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A NON-RANDOMIZED NON-NAIVE COMPARATIVE STUDY OF THE EFFECTS OF KAPALABHATI AND BREATH AWARENESS ON EVENT RELATED POTENTIALS IN TRAINED YOGA PRACTITIONERS

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Abstract:

ABSTRACT
Objectives: The study was conducted to compare the P300 event related potentials recorded before and after (i) high frequency yoga breathing (HFYB) and (ii) breath awareness.
Design: The P300 was recorded in participants of two groups before and after the intervention session (1 minute in duration).
Settings/Location: All participants were receiving yoga training in a residential yoga center. This was Swami Vivekanada Yoga Research Foundation in Bangalore, India.
Subjects: Thirty male participants formed two groups (n=15 each) with comparable ages, (within an age range of 20 to 35 years) and comparable experience of the two techniques, the minimum experience being three months.
Interventions: The two groups were each given a separate intervention. One group practiced a HFYB at a frequency of approximately 2.0 Hz, called kapalabhati. The other group practiced breath awareness during which participants were aware of their breath while seated, relaxed.
Outcome Measures: The P300 event related potential which is generated when attending to and discriminating between auditory stimuli was recorded before and after both techniques.
Results: The P300 peak latency decreased after HFYB and the P300 peak amplitude increased after breath awareness.
Conclusions: Both practices (HFYB and Breath awareness), though very different, influenced the P300. HFYB reduced the peak latency suggesting a decrease in time needed for this task which requires selective attention. Breath awareness increased the P300 peak amplitude suggesting an increase in the neural resources available

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Meesha Joshi M.Sc. and Shirley Telles, Ph.D.

Swami Vivekananda Yoga Research Foundation, Bangalore, India

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Address all correspondence to Shirley Telles, Ph.D., Patanjali Yogpeeth, Maharishi Dayanand Gram, Bahadrabad, Haridwar, Uttarakhand 249408, India. Telephone: +91.01334.244805; Telefax: +91.01334.244805, E-mail: shirleytelles@gmail.com

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INTRODUCTION

Breath regulation is an important part of *Hatha* yoga practice and there are several practices which involve changing the rate, depth, and other aspects of breathing.[1,2] One of the techniques involves high frequency breathing (i.e., approximately at 2.0 Hz) with forceful exhalation. This technique is called *kapalabhati* in Sanskrit (*kapala* = forehead, *bhati* = shining) which suggests that the practice stimulates the brain.[3] *Kapalabhati* is hence a high frequency yoga breathing (HFYB) technique.

In eleven advanced practitioners the alpha and beta-1 activity in the electroencephalogram (EEG) increased during the first five minutes of a fifteen minute HFYB (*kapalabhati*) session.[4] Beta1 activity remained high in the next five minutes, though theta activity increased in the later part in the practice. This trend of increased theta activity continued after the 15-minute practice session which was characterised by a relative increase of slower EEG frequencies and subjective relaxation.

HFYB practice was associated with autonomic changes, based on the heart rate variability, suggestive of increased sympathetic and reduced vagal activity.[5] Increased sympathetic tone is associated with better vigilance.[6] Hence the shift in the autonomic balance towards sympathetic dominance following HFYB may have some bearing on the fact that HFYB practice improved performance in a task for attention and was reported as a brief communication (i.e., as a 'Letter to the Editor').[7]

The effect of HFYB on attention was studied in medical students, middle-aged adults, and people over the age of sixty years.[7] All of them were given a cancellation task before and after an one-minute session of HFYB on one day and before and after a breath awareness session (as an alternate intervention) on another day. All three categories of volunteers showed improved performance in the cancellation task which requires selective and sustained

attention, as well as the ability to shift attention, after HFYB. The study did not attempt to understand the mechanisms underlying the improvement.

The present study was designed to assess the effects of HFYB (i.e., *kapalabhati)* and breath awareness on an event related potential generated and associated with the ability to pay attention to a given stimulus and discriminate between stimuli. The P300 component of event related potentials is considered a neuro-electric phenomenon, since it is generated when participants attend to and discriminate between stimuli which differ on a single aspect.[8] In auditory stimuli, the difference is in their frequency. The P300 reflects cognitive events requiring attentional and immediate memory processes. In the present study the P300 was recorded before and after (i) High frequency yoga breathing (i.e., HFYB or *kapalabhati*) and (ii) breath awareness.

