. |
| 6      | Ghiya & Lee     | 2012 | 23          | HRV                                  | InTP, lnL and lnHF were greater during both post-Alternate Nostril Breathing and post-Faced Breathing compared to PRE. Mean Arterial Pressure (MAP) and lnLF/lnHF did not significantly differ between conditions. |
| 7      | Mason et al.    | 2013 | 17          | BRS                                  | BRS increased with slow breathing techniques with or without respiratory Ujjayi except with inspiratory + expiratory Ujjayi. The maximal increase in BRS and decrease in blood pressure were found in slow breathing with equal inspiration and expiration. |
| 8      | Sinha et al.    | 2013 | 25          | Expiration: inspiration ratio, 30:15 ratio | Alternate nostril breathing for 5 min/day, for 6 weeks increased parasympathetic tone. |
| 9      | Adhana et al.   | 2013 | 30          | Electromyogram (EMG), GSR, Finger tip temperature (FTT), HR and RR, SBP and DBP | Slow yogic breathing lead to reduction in SBP and DBP. Significant modifications were also found in HR RR, EMG, GSR and rise in FTT. |
| 10     | Turankar et al. | 2013 | 12          | BP, Pulmonary function tests (PFT), GSR | Practice of Anulom Vilom Pranayama with breath holding was found to increase GSR in Pranayama group. |
| 11     | Sharma et al.   | 2013 | 90          | Perceived stress scale (PSS), HR, BP | No significant changes in BP or PFT were noted. |
| 12     | Pal et al.      | 2014 | 85          | HRV                                  | HRV indices representing sympathetic activity were increased in the Right nostril breathing group and indices representing parasympathetic activity were increased in Left Nostril Breathing group. |
| 13     | Bhavanani et al.| 2014 | 20          | Reaction time, HR, BP                | BP reduced following Chandara Nadi Pranayama, Chandrabhedana and Nadishuddhi and increased following Surya Nadi Pranayama and Suryabhedana. Reduction in reaction time was observed with SN and SB. |
| 14     | Goyal et al.    | 2014 | 50          | BP, HR, Rate pressure product        | Pranayama along with antihypertensive medications reduced BP significantly compared to medications alone. RPP reduced significantly in the Pranayama group. |
| 15     | Hakked et al.   | 2017 | 27          | Spirometry                           | Training in Yogic Breathing for one month enhance lung functions in professional swimmers. |
| 16     | Nivethitha et al.| 2017 | 16         | HRV                                  | HF component of HRV reduced during the practice of Bhumari Pranayama along with an increase in LF component and HR. The changes normalized after the conclusion of the practice. |
of exercise, therefore requiring antioxidant supply [52]. Yogic breathing for 1 h was found to effectively enhance the antioxidant defense status in athletes following an exhaustive exercise bout compared to control group who practiced quiet sitting. It was correlated to lower levels of cortisol and enhanced melatonin levels. The authors therefore suggest that rhythmic yogic breathing can protect the athletes from long term complications of free radicals [53].

### 3.4.3. Molecular changes with yogic breathing

The modifications in stress levels, physiological variables and cognition due to yogic breathing have been established through several studies quoted. The need for understanding the molecular biomarkers suggesting the pathways involved prompted a recent study, in which salivary proteomes were analyzed during 20 min of yogic breathing practice. The study revealed that the biomarkers called Deleted in Malignant Brain Tumor-1 (DMBT1) and Ig lambda-2 chain C region (IGLC2) were differentially expressed in yogic breathing group. DMBT1 was elevated in 7 of yogic breathing group by 10-fold and 11-fold at 10 and 15 min, respectively, whereas it was undetectable in the time-matched control group. IGLC2 also showed significant increase in the yogic breathing group when compared to controls [54]. This study was the first to indicate the feasibility of acute practice for the stimulation and detection of salivary protein biomarkers.

The studies indicate modulation of metabolism and modifications of biochemical markers with the practice of yogic breathing. These changes could be correlated to the traditional understanding of the flow of Prana (vital energy) controlling the physical functions in the body. Also, the studies confer the excitatory effect of right nostril breathing described in ancient Indian literature. Table 4 illustrates the biochemical and metabolic changes following yogic breathing.

