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HIGH FREQUENCY YOGA BREATHING

A REVIEW OF NERVOUS SYSTEM EFFECTS AND ADJUNCTIVE THERAPEUTIC AND PREMEDITATION POTENTIAL

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ABSTRACT

High frequency yoga breathing (HFYB) results in a shifting of the autonomic nervous system balance towards sympathetic nervous system dominance. In an effort to more fully understand the complex effects of this form of yogic breath-work, tests are being conducted on practitioners' physiological and neurological response processes. Studies on *heart rate variability* (HRV) indicating cardiac autonomic control have shown a resulting reduction of vagal activity following HFYB, leading to passive sympathetic dominance without overt excitation or exhaustion. Comparative cognitive tests taken after the practice have shown that HFYB results in reduced auditory and visual reaction times, and a decrease in optical illusion. The vigilant, wakeful, yet relaxed state induced by HFYB has been associated with improvements in attention, memory, sensorimotor performance, and mood. As breathing bridges conscious and unconscious functions, the potential role of HFYB as an adjunctive therapeutic intervention as well as its possible application in preparation for meditation is considered.

Key words

High frequency yoga breathing, autonomic nervous system, therapy, meditation

1 High frequency yoga breathing

The scope of this review is to provide an overview of the documented effects of *high frequency yoga breathing* (HFYB) on the nervous system. High frequency yoga breathing is a yogic breath control practice characterized by a high rate of respiration (1.0–2.0 Hz) (Telles, Singh and Balkrishna 2015). There are many types of HFYB practice, of which the *kapalabhati*, *bhastrika*, and *kukkuriya* forms have been the most researched for their effects. *Kapalbhati* is a breathing style in which the exhalation is active through rapid voluntary movement of abdominal wall to the back and the inhalation occurs by relaxing the abdominal muscles. *Bhastrika* is a breathing style in which both the inhalation and exhalation are active and rapid. There are three basic varieties of *bhastrika*: one uses diaphragmatic breathing executed by abdominal muscles, the second uses thoracic breathing, and the third uses both. *Kukkuriya* utilizes rapid breathing through the mouth (Kumar et al. 2013). For the purposes of this review, all three will be referred to as HFYB. Basic research on the effects of HFYB on the physiological breathing process has been conducted by Kuvalayananda (1963), and Ebert (1989). The respirogram of *kapalabhati* and bhastrika is given by Ebert (1989). For example, in the case of *kapalabhati*, the air volume per minute decreases as the practice progresses. In the case of *bhastrika*, the per minute air exchange increases.

Improvements in both psychological and cardiovascular health are reported to result from the autonomic nervous system modulations that correspond with regulated yogic breathing (Telleset al. 2015). Body psychotherapy uses breath-work to soothe and center patients as well as charge and stimulate in preparation for emotional and physical processing (Caldwell and Victoria 2011). Most of the physiological, psychological, and cognitive effects of HFYB are attributed to the complex shifts in the autonomic nervous system that occur during and after the practice (Brown and Gerbarg 2005b; Raghuraj, Ramakrishnan, Nagendra and Telles 1998; Sharma et al. 2014). Due to its empirically measured and subjectively reported effects of both enhanced alertness and resulting states of calm (Telleset al. 2015), HFYB has emerged as a potentially potent adjunctive tool in therapeutic treatment (Brown and Gerbarg 2005a) and in preparation for meditation (Ebert 1989; Hirai 1973).

2 Measures of authonomic neurous system modulation

2.1 Heart rate variability

Heart rate variability (HRV) is used to indicate autonomic control by the cardiovascular system (Raghurajet al. 1998). Heart rate variability has been measured by *high frequency* (HF) and *low frequency* (LF) components and their relationship, which is understood to be a better indicator of autonomic status than heart rate alone (Raghuraj et al. 1998). The HF component is related to vagal activation, the LF component to sympathetic nervous system activation, and the LF/HF ratio reflects sympathovagal balance (Raghurajet al. 1998). Studies on conscious breath alterations are of particular interest as the integrative role of respiratory and cardiovascular rhythms have been understood in yogic contexts as the ability of breath regulation to influence brain function (Gilbert 1999). Practitioners of HFYB have described the effects as energizing, cleansing, and mind-clearing (Gilbert 1999). High frequency yoga breathing has been associated with an increase in vigilance and attention, both with and without sympathetic nervous system modulation (Telles, Singh and Balkrishna 2011). Hence, the effects of HFYB on HRV have been an avenue to examine its impact on practitioners (Telles, Singh et al. 2011).