MATERIALS AND METHODS

Participants

The participants were thirty male volunteers with ages between 20 and 35 years. The thirty participants actually comprised two groups (n = 15 each). One was asked to practice HFYB group average and the other group was asked to practice breath awareness. The mean age ± S.D. of the group who practiced *kapalabhati* was 26.0 ± 4.6 years, and for the breath awareness group it was 27.6 ± 3.7 years. The two groups' ages did not differ significantly ($p>0.05$, t-test for unpaired data). The immediate effects of these practices were assessed as described below, under 'Design of the study'. They were all residing at a yoga center, i.e., Swami Vivekanada Yoga Research Foundation, in Bangalore, India. These two groups were drawn from a larger sample, based on (i) their willingness to participate in the trial, (ii) their having normal health and not being on medication, and (iii) all of them having a minimum of three months experience of both HFYB (*kapalabhati*) and breath awareness. Males alone were studied as the P300 (evoked by visual stimuli) varied with gender.[9] The study was approved by the Institution's Ethics Committee and all participants gave their signed consent to participate.

Design of the study

All thirty participants were assessed before and after one-minute practice sessions. For half the participants the practice session was HFYB, and for the remaining fifteen participants the practice was breath awareness. For both groups the duration of a practice session was one minute. While all participants were drawn from a comparable larger sample (i.e., persons receiving training in yoga at a residential training center) they were not randomly assigned to the two groups. On the other hand participants did not self-select to which group they would be assigned. Hence they can be considered as two comparable, though non-randomized

groups. The absence of a standard method to assign persons to the two groups is a methodological limitation of the study.

Also, the participants were all yoga practitioners, residing at a yoga center. While being given training participants are taught that the practice of HFYB (*kapalabhati)* could increase alertness and the ability to be attentive. Participants are also taught that breath awareness is practiced to increase the ability to be aware of internal sensations. Given this background, even though they were not especially told that the P300 task is a task to assess attention participants can be considered non-naïve and may have been aware of the hypothesis of the study, which is another limitation of the study and arises from the participants' knowledge about the yoga practices.

Recording conditions

P300 auditory event related potentials were recorded using a Nicolet Bravo System (U.S.A.). The P300 component is generated by giving a simple task requiring discrimination between two stimuli which are presented in a random sequence known as the 'oddball' paradigm, i.e. with the infrequent stimulus, being considered the odd ball.[8] During assessments subjects were seated in a sound attenuated and dimly lit cabin and were monitored on a closed circuit television, receiving instructions through an intercom.

Electrode positions

Ag/AgCl disk electrodes were affixed with electrode gel (ten 20 conductive paste, D.O. Weaver, U.S.A.) at C_z referred to linked earlobes with the ground electrode at FPz, based on the International 10-20 system for electrode placement.[10] Eye movements were recorded with an electro-oculogram (EOG) as a bipolar derivation with electrodes placed 1 cm above and 1

cm below the outer canthus of the right eye. All electrode impedances were kept below 5 kilo ohms.

Amplifier settings

The electroencephalographic (EEG) activity was amplified with a sensitivity of 100μV. The pre-stimulus delay was set at 75 ms and the P300 ERPs were computer averaged in 300 trial sweeps, with a range between 75 and 750 ms. The rejection level for artifacts was kept at 90 percent. The low pass filter was set at 0.01 Hz and the high pass filter was set at 30 Hz.

Stimulus Characteristics

Binaural tone stimuli of alternating polarity delivered at 0.9 ms with a frequency of 1 KHz for standard stimuli and 2 KHz for target stimuli were used to trigger online averaging of the EEG.[8] The percentage of standard stimuli was set at 80 and for the target stimuli was set at 20. The stimulus intensity was kept at 70 db SPL.

Recording procedure

Assessments were recorded immediately before and after the intervention. Participants were asked to keep their eyes closed during a recording. They were asked to avoid substances which would influence their cognitive functions (e.g., tea and coffee for the caffeine content) on the day prior to and on the day of the assessments. The standard and target stimuli were delivered through close fitting earphones (TDH-39, Amplivox, U.K.). Participants were asked to distinguish between tones and mentally count target stimuli.

Interventions

HFYB or *kapalabhati* practice involves rapid breathing with a frequency of approximately 2.0 Hz, during which only exhalation is an active process. Participants were asked to start the practice and after approximately 10 seconds they would reach the final rate (in this case, approximately 2.0 Hz). This would be the actual beginning of the one minute session. The subjects were timed by the experimenter and after a minute they were asked to stop. Hence their actual breathing session was for 70 seconds, out of which they would have been breathing at the expected rate for approximately 60 seconds and taking 10 seconds to attain the final rate. The fact that approximately 10 seconds is required to reach the expected rate of approximately 2.0 Hz is based on previous unpublished observations. Throughout the practice the practitioners sit upright, close their eyes and breathe in and out through their nose. At the end of each session participants were asked whether they experienced dizziness, tingling or numbness of the fingers or lightheadedness, as possible signs of hyperventilation. None of them reported any of these symptoms. However attempting to assess hyperventilation based on these symptoms rather than measured carbon dioxide levels is recognized as inadequate and is a limitation of the study.

