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Performance in the Trail making Test following High Frequency Yoga Breathing and Breath Awareness

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Abstract

Background: A combination of yoga breathing techniques including high frequency yoga breathing practiced over 12 weeks resulted in improved performance in trail making test (TMT). However it is not studied whether a brief session of yoga breathing techniques will cause similar results in TMT performance.

Aims: This study intended to assess the effect of a brief session of high frequency yoga breathing or breath awareness separately on the TMT performance.

Settings and Design: Self as control study.

Methods and Material: Fifty three participants (aged between 18 and 46 years; group average 26.0 (SD = 7.3) years; all males were recruited in north India. They were randomly assigned to three sessions on three separate days at the same time of the day. These were HFYB or BAW or Quiet sitting (QS). Both parts, A and B of the TMT, with the STAI-S were determined before and after each session.

Statistical Analysis used: Analyses were repeated measures ANOVA, with post-hoc multiple comparisons carried out using SPSS Version 18. There were 2 within-subject factors: (i) Sessions (HFYB, BAW and QS) and (ii) States (before and after).

Results: Following the HFYB session TMT-A time reduced (P = 0.001). After BAW TMT-B time reduced (P = 0.01), and the STAI-S scores also decreased (P = 0.01). Both voluntarily regulated yoga breathing techniques, i.e., HFYB and BAW improved the performance in the TMT. HFYB improved psychomotor speed and ability to keep attention sustained while visually scanning the worksheet.

Conclusions: BAW improved flexibility in thinking, working memory and shifting strategies, while reducing state anxiety.

Keywords: Breath awareness; High frequency yoga breathing; Trail making test (TMT); Cognitive flexibility; State anxiety.

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INTRODUCTION

A comprehensive review of yoga breathing practices which included 68 studies after screening 1400 references from 3 databases described neurocognitive benefits of these practices including improved attention.[1] The trail making test reflects a wide variety of executive functions

including shifting attention.[2] Performance in the trail making test (TMT) improved after practicing a combination of yoga voluntarily regulated breathing techniques (*pranayamas*), when 67 healthy medical students showed a reduction in total time taken to complete both parts of the TMT (A and B), related to the practice of *pranayamas* [i.e., bumblebee breath (*bhramari*), alternate nostril breathing (*anulom vilom*), high frequency yoga breathing (*kapalabhati*) and bellows breath (*bhastrika*)] for 4 weeks.[3] There was a reduction in the total time taken to complete both parts of the TMT in 84 healthy participants who practiced both fast and slow pranayamas for 12 weeks.[4] Fast pranayamas included high frequency yoga breathing (*kapalabhati*), bellows breath (*bhastrika*) and dog-panting breath (*kukkuriya*). Slow pranayamas included a cleansing breath (*nadishodhana*), exhalation with a sound (*pranav*) and breathing with short periods of breath-holding (*savitri*).

These studies mentioned,[3,4] determined the longitudinal effect of a combination of voluntarily breath regulation techniques including high frequency yoga breathing on executive functions using TMT (A and B). This approach to study the effect of breathing practices on TMT (A and B) has limitation that the effect of an individual breath regulation technique cannot be determined. Apart from this the studies did not use self as control study design which is useful to reduce variations caused by inter-individual factors between the experimental, active control and control sessions.

A specific high frequency, yoga based, regulated breathing, i.e., *kapalabhati* (*kapala* = forehead; *bhati* = shining in *Sanskrit*); respiratory rate 1.0 Hz to 2.0 Hz when assessed for immediate effect has consistently improved the performance in attention tasks.[5,6] One minute of HFYB at the rate of 2.0 Hz reduced the time required to complete a cancellation task in medical students, middle aged adults and people aged over the age of 60 years.[7] This task tests abilities to direct the attention selectively and to maintain sustained attention. Also, HFYB practiced at 2.0 Hz showed a reduction in the peak latency of the P300 ERP potential elicited by the auditory oddball paradigm.[5] The results suggested a decrease in the time needed to distinguish the auditory tones following HFYB suggesting that HFYB reduced the time needed for this selective attention task. HFYB was compared with (i) breath awareness (BAW), which is an inherent part of all *pranayamas* and also with a control session. (ii) In the same study, BAW resulted in an increase in the peak amplitude of the P300 wave, a result which implies an increase in the neurons recruited to complete the P300 attention task. In another study following HFYB at 1.0 Hz and BAW for 10 minutes, there was better performance in a task which assesses the dexterity of the fingers and a reduction in errors and time to complete a task which assesses shape and size discrimination.[6] The results were speculated to be due to the beneficial effects on attention of these practices.