In a study comparing slow breath work to HFYB, Raghuraj et al. (1998) found no significant change in participants' (n=12) HRV after slow breathing. However, after the HFYB practice, participants' (n=12) measurements showed an immediate increase in the LF component, a decrease in the HF component, and an increase in the LF/HF ratio after one minute of practice. Rhaghuraj et al. (1998) interpreted these results as showing that, after HFYB, there was an increase in sympathetic nervous system activation and a decrease in vagal efferent activity.

In a later study, Telles and Singh et al. (2011) compared the effects of both HFYB and breath awareness (BAW) on HRV. Breath awareness is simply sitting and witnessing the breath (Telles et al. 2015). Telles and Singh et al. (2011) compared the two practices, for it is understood that BAW alone improves attention, and BAW is part of HFYB practice. The researchers measured effects before, during, and after the participants' (n=38) breath practices. The practice time for each form of practice consisted of three, five minute increments. The recorded HRV and respiration changes for both practices were associated with reduced parasympathetic modulation, but the magnitude of change was greater for HFYB during the practice, while for BAW it was greater after. Measures of time domain also showed that, during and after HFYB, vagal modulation decreased. The same trend was found after, but not during, BAW (Telles and Singh et al. 2011).

For this same study, Telles and Singh et al. (2011) considered the hypothesized increase in sympathetic modulation to be plausible, as the state is associated with the vigilance linked to both breath practices. Interestingly, frequency domain analysis showed no significant change in the LF and HF variables for HFYB. The researchers interpreted the data as suggesting that HFYB induces a parasympathetic withdrawal, but not the sympathetic activation that would be expected to simultaneously occur. Given the lack of sympathetic modulation increase during HFYB, the author suggested that reports on enhanced attention and performance tasks are due to shifts, resulting from vagal withdrawal alone, especially from cardiac vagal modulation. They speculated that HRV changes may be due to conscious cortical influence on respiration, as there is a close association between cardiovascular and respiratory centers in the brainstem. The studies by Raghuraj et al. (1998) and Telles and Singh et al. (2011) support the finding that HFYB reduces vagal modulation and shifts autonomic balance to the sympathetic nervous system.

2.2 Metabolism

Researchers Telles et al. (2015) conducted a study on HFYB and the effects on metabolism in experienced practitioners and evaluated the effects on carbon dioxide output, oxygen uptake, and ventilation. They understood that autonomic nervous system alterations can influence oxygen consumption and energy expenditure, and that HFYB has been recorded to affect autonomic variables and increase oxygen consumption with different effects compared to other hyper-metabolic states. Telles et al. (2015) compared participants (n=47) engaging in HFYB and BAW, with a control group (n=20). It was found that, along with the increased ventilation, the HFYB induced a hypermetabolic state (34.6 percent increase in oxygen consumption). As breath frequency increased, tidal volume decreased. Blood chemistry data showed that arterial carbon dioxide levels were reduced as expected with increased ventilation, but without hyperventilation symptoms. After the HFYB, ventilation returned to baseline, an effect contrasting with other hypermetabolic states that characteristically follow increased ventilation (Telles et al. 2015).

With oxygen levels returning to baseline after the practice, the findings by Telles et al. (2015) indicated that the abdominal work involved in HFYB did not result in an oxygen debt as would be otherwise expected. The researchers suggested that this could be attributed to the relaxed mental state that previous studies have reported to occur during and after HFYB based on EEG recordings. Telles et al. (2015) suggested that HFYB could be used to increase energy expenditure without inducing the increased ventilation and oxygen debt that typically result from mental and physical exertion. They further noted a possible clinical application with respect to treating stress-related illnesses and hypometabolic states (Telles et al. 2015).