Breath awareness was the 'alternate' intervention. During this practice the participants were asked to sit quietly being aware of their breath without manipulating their breathing. They were asked to be aware of the flow of air as it enters and passes through the nasal passage. Hence throughout the practice the attention is directed towards the breath.

Data extraction

The peak amplitude (in μV) was defined as the voltage difference between a pre-stimulus baseline and the largest positive peak of the P300 within a 250-450 ms latency window. The peak latency (ms) was defined as the time from stimulus onset to the point of maximum

positive amplitude within the latency window. The peak latency and peak amplitude were measured for potentials recorded at Cz referred to linked earlobes.

Data analysis

The peak amplitudes and peak latencies obtained before and after HFYB practice and after breath awareness were compared using a repeated measures ANOVA, with one Between subjects factor (i.e., Groups, with two levels, HFYB group and Breath awareness group), and one Within subjects factor (i.e., States, with two levels, Pre and Post).

Post-hoc analysis with multiple comparisons and Bonferroni adjustment was carried out to compare values recorded before and after HFYB, as well as before and after breath awareness.

RESULTS

Repeated measures Analysis of Variance (ANOVA)

The peak latency of the P300 potential showed a significant difference between States [i.e., Pre and Post, with $F = 7.829$, $df = 1,14$, $p < 0.05$]. For the P300 peak amplitude there was a significant interaction between Groups (i.e., HFYB and Breath awareness groups) and States (i.e., Pre and Post) [$F = 4.746$, $df = 1,14$, $p<0.05$]. In both cases the Hyunh-Feldt epsilon was equal to 1.

Post-hoc comparisons

Multiple *post-hoc* comparisons were carried out with Bonferroni adjustment. There was a significant reduction in the P300 peak latency following HFYB compared to before ($p < 0.05$, one tailed). Following breath awareness on the other hand, the P300 peak amplitude increased significantly compared to before ($p<0.05$, two-tailed).

The group mean values ± S.D., of the P300 peak latencies and peak amplitudes recorded from Cz are given in Table 1.

DISCUSSION

One minute of high frequency yoga breathing (i.e., HFYB, at approximately 2.0 Hz) decreased the P300 peak latency, while a one-minute session of breath awareness increased the P300 peak amplitude.

In earlier studies the P300 has been recorded before and after meditation techniques and after another yoga breathing practice. For example, definite changes were recorded in the P300 following Transcendental Meditation (TM).[11] The P300 was recorded using a passive auditory listening trial paradigm with variable inter-stimulus intervals between identical tone stimuli. There were three groups, viz., experienced TM meditators, novices to TM and non-meditator controls. The two groups of meditators had shorter latencies despite differences in ages (e.g., an average age of 41 years in experienced mediators and an average age of 20 years in novices). In another study the P300 was assessed in experienced TM practitioners at pre-test baseline, after ten minutes of rest, or after ten minutes of TM practice with conditions counter-balanced across meditators.[12] After TM, the P300 latency decreased relative to no change after the rest condition.

The P300 was also studied before and after practicing another meditation technique, called cyclic mediation (CM).[13] CM consists of cycles of ‘stimulating’ and of ‘calming’ practices. Comparisons were made with P300 recordings taken before and after an equal duration of supine rest. A greater magnitude of decrease in latency was noted after CM compared to supine rest.

There is a single report of the effect of practicing a voluntarily regulated breathing technique (or *pranayama*) on the P300.[14] The participants were patients with depression and the comparison was with people with normal health. P300 amplitudes were lower in depressives to begin with, but the amplitudes increased after practicing the yoga breathing technique (*Sudarshan Kriya Yoga*), for three months, so that the amplitudes were comparable with those of unaffected persons.

The P300 latency reflects the speed of stimulus classification, is generally not related to the overt response, and is independent of the behavioral reaction time.[15] The P300 latency is hence an index of stimulus processing rather than response generation and is used as a motor–free measure of cognitive function. The P300 peak latency is negatively correlated with mental functions in normal persons; shorter latencies being associated with superior cognitive performance in tasks for attention and immediate memory. The P300 amplitude is believed to indicate the level of activity related to processing incoming information and is sensitive to the resources available for attention engaged in completing the task.[16]

The neuroelectric events which underlie the generation of the P300 arise from interaction between the frontal lobe, the hippocampus, and the temporoparietal lobe.[17] The primary neural generators for the P300 are in the anterior cingulate when new stimuli are processed into working memory. Subsequent activation of the hippocampal formation occurs when interconnections between the frontal lobe and the temporal or parietal lobe are active.[18]

The decreased P300 peak latency following HFYB suggests that the practice may have reduced the time required for this task which requires selective attention. Based on the change in the P300 peak amplitude, breath awareness appeared to increase the neural resources available for the attentional task.