With this background the present study was planned to determine the immediate effects of HFYB and BAW separately on the TMT performance.

MATERIAL AND METHODS

Study design

For all participants there were three separate assessment days maintaining the time of day constant for each person. The three assessment sessions were (i) quiet sitting (control session), (ii) breath awareness (intervention session) and (iii) high frequency yoga breathing (HFYB). The session sequence was in random order (www.randomizer.org), so that the order of the sessions was not same for the 53 participants. The sequence of sessions for the first two participants is provided below as an example. For the first participant, the sessions sequence was as follows: (i) high frequency yoga breathing (HFYB), (ii) breath awareness followed by (iii) quiet sitting. While for the next participant the sequence of the sessions was as follows: (i) quiet sitting, (ii) breath awareness and (iii) high frequency yoga breathing. Hence the sequence differed for the participants. For all the three sessions the total duration was 18 minutes, with 3 epochs of 5 minutes practice and 1 minute of rest in between. Participants were assessed at the beginning and end of the sessions. The study was carried out between July 2016 and October 2016. This study design is depicted in schematic form in Fig.1.

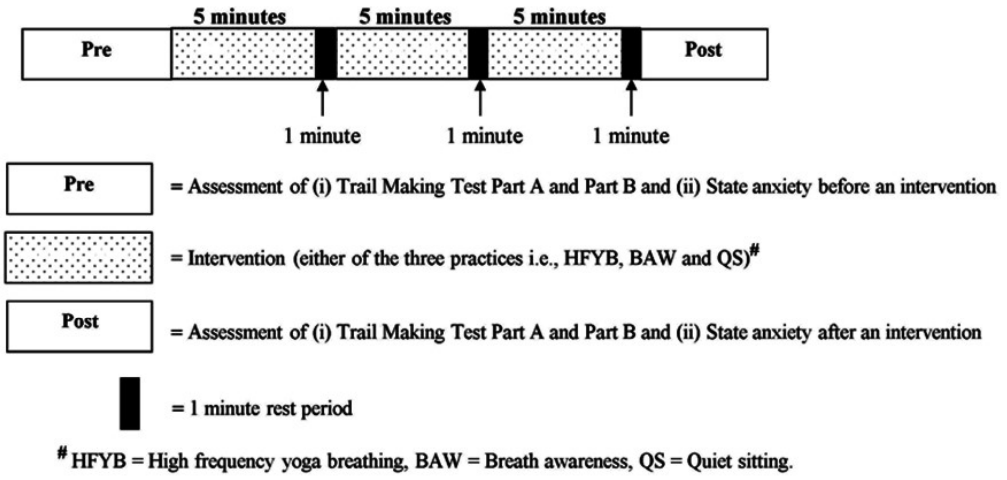

Fig. 1: Schematic Presentation of A Study Session

Participants

Fifty three male participants with ages ranging between 18 to 46 years (group average age 26.0 (SD = 7.3) years were recruited. The criteria for inclusion in the study were: (i) healthy males, (ii) experience of at least three months practice of voluntarily regulated yoga breathing techniques and (iii) being able to practice HFYB at the rate of 60 breaths per minute (50-70 breaths per minute) for 20 minutes. The criteria set to exclude participants from the trial were: (i) a past history of seizures or diagnosed epilepsy, (ii) any surgery of the abdomen or chest in the year prior to assessment, and (iii) the intake of any medication, or substances which alter the mental state. No participant was excluded for these criteria. The sample size had not been determined before beginning the experiment. However, post-hoc calculations, based on changes in time taken to complete TMT part A after HFYB; with effect size = 0.52 showed the Power was 1.000 (G Power Software, Version 3).[8] The signed consent which was voluntary and informed consent was taken from each of the participants. The study had been approved by the ethics committee of the institution which was formed based on recommendations of Indian Council of Medical Research and adheres to Helsinki's declaration involving human subjects.