### 3.5. Health benefits of yogic breath regulation

#### 3.5.1. Yogic breathing in cardiovascular diseases

The physiological effects of yogic breathing practices observed through various experiments correlating with the traditional textual understanding, have been used in various clinical setups. Few studies were conducted to understand the immediate effect of yogic breathing techniques in hypertensive subjects. Following Sukha Pranayama for 5 min at 6 breaths per min, there was significant reduction in HR, SBP, pulse pressure, mean arterial pressure, rate-pressure product, and double product with an insignificant fall in diastolic pressure [55]. The practice of Pranava Pranayama demonstrated similar effects. Following 5 min of Pranava Pranayama, there was a reduction in SBP, HR and pulse pressure [56]. Another study showed immediate reduction in HR, SBP and pulse pressure in hypertensive patients following 27 rounds of left UNB [57]. A study showing the effect of 3 months regular practice of slow breathing for 5 min/day maintaining 2:1 ratio of exhalation:inhalation demonstrated significant reduction in SBP, DBP, HR, RR and increased fingertip temperature [58]. Another study involving 6 weeks training in Pranayama along with antihypertensive medications reduced BP significantly compared to medication alone. Rate pressure product reduced significantly in the Pranayama group [59]. A study demonstrated the beneficial effects of the practice of Pranayama in patients with cardiac arrhythmia, demonstrating improvement in QTd, QTc-d, JTd, and JTc-d in the ECG following the Pranayama session, indicating reduction in the indices of ventricular repolarization dispersion [60].

#### 3.5.2. Yogic breathing in respiratory disorders

The effects of yogic breathing in respiratory disorders were also evaluated. A study assessed the effect of yogic breathing in asthmatics, in which patients were made to breathe through a Pink City Lung exerciser at 1:2 ratio of inhalation: exhalation for 2 weeks, 15 min/day. At the end of 2 weeks, mean forced expiratory volume in 1 s (FEV1), peak expiratory flow rate, symptom score, and inhaler use improved in the experimental group, when compared to controls who were breathing through a placebo device. As an indicator of airway reactivity, the dose of histamine needed to provoke a 20% reduction in FEV1 (PD 20) was assessed, which increased significantly during Pranayama breathing but not with the placebo device [61]. Subsequent studies show stability [62,63] and improvement [64] of symptoms in patients with asthma. There was also

| Sl No. | Author | Year | Sample size | Variables studied | Findings |
|--------|--------|------|-------------|-------------------|----------|
| 1      | Pratap et al. | 1978 | 10          | Arterial blood gas | No significance changes in arterial blood gases were noted after Pranayama. Possibility of mental effects of this practice was proposed due to neural mechanisms. |
| 2      | Desai & Gharote | 1990 | 12          | Blood Urea, Creatinine, tyrosine | An increase in oxygen consumption was noted in Yoga breathing with short kumbhaka and a reduction with prolonged kumbhaka. |
| 3      | Telles & Desiraju | 1991 | 10          | Oxygen consumption | Baseline oxygen consumption increased following right nostril breathing, which was more than alternate nostril breathing and increase with left nostril breathing. GSR increased with left nostril breathing. |
| 4      | Telles et al. | 1994 | 48          | Oxygen consumption, GSR | Following the right nostril breathing, there was an increase in oxygen consumption and SBP and reduction in digit pulse volume. Right nostril as well as normal breathing reduced GSR. |
| 5      | Telles et al. | 1996 | 12          | Oxygen consumption, blood pressure, digit pulse volume, GSR | The free radicals were decreased significantly following practice of Pranayama but the SOD was increased insignificantly as compared to the control group. |
| 6      | Bhattacharya et al. | 2002 | 60          | SOD, Free radicals | DMBT1 was elevated in yogic breathing group by 10-fold, whereas it was undetectable in the time-matched controls. IGLC2 also showed a significant increase in Yogic Breathing group. |
| 7      | Balasubramanian et al. | 2015 | 20          | Salivary Proteome –DMBT1 and IGLC2. | 

Table 4

Biochemical and metabolic changes following yogic breathing.
improvement noted in FEV1 and peak expiratory flow rate (PEFR) in asthmatics [64]. A recent study also shows enhanced FEV1, FVC and FEV1:FVC ratio following 10 min practice of Kapalabhati in patients with asthma [65].

Pranayama was used to aid people trying to undergo cigarette withdrawal. Practice of 10 min of yogic breathing helped in reducing the craving measures than breathing video controls, viz. withdrawal. Practice of 10 min of yogic breathing helped in patients with pulmonary tuberculosis (PTB), who performed Bhramari Pranayama for 45 min per day, 3 days a week for 8 weeks. There were significant improvements noted in the body weight, body mass index, symptom scores, pulmonary function and health related quality of life with conversion of positive to negative FME for acid fast bacilli [67].