The results of all three of these studies (Raghuraj et al. 1998; Telles et al. 2015; Telles and Singh et al. 2011) support the perception that HFYB reduces vagal modulation and can shift autonomic balance to the sympathetic nervous system, a balance associated with vigilance and wakefulness, without overt activation of the sympathetic nervous system, and with an immediate return to a relaxed state after the practice. The ability to energize and stimulate wakefulness, without exhaustion or over-excitation, and while maintaining a relaxed interoceptive state, suggests that HFYB is an intervention worthy of further study, particularly with respect to its potential application in therapeutic settings and as a preparation for meditation.

3 Measures of cognitive function

3.1 Reaction time and P300 latency

A reduction in *reaction time* (RT) is understood to indicate an enhancement of corticalarousal, central nervous system processing ability, and sensory-motor performance (Bhavanani, Madanmohan and Udupa 2003). Bhavanani et al. (2003) measured auditory and visual RTs before and after twenty-two participants engaged in nine rounds of HFYB. They predicted reductions in both measurements and the results did indicate that HFYB produced significant reductions in both visual and auditory RTs. The authors recognized their findings as compatible with evidence from other studies that HFYB induces enhanced mental activity and an alert and calm state. They surmised that the abdominal muscular activity associated with HFYB induces moderations in afferent inputs from the thorax and abdomen that subsequently modulate the activity in the ascending reticular activating system and in the thalamocortical brain region (Bhavanani et al. 2003). Further research studies need to be designed to test this hypothesis.

Sharma et al. (2014) tested the cumulative effects of both fast and slow yoga breath practices on cognitive functions among eighty-four participants over the course of twelve weeks. Because of the use of yogic breathwork for stress reduction and the known negative impact of stress on executive functions, they tested the effects of these practices on concentration span, mental flexibility, working memory, and information scanning and retrieval. They tested height, weight, RT, and a cognitive functions battery: trail making A and B and forward and reverse digit spans. The results indicated significant increases in attention and memory retention and significant decreases in perceived stress after both HFYB and slow breath practices. Additionally, the HFYB results revealed effects on sensorimotor performance, namely faster auditory and visual RTs. The authors attributed the cognitive improvements to stress reduction as the prefrontal cortex integrates information from current stress levels along with emotional and cognitive processes. Based on their findings, Sharma et al. (2014) hypothesized that enhanced parasympathetic tone resulting from the breath practices could be a major contributor to the cognitive effects. They suggested that the research be extended to clinical populations that may have compromised cognitive functions due to psychiatric conditions.

Joshi and Telles (2009) studied the effect of HFYB on P300 event-related potentials (ERP). The P300 ERP measures the brain's neuroelectric response to auditory stimuli, namely the ability to attend to and discriminate between subtly different stimuli (frequency in this study). It is not a measure of behavioral RT, but rather of underlying informational processing associated with the interactions of the anterior cingulate, hippocampus, and frontal, temporal, and parietal regions. Thus, P300 results reflect attention and immediate memory cognitive processes. Joshi and Telles (2009) collected data from thirty participants before and after one minute sessions of HFYB (n=15) and BAW (n=15) practices. They found that the practices affected P300 measurements in different ways. Breath awareness practice increased the peak amplitude, which is understood to show an enhancement of neural resource availability. In comparison, HFYB registered a reduction in peak latency (the time needed for a task), which is understood as an enhancement in selective attention. The authors offered two hypothetical explanations of the decrease in P300 peak latency following HFYB:

1) interoceptive awareness and relaxation is incorporated into yogic breathing practices

and is speculated to enhance overall awareness and attention, and

2) the effort involved in yogic breath-work has shown that sympathetic activation (better vigilance) occurs alongside the relaxed state associated with parasympathetic dominance, thus resulting in a state of relaxed alertness (Joshi and Telles 2009).

These three studies (Bhavani et al. 2003; Joshi and Telles 2009; Sharma et al. 2014) provide evidence that HFYB may improve cognitive functioning. The study by Sharma et al. (2014) differentiated the effects of HFYB from slow yogic breathing and Joshi and Telles (2009) further differentiated the effects from simple BAW.