The decrease in P300 latency after different yoga practices such as high frequency yoga breathing in the present study and following meditation techniques such as TM[11,12] and CM[13] in earlier studies, could be related to two factors. These two factors, which have been mentioned below may also apply to the increased P300 amplitude following breath awareness (in the present study) and following Sudarshan Kriya Yoga, in an earlier study.[14] However the contribution of these factors to the changes in P300 is entirely speculative and is not backed by any additional recordings.

The first factor is that all yoga practices, including yoga postures (*yogasanas)*, voluntarily regulated breathing (*pranayama)*, and meditation emphasize the importance of relaxation and awareness of internal sensations.[19]

In connection with this, an objective assessment was made of the ability of experienced meditators to detect their heartbeat, which is a standard, non-invasive measure of resting interoceptive awareness.[20] While no objectively recorded difference was found between meditators and non-meditators, meditators consistently self-rated their interoceptive performance as superior and the difficulty of the task as easier. Hence a feeling of being able to be aware of internal sensations could facilitate overall awareness and the ability to be attentive. However this again is speculation. This factor may be particularly relevant for the increased P300 peak amplitude following breath awareness.

The second factor is that a substantial percentage of yoga practices are recognized to involve a certain amount of strain. In contrast, some of the changes associated with practicing yoga techniques, which includes postures (*asanas),* regulated breathing (*pranayama*) and meditation, reflect reduced strain. The most often quoted and early documented changes were a decrease in heart and breath rates and in oxygen consumption following TM.[21] These changes suggested that meditation was a state of parasympathetic dominance. However

subsequent studies have shown that most yoga techniques do show increased activity in some subdivisions of the sympathetic nervous system (this may be cardiosympathetic, vasomotor or sudomotor sympathetic nervous system activity) which often occur along with other changes suggestive of reduced arousal, hence giving rise to the description of these practices as producing a state of 'alertful rest'.

This has been shown for meditation[22,23,24], high frequency yoga breathing or *kapalabhati*[5,25] and even for yoga postures (*asanas*).[26] Since increased sympathetic activity is associated with better vigilance[5] the fact that yoga practice may increase activity in some subdivisions of the sympathetic nervous system may also explain the improved performance in the P300 oddball task after HFYB. However, though autonomic changes have been studied during breath awareness, there were no signs of increased sympathetic nervous system activity during breath awareness.[27] Hence this explanation (i.e., of increased sympathetic activity and of better vigilance) may more clearly explain the improved P300 performance after HFYB, while the improved interoception may better explain the improvement after breath awareness.

Hence, both interventions (i.e., HFYB and breath awareness) influenced the performance in the P300 task. HFYB reduced the time required for the task, whereas breath awareness appeared to increase the available neural resources required for the task. Further studies with simultaneous monitoring of autonomic variables, would help to understand whether autonomic changes did contribute to the changes in the P300 component following these practices. In the absence of such recordings all the ideas presented here about the possible mechanisms involved are mere speculations, which is a limitation of the study. Other limitations of the study include the fact that the subjects were non-naive to the intervention and hence there was no way of knowing if the brain effects were influenced by their

expectations. Finally since both interventions were given for a very brief duration, i.e., one minute each, this limits interpreting the findings and future studies would use longer duration interventions.

CONCLUSIONS

Both practices (i.e., high frequency yoga breathing and breath awareness), though very different, influenced the P300. High frequency yoga breathing (at approximately 2.0 Hz) reduced the P300 peak latency suggesting a decrease in the time needed for this task which requires selective attention. Breath awareness increased the P300 peak amplitude suggesting an increase in the neural resources available for the task.

AUTHOR DISCLOSURE STATEMENT

The authors state that “No competing financial interests exist."

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Table 1 Peak latencies and peak amplitudes of P300 pre and post high frequency yoga breathing (HFYB) and breath awareness. Values are group mean ± S.D.

		HFYB (n=15)	Breath Awareness (n=15)
Latency, (ms)	**PRE**	358.20 ± 32.53	362.80 ± 25.32
	POST	339.20 † ± 29.99	340.40 ± 45.57
Amplitude, (μV)	**PRE**	8.25 ± 4.90	5.23 ± 4.04
	POST	6.79 ± 2.79	6.55 * ± 3.96

†p<0.05 (one-tailed), * p<0.05 (two-tailed), post-hoc tests with Bonferroni adjustment, comparing 'Post' with respective 'Pre' values