3.5.3. Yogic breathing in diabetes mellitus
Diabetes is a major healthcare burden in recent years that causes loss of quality of life (QoL) and requires lifestyle modifications. There was significant improvement in the QoL and a non-significant trend toward improvement in glycemic control in the group practicing the comprehensive yogic breathing program

| Sl No. | Author          | Year | Sample size | Disorder      | Variables studied                  | Findings                                                                 |
|--------|-----------------|------|-------------|---------------|-------------------------------------|--------------------------------------------------------------------------|
| 1      | Singh et al.    | 1990 | 18          | Br. Asthma    | Airway reactivity, airway caliber   | Increase in the need of histamine for reduction in forced expiratory volume in 1 s (FEV1) with Pranayama in ratio of 1:2 for inhalation: exhalation than control group. |
| 2      | Cooper et al.   | 2003 | 90          | Br. Asthma    | Symptom scores, FEV1               | At 3rd and 6th month, symptoms remained stable in Pranayama group, whereas decrease in symptoms was noted in Buteyko breathing. No between group difference in FEV1 were noted. |
| 3      | Saxena & Saxena | 2009 | 50          | Br. Asthma    | Peak Expiratory Flow Rate (PEFR), FEV1, Symptoms | A combination of slow breathing, Bhramari and Omkara significantly improved symptoms, FEV1 and PEFR in patients with Bronchial Asthma. Buteyko breathing showed better trends of improvement in quality of life and asthma control than the group performing the Pranayama. |
| 4      | Prem et al.     | 2013 | 120         | Br. Asthma    | Asthma Quality of life, PFT         | 10 min of practice of Kapalabhati enhances FEV1, FVC and FEV1:FVC ratio in patients with mild to moderate Asthma, when compared to control who performed deep breathing. |
| 5      | Raghavendra et al. | 2016 | 60          | Br. Asthma    | FEV1, FVC, FEV1:FVC                | In patients with cardiac arrhythmias, there was improvement in QTd, QTc-d, JTd, and JTc-d following the Pranayama session, indicating reduction the indices of ventricular repolarization dispersion. |
| 6      | Dabhade et al.  | 2012 | 15          | Cardiac Arrhythmias | ECG                            | Improved quality of sleep, quality of life and reduced anxiety following Pranayama between 2 chemotherapy sessions. |
| 7      | Dhruva et al.   | 2012 | 16          | Cancer        | Cancer related Symptoms, quality of life | Scores of Cancer related fatigue reduced following practice of Pranayama along with radiation therapy (RT) than RT alone. |
| 8      | Chakraharty et al. | 2015 | 160         | Cancer        | Cancer related fatigue             | There was significant improvement in the QOL and a non-significant trend toward improvement in glycemic control in the group practicing the yogic breathing program than standard treatment alone. |
| 9      | Jyotsna et al.  | 2012 | 49          | Type 2 Diabetes Mellitus | WHOQOL BREF, FBS, PPBS, HbA1C | There was significant improvement in the QOL and a non-significant trend toward improvement in glycemic control in the group practicing the yogic breathing program than standard treatment alone. |
| 10     | Jyotsna et al.  | 2013 | 64          | Type 2 Diabetes Mellitus | Cardiac autonomic functions | Pranayama along with standard therapy improved sympathetic functions in diabetics than those who were on standard therapy alone. Immediate reduction in heart rate, systolic pressure, pulse pressure following Chandra Nadi Pranayama was noted |
| 11     | Bhavanani et al. | 2012 | 22          | Hypertension  | Heart rate, blood pressure         | Reduction in systolic pressure, pulse pressure and heart rate in hypertensive patients was observed following Pranayama. Uninostil breathing practice reduced anxiety in post stroke cases and improved language measures in individuals with aphasia due to stroke. |
| 12     | Bhavanani et al. | 2012 | 29          | Hypertension  | Heart rate, blood pressure         | In 2 out of 3 cases of stroke induced aphasia, Forced Uninostil breathing along with speech therapy showed improvement in correct information unit and word productivity. |
| 13     | Marshall et al. | 2013 | 11          | Stroke        | Attention, language, spatial abilities, depression, and anxiety | Following practice of Pranayama for a semester, fewer participants experienced high test anxiety, compared to the control group. Participants in the Pranayama group also had higher scores in the test performance than controls. |
| 14     | Marshall et al. | 2015 | 3           | Stroke        | Western Aphasia Battery-R (WAB-R) and Communication Abilities of Daily Living-2 (CADL-2) | There were significant changes in weight, body mass index, symptom scores, pulmonary function and health related quality of life with conversion of positive to negative FME for acid fast bacilli, when the patient of Pulmonary Tuberculosis |
compared with the group that was following standard treatment alone [68]. Diabetic patients also are known to have sympathovagal imbalance. Practice of Pranayama for 6 months along with standard therapy improved sympathetic functions in diabetics than those who were on standard therapy alone [69].