3.2 Optical illusion

Telles, Maharana, Balrana, and Balkrishna (2011) studied HFYB for its effects on optical illusion, as attention is known to impact visual perception. They noted that cognitive-judgmental and cortical factors may influence the perception of optical illusion and that these factors are related to strategy mechanisms in contrast to structural mechanisms. Telles and Maharanaet al. (2011) used the Müller-Lyer illusion apparatus to measure and compare participants practicing HFYB (n=15) and participants practicing BAW (n=15) against a control group who were in a simple state of rest (n=15). The degree of optical illusion was measured before and after two, eighteen minute sessions. The control group showed no significant difference in the degree of optical illusion between pre- and post-comparison. Both yogic breath practices showed a decrease in the degree of optical illusion after two sets of each practice. Telles and Maharana et al. (2011) suggested that, in the case of HFYB, the decrease in optical illusion may be attributed to the activation of the neural systems involved in perception, memory, and concentration.

The reported effects on decreased optical illusion provide further evidence that HFYB may enhance cognitive-judgmental factors in information processing. Linking these results (Telles and Maharana et al. 2011) with the cognitive improvements found by Sharma et al. (2014) of enhanced sensorimotor performance, and the findings of decreased RTs by Bhavanani et al. (2003) reveals the potential that HFYB may enhance central nervous system processing.

4 Therapeutic potential

The aforementioned studies give reason to speculate that HFYB could be a potential psychotherapeutic tool as several of the researchers suggested (Bhavanani et al. 2003; Sharma et al. 2014; Telles et al. 2015). Researchers are beginning to create models for applications of yogic breath-work in psychotherapy. One example is a model by Brown and Gerbarg (2005a) based on *Sudarshan Kriya Yoga* (SKY), a practice comprised of four breath components, one of which is a form of HFYB. The central nervous system excitation during HFYB has been registered as gamma waves on EEG readings and corresponds with the subjective stimulation reported during the practice; and practitioners' report alertness coupled with a state of emotional calm following HFYB (Brown and Gerbarg 2005a). Along with the activation of the sympathetic nervous system observed in the cortex, Brown and Gerbarg (2005a) postulate that SKY, which includes HFYB, enhances the ability to deal effectively with stress over time and in acute forms. The toning of the nervous system may build up reserves and prevent depletion or a decline into states of hypo- or hyper-reaction (Brown and Gerbarg 2005a).

It is important to point out that Brown and Gerbarg's (2005a) model uses SKY, of which HFYB is an essential component of the four-part exercise and is not promoted on its own. In this way, HFYB is part of a longer practice that trains practitioners to regulate their nervous system: *"By taking the nervous system through its paces, similar to practicing musical scales, SKY provides a kind of autonomic/ endocrine training exercise that ultimately may strengthen, stabilize, and enhance the flexibility of the system"* (Brown and Gerbarg 2005a).

The practice of SKY was tested with a group of individuals with depression and resulted in a significant decrease in cortisol levels (a marker of stress) as well as subjective depression scores (Brown andGerbarg 2005a). Brown and Gerbarg (2005a) cited a comparative study in which SKY, electroconvulsive therapy (ECT), and a tricyclic antidepressant were tested with patients with severe depression. This study found that significant transient increases in prolactin were associated with SKY and ECT. Prolactin is a hormone known to reduce fear and anxiety and is released through vagal nerve function (Brown and Gerbarg 2005a).

Brown and Gerbarg (2005a) further suggested research exploring the potential association between oxytocin release and SKY. They cited that oxytocin, a hormone attributed to social bonding and the reduction of stress in response to social separation, is affiliated with the parasympathetic nervous system and the regulation of the hypothalamic-pituitary-adrenal pathway. Oxytocin is hypothesized to play a role in the subjective experiences of well-being, bonding, closeness, attachment, and belonging that practitioners report after SKY training (Brown and Gerbarg 2005a). Due to the recorded effects of HFYB and other yogic breath practices on the nervous system, it seems reasonable to begin studying the effects on hormone levels that play a role in well-being.