ASSESSMENTS

Trail making test (TMT)

The trail making test, was administered before and after the three sessions (HFYB, BAW and QS) for each participant. The test was conducted individually. First the procedure to perform TMT Part A was detailed to each participant individually and a sample part of TMT A was used to see how much they understood. After this the subject performed the actual TMT Part A test. This procedure was repeated for Part B. Whenever the participant made an error, it was pointed out straight away and the participant was instructed to correct the mistake and continue. The time taken to complete the test was noted separately for Part A and Part B using a stopwatch which had the accuracy of 10 milliseconds.

Derived TMT scores

Two derived TMT scores were determined.[9] These were (i) trail cost (i.e., the difference between the time taken to complete TMT Part B and Part A) and (ii) trail ratio (i.e., ratio of time required to complete TMT Part B and Part A).

Spielberger's State trait anxiety inventory State (STAI-S)

State anxiety was measured with Spielberger's State Trait Anxiety Inventory (State) which has 20 items to determine state anxiety or anxiety at the moment.[10] The participants were asked to select the number which most closely corresponded to the intensity of what felt when being tests on the scale: 1 = not at all, 2 = somewhat, 3 = moderately, or 4 = very much so. State anxiety was assessed at the beginning and at the end of all three sessions.

INTERVENTION

Assessments of all participants were recorded at the beginning and the end of three intervention sessions. The sessions were (i) quiet sitting (QS,

control), (ii) breath awareness (intervention) and (iii) high frequency yoga breathing (HFYB). Each session was for 18 minutes. The method of practice of each session is presented below.

High frequency yoga breathing

High frequency yoga breathing (HFYB) Participants were requested to sit cross legged (sukhasana = comfortable posture) keeping their spine straight and with closed eyes. During HFYB the participant actively exhaled while contracting the muscles of the anterior abdomen, followed by inhalation which was passive. The participants maintained their breath rate between 50 and 70 breaths per minute (0.8-1.2 Hz).

Breath awareness (BAW)

Participants were in the same posture as for HFYB. They were seated in sukhasana (easy, cross legged pose), keeping their spine straight and their eyes closed. In this pose participants were asked to be aware of the movement of their breath in the nasal passage, during both phases of respiration, without attempting to regulate or modify the airflow.

Quiet sitting (QS)

The participants were asked to sit in *sukhasana* (at ease, cross-legged pose). During this control practice participants were asked to keep their back straight and close their eyes. Participants were not given instructions about their thoughts or directing their attention. During quiet sitting, participants were permitted to pass thoughts through their mind without modifying their thoughts. They were asked to avoid modifying their breath or being aware to their breathing.

Data analysis

Multiple repeated measures analyses of variance (RM-ANOVA) followed by post-hoc tests with Bonferroni adjustment were performed to compare values before and after the 3 sessions, using SPSS Version 18.0. There were 2 within subject factors: (i) Sessions with three levels (i.e., HFYB, BAW and QS) and (ii) States with two levels (i.e., before and after).

RESULTS

Repeated measures analyses of variance (RM ANOVA)

In the RM ANOVA, a significant difference between the two States (Pre, Post) was obtained for time taken to complete (i) trail making test (TMT) Part A and (ii) trail making test (TMT) Part B.

There was also a significant Sessions by States interaction for time taken to complete TMT Part B, suggesting the interdependence of States and Sessions.

The F, df, Eta squared, Huynh-Feldt epsilon and P values are provided in (Table 1).

Table 1: ANOVA values for the variables studied.

Sl. No.	Variables	Factor	F	df	Partial Eta Squared	Huynh-Feldt epsilon	p value
1	TMT Part A (in seconds)	States	20.013	1,52	0.278	1	<0.001
		Sessions	0.915	1.775,92.310	0.017	0.888	0.394
		Sessions x States	2.108	1.497,77.832	0.039	0.748	0.14
2	TMT Part B (in seconds)	States	6.401	1,52	0.11	1	0.014
		Sessions	0.502	1.826,91.935	0.01	0.913	0.59
		Sessions x States	1.678	1.962,102.000	0.031	0.981	0.192
3	Trail cost (in seconds)	States	1.104	1,52	0.021	1	0.298
		Sessions	0.144	1.883,97.937	0.003	0.942	0.854
		Sessions x States	1.062	1.980,102.956	0.02	0.99	0.349
4	Trail ratio	States	0.851	1,52	0.016	1	0.36
		Sessions	0.68	2,104	0.001	1	0.934
		Sessions x States	0.473	2,104	0.009	1	0.625
5	State anxiety (scores)	States	7.28	1.000,52	0.123	1	0.009
		Sessions	0.439	1.688,87.755	0.008	0.844	0.612
		Sessions x States	0.66	1.680,87.336	0.013	0.84	0.494