3.5.4. Yogic breathing in other diseases

A controlled study evaluating the effect of slow Pranayama breathing compared to normal breathing on pain perception demonstrated reduced ratings of pain intensity and unpleasantness, particularly for moderately versus mildly painful thermal stimuli with slow breathing [70]. A pilot RCT comparing effects of Pranayama as an ancillary technique to usual care for patients receiving chemotherapy demonstrated improved quality of sleep, QoL and reduced anxiety with the practice of Pranayama between 2 chemotherapy sessions [71]. An RCT involving 160 cancer patients undergoing radiotherapy demonstrated significant difference in protein thiols and serum glutathione in patients who practiced combination of Nadishuddhi, Bhranami and Shitali Pranayama for 30 min/day, twice daily/5 days a week, when compared to controls who received radiotherapy alone [72]. Pranayama as an adjunct therapy to radiotherapy was also found to be beneficial to reduce the cancer related fatigue [73].

Table 5 summarizes the health benefits of yogic breath regulation in various clinical population.

3.6. Complications of yogic breathing

The practice of Pranayama is generally considered safe and we could find only one case report reporting an adverse effect of yogic breathing during our review of literature. A case of spontaneous pneumothorax caused due to a Yoga breathing technique called Kapalabhati was reported [74]. A review also denoted cases of rectus sheath hematoma and pneumomediastinum due to practice of unspecified Pranayama [75].

4. Conclusion

Pranayama or yogic breathing practices were found to influence the neurocognitive abilities, autonomic and pulmonary functions as well as the biochemical and metabolic activities in the body. The studies in the clinical populations, show the effects of yogic breathing in modulating cardiovascular variables in patients with hypertension and cardiac arrhythmias, relieving the symptoms and enhancing the pulmonary functions in bronchial asthma, as an ancillary aid to modify the body weight and symptoms of pulmonary tuberculosis, to enhance mood for patients withdrawing from cigarette smoking, to reduce the reaction time in specially abled children, to manage anxiety and stress in students, to modulate the pain perception, improve the QoL and sympathetic activity in patients with diabetes, reduce the cancer related symptoms and enhancing the antioxidant status of patients undergoing radiotherapy and chemotherapy for cancer. Thus the cost effective and safe practices of yogic breathing could aid in prevention and management of various non-communicable diseases. They may also play a role in management of communicable diseases such as pulmonary tuberculosis.

The limitations of the current review include limiting the search to free online databases, which might limit the access to actual research work done in the field. Also, the current review is limited to narration of the current available scientific literature on yogic breathing and no attempt was made to establish the statistical validity of the data presented in the literature.

Overall, we found the practice of yogic breathing safe, when practiced under guidance of a trained teacher. Though several studies are available elucidating the effects of yogic breathing, they lack methodological rigor. Considering the positive effects of yogic breathing, further large scale studies with better methodological designs to understand the mechanisms involved with yogic breathing are warranted.

Sources of funding

None.

Conflict of interest

None.

References

[1] Taimni I. The science of yoga: the yoga-sutras of Patanjali. In Sanskrit with Transliteration in Roman, Translation and Commentary in English. Thes- topohical Publishing House; 1999.

[2] Muktibodhananda S. Hatha yoga Pradipika: light on hatha yoga. 2nd ed. Bihar: Yoga Publication Trust; 2002.

[3] Jeter PE, Slutsky J, Singh N, Khalsa SBS. Yoga as a therapeutic intervention: a bibliometric analysis of published research studies from 1967 to 2013. J Altern Complement Med 2015;21:586–92.

[4] Sengupta P, Chaudhuri P, Bhattacharya K. Male reproductive health and yoga. Int J Yoga 2013;6:87–95.

[5] Sengupta P. Health impacts of yoga and pranayama: a state-of-the-art review. Int J Prev Med 2012:3:444–58.