Brown and Gerbarg (2005b) reviewed several studies that have shown SKY to be an effective treatment for depression, insomnia, post-traumatic stress disorder, phobias, substance abuse, and medical conditions related to stress. They mentioned that HFYB is, in general, contraindicated for individuals with bipolar disorder, severe borderline personality disorder, and psychotic disorders. They recommended accommodations for individuals with anxiety who tend to hyperventilate: for example, the HFYB portion of SKY may need to be slowed down to maintain a sense of control and avoid triggering a panic attack. Brown and Gerbarg (2005b) warned that SKY breathing may evoke sensations related to trauma. However, when patients are, prior to practice, informed of the possibility for emotional or physical reactions, and when such reactions are experienced in a supportive therapeutic context, the possibility of releasing pain without re-experiencing trauma is increased (Brown and Gerbarg 2005b).

Clinicians trained in proper breath techniques have employed HFYB as a sole intervention. Christopher Gilbert (personal communication 2015), a clinical psychologist and breathing sciences professor, does use HFYB with individuals suffering from chronic pain as a temporary antidote to the drowsy side effects produced by narcotics medication. The author of this review, a certified psychiatric rehabilitation practitioner and yoga teacher, has also used HFYB with clients to counteract medication side effects and depression in order to improve concentration and mood. It is noteworthy that many studies are finding the effects of HFYB to result in an alert and relaxed state in healthy participants (Telles et al. 2015) and that mental health practitioners are finding beneficial results working with clinical populations.

Yogic breathing, as an adjunct treatment to other forms of psychotherapy, could be a powerful tool. Improvements in psychological, cognitive, and physiological health are all reported to result from the autonomic nervous system shifts that correspond with HFYB (Brown and Gerbarg 2005b; Raghuraj et al. 1998; Sharma et al. 2014; Telles et al. 2015). Further research needs to be done to more fully understand the complex effects of HFYB on the nervous system so that its utilization and clinical application can be well-informed and effective.

The cited studies of HFYB that examined HRV utilized the measure of LF/HF ratio (Raghuraj et al. 1998; Telles, Singh and Balkrishna 2011). Current research indicates that this traditional measure is controversial in its use to assess sympathetic and parasympathetic balance (Bob Whitehouse personal communication). The LF component is a more accurate reflection of baroreflex activity rather than cardiac sympathetic activation, for which it is has often been used (McCraty and Shaffer 2015). Increases in *Very Low Frequency* (VLF), a rhythm generated directly by the heart may be a better measure of sympathetic nervous system modulationthan LF (McCraty and Shaffer 2015; Bob Whitehouse personal communication). Although current and past research indicates promise, it would benefit the body of HFYB and HRV studies if future experiments utilized VLF measures instead of LF.

Most of the studies in this review partnered with healthy male participants within the age ranges of thirteen to forty (Bhavanani et al. 2003; Joshi and Telles 2009; Telles and Maharana et al. 2011; Telles and Singh et al. 2011; Telles et al. 2015). Another area of expansion for this body of research would be to test the effects with larger population samples that are more diverse. Including HFYB as a component within a larger yogic breath sequence like SKY is the recommended form to continue studies of the therapeutic effects with clinical populations.

5 Application possibility in meditation training

Considering the above data, HFYB could be used in meditation training to increase energy level (Telles et al. 2015), improve clarity of mind (Gilbert 1999), enhance attention (Bhavanani, Madanmohan and Udupa 2003; Bhavanani et al. 2003; Telles, Singh and Balkrishna 2011), lower optical illusion factors (Telles and Maharanaet al. 2011), and increase interoceptive awareness and relaxed alertness (Joshi and Telles 2009). These effects follow both HFYB as well as slow breathing (lower air volume per minute) during meditation (Hirai 1973). *Kukkuriya* breath-work would be less applicable in meditation training for contextual reasons, but other forms of HFYB could greatly support meditation practice.

Apart from slow breathing training (Hirai 1973; Mangalo 1988) for meditation, HFYB has a distinct number of benefits for preparing students of meditation in the capacity to focus attention and free the mind from distractions. Through these enhancements, the experiential aspects of meditation practice could progress in a shorter time than in training omitting HFYB.

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