[6] Srinivasan TM. Pranayama and brain correlates. Anc Sci Life 1991;11:2–6.

[7] Stancäk A, Kuna M, Srinivasan, Dostalé S, Chushdevananda S. Kapalabhati – yogic cleansing exercise. II. EEG topography analysis. Homeost Heal Dis 2000;18:182–9.

[8] Pradhan B. Effect of kapalabhati on performance of six-letter cancellation and digit letter substitution task in adults. Int J Yoga 2013;6:128–30.

[9] Telles S, Yadav A, Gupta RK, Balkrishna A. Reaction time following yoga bellows-type breathing and breath awareness. Percept Mot Skills 2013;117:1131–40.

[10] Bhavanani AB, Madanmohan, Udupa K. Acute effect of mukha bhastrika (a yogic bellows type breathing) on reaction time. Indian J Physiol Pharmacol 2003;47:297–300.

[11] Bhavanani AB, Ramanathan M, Harichandrakumar KT. Immediate effect of mukha bhastrika (a bellows type pranayama) on reaction time in mentally challenged adolescents. Indian J Physiol Pharmacol 2012;56:174–80.

[12] Sharma VK, M R, S V, Subramanian SK, Bhavanani AB, Madanmohan, et al. Effect of fast and slow pranayama practice on cognitive functions in healthy volunteers. J Clin Diagn Res 2014;8:10–3.

[13] Vialatte FR, Bakardjian H, Prasad R, Cichocki A. EEG paroxysmal gamma waves during Bhranami Pranayuma: a yoga breathing technique. Conscious Cogn 2009;18:977–88.

[14] Rajesh SK, Ilaivarasu JV, Srinivasan TM. Effect of Bhramari Pranayama on response inhibition: evidence from the stop signal task. Int J Yoga 2014;7:138–41.

[15] Nagendra HR. Pranayama – the art and science. Bangalore: Swami Vivekananda Yoga Prakashan; 2007.

[16] Jella SA, Shannahoff-Khalsa DS. The effects of unilateral forced nostril breathing on cognitive performance. Int J Neurosci 1993;73:61–8.

[17] Telles S, Singh N, Puthege R. Changes in F500 following alternate nostril yoga breathing and breath awareness. Biopsychosoc Med 2013;7:11.

[18] Telles S, Joseph C, Venkatesh S, Desiraju T. Alterations of auditory middle latency evoked potentials during yogic consciously regulated breathing and attentive state of mind. Int J Psychophysiol 1993;14:189–98.

[19] Telles S, Yadav A, Kumar N, Sharma S, Vishwashwaraiah NK, Balkrishna A. Blood pressure and P300 wave in individuals with hypertension after alternate nostril breathing, breath awareness, and no intervention. Med Sci Monit 2013;19:61–6.

[20] Marshall RS, Basilakos A, Williams T, Love-Myers K. Exploring the benefits of unilateral nostril breathing practice post-stroke: attention, language, spatial abilities, depression, and anxiety. J Altern Complement Med 2014;20:85–94.

[21] Marshall RS, Laures-Gore J, DuBay M, Williams T, Bryant D. Unilateral forced nostril breathing and aphasia – exploring unilateral forced nostril breathing as an adjunct to aphasia treatment: a case series. J Altern Complement Med 2015;21:91–9.

[22] Shannahoff-Khalsa DS, Kennedy B. The effects of unilateral forced nostril breathing on the heart. Int J Neurosci 1993;73:47–60.

[23] Pal GK, Agarwal A, Kairthik S,Pal P, Nanda N. Slow yogic breathing through right and left nostril influences sympathovagal balance, heart rate variability, and cardiovascular risks in young adults. N Am J Med Sci 2014;6:145–51.

[24] Turankar AV, Jain S, Patel SB, Sinha SR, Joshi AD, Vailish BN, et al. Effects of slow breathing exercise on cardiovascular functions, pulmonary functions &
galvanic skin resistance in healthy human volunteers – a pilot study. Indian J Med Res 2013;137:916–21.

[25] Sinha AN, Deepak D, Gossip 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.

[26] Jovanov E. On spectral analysis of heart rate variability during very slow yogic breathing. IEEE Eng Med Biol Soc 2005;3:2467–70.

[27] Upadhyay Dhungel K, Malhotra V, Sarkar D, Prajapati R. Effect of alternate nostril breathing exercise on cardiorespiratory functions. Nepal Med Coll J 2008;10:25–7.

[28] Bhargava R, Gogate MG, Masurenhas JF. Autonomic responses to breath holding and its variations following pranayama. Indian J Physiol Pharmacol 1988;32:257–64.

[29] Bhavanani AB, Ramanathan M, Balaji R, Pushpa D. Differential effects of un nostril and alternate nostril pranayamas on cardiovascular parameters and reaction time. Int J Yoga 2014;7:60–5.

[30] Shannahhoff-Khalsa DS, Sramek BB, Kennel MB, Jamieson SW. Hemodynamic observations on a yogic breathing technique claimed to help eliminate and prevent heart attacks: a pilot study. J Altern Complement Med 2004;10:757–66.

[31] 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 Altern Med 2013;2013:743504.

[32] Pal GK, Velumury S, Madhavanan. Effect of short-term practice of breathing exercises on autonomic functions in normal human volunteers. Indian J Med Res 2004;120:112–15.

[33] Sharma VK, Trakoo M, Subramaniam V, Rajayekumar M, Bhavanani AB, Sahai A. Effect of fast and slow pranayama on perceived stress and cardiovascular parameters in young health-care students. Indian J Yoga 2013;6:104–10.

[34] Thangavel D, Gaur GS, Sharma VK, Bhavanani AB, Rajayekumar M, Syam SA. Effect of slow and fast pranayama training on handgrip strength and endurance in healthy volunteers. J Clin Diagn Res 2014;8:BC01–3.

[35] Raghuraj P, Ramakrishnan AG, Nagendra HR, Telles S. Effect of two selected yogic breathing techniques on heart rate variability. Indian J Physiol Pharmacol 1998;42:467–72.

[36] Stanack A, Runa M, Simnivasan, Vishnudevavananda S, Dostalek C. Kapalabhati – yogic cleansing exercise. J Cardiovascular and respiratory changes. Homeost Health Dis 1991;33:126–34.

[37] 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.

[38] Pramankit T, Sharma HO, Mishra S, Mishra A, Prajaptai R, Singh S. Immediate effect of slow pace bhastrika pranayama on blood pressure and heart rate, vol. 15, 2009.

[39] Niverthira L, Manjunath NK, Mooventhavan A. Heart rate variability changes during and after the practice of bhramari pranayama. Int J Yoga 2017;10:99–102.

[40] Nemati A. The effect of pranayama on test anxiety and test performance. Int J Yoga Ther 2013;3:60–65.

[41] Mohanty S, Saoji AA. Comments on "alternate nostril breathing at different rates and its influence on heart rate variability in non practitioners of yoga". J Clin Diagn Res 2016;10:CL01.

[42] Sivalakumar G, Prabhu K, Baliga R, Patil MK, Manjunatha S, Krishnamurthy Prabhu K, et al. Acute effects of deep breathing for a short duration (2–10 minutes) on pulmonary functions in healthy young volunteers. Indian J Physiol Pharmacol 2011;55:154–8.

[43] Dinesh T, Gaur G, Sharma V, Madanmohan T, Harichandra Kumar K, Bhavanani A. Comparative effect of 12 weeks of slow and fast pranayama training on pulmonary function in young, healthy volunteers: a randomized controlled trial. Int J Yoga 2015;8:22–6.

[44] Hakled CS, Balakrishnan R, Krishnamurthy MN. Yogic breathing practices improve lung functions of competitive young swimmers. J Ayurveda Integr Med 2017 Apr–Jun;8(2):99–104.

[45] Pratap V, Berrettini WH, Smith C. Arterial blood gases in pranayama practice. Percept Mot Skills 1978;46:171–4.

[46] Desai BP, Ghoreto ML. Effect of Kapalabhati on blood urea, creatinine and tyrosine. Act Nerv Super (Praga) 1990;32:95–8.

[47] Telles S, Desrajai T. Oxygen consumption during pranayamic type of very slow-rate breathing. Indian J Med Res 1991;94:357–63.

[48] Telles S, Nagarathna R, Nagendra HR. Breathing through a particular nostril can alter metabolism and autonomic activities. Indian J Physiol Pharmacol 1994;38:133–7.

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

[50] Raghuraj P, Telles S. Immediate effect of specific nostril manipulating yoga breathing practices on autonomic and respiratory variables. Appl Psychophys Biofeedback 2008;33:65–75.

[51] Bhattacharya S, Pandey US, Verma NS. Improvement in oxidative status with yogic breathing in young healthy males. Indian J Physiol Pharmacol 2002;46:549–54.