Post-hoc analyses

The TMT-A time decreased (P = 0.001) significantly after HFYB compared to before with 95% confidence intervals (CI) of [9.515, 3.881]. While, after BAW there was a significant decrease in TMT-B time (P = 0.01) with 95% CI of [16.290, -1.535]) and trail cost (P = 0.01) with 95% CI of [10.610, -9.252]). Also after BAW, there was a significant decrease (P = 0.01) in the state trait anxiety inventory-state (STAI-S) scores with 95% CI of [5.007, -856]).

The group mean values (Standard deviation SD) for (i) time taken to complete the trail making test (TMT) Part A, (ii) time taken to complete the trail making test (TMT) Part B, (iii) trail cost (i.e., time taken to complete the TMT Part B minus time taken to complete the TMT Part A), (iv) trail ratio (i.e., time taken to complete TMT Part B/time taken to complete TMT Part A) and (v) Spielberger's state trait anxiety inventory state (STAI-S) scores before and after the three sessions (i.e., high frequency yoga breathing, breath awareness and quiet sitting) are given in (Table 2).

Table 2: Changes in the time taken to complete trail making test (TMT) Part A, TMT Part B, trail cost, trail ratio and state anxiety before and after the three sessions.

Variables	Sessions								
	HFYB (n = 53)			BAW (n = 53)			QS (n = 53)		
	Before	After	Cohen's d	Before	After	Cohen's d	Before	After	Cohen's d
TMT Part A (seconds)	32.6±16.6	25.9±9.4***	0.52	31.8±14.1	28.6±15.7	0.21	29.1±9.4	27.3±9.4	0.24
TMT Part B (seconds)	72.8±31.3	65.4±29.2	0.24	76.7±32.3	66.7±29.9**	0.32	69.1±26.4	67.6±29.4	0.06
Trail cost (seconds)	40.25±29.92	39.57±23.97	0.03	44.91±23.83	38.13±24.88*	0.28	40.06±20.53	40.32±23.98	0.01
Trail ratio	2.49±0.87	2.57±0.74	0.1	2.51±0.75	2.47±0.75	0.05	2.40±0.55	2.52±0.80	0.15
State anxiety (scores)	30.6±8.9	28.5±10.7	0.21	30.8±8.6	28.0±6.6**	0.37	29.3±7.2	28.2±8.2	0.17

DISCUSSION

The time taken to complete Part A of the trail making test (TMT) reduced following high frequency yoga breathing whereas the time taken to complete Part B, and the trail cost (Time B-Time A) reduced following breath awareness (BAW). Also, following BAW there was a reduction in state anxiety.

The trail making test is a reliable neuropsychological test of visual attention and the ability to switch tasks.[11] The goal of the test for the subject is to finish the test as quickly as possible. The primary assessment of performance is based on the time taken to complete the test. Part A examines cognitive processing speed, while part B examines the executive functioning.

The trail making test (part A) examines cognitive processing speed.[11] TMT-A represents a perceptual speed construct, which involves perception of the stimuli, a simple motor response and in addition the ability to judge the physical identity of the letters or digits.[12] Part B of the trail making test examines executive functioning, as does the trail cost[11,13] and the trail ratio.[11] Trail B requires instant recognition and understanding the significance of the numbers and letters, the ability to scan the page continuously so as to identify the next number or letter in sequence, ability to be flexible in integrating the numeric and letter series correctly, and completing these tasks keeping time in mind.[12]

In the present study 18 minutes of high frequency breathing practice reduced the time taken to complete TMT-A. TMT-A is understood to reflect processing speed.[11] This finding of the present study can be compared with results of an earlier study which reported improved performance in a letter cancellation task in pre teen children following high frequency yoga breathing practice for 18 minutes at 1.0 Hz which was comparable to the present study.[14] Similar to TMT-A and six letter cancellation task requires visual selectivity and motor skill. Hence reduction in time taken to complete TMT-A could be result of beneficial effects of high frequency yoga breathing on visual selectivity and motor skills.

After 18 minutes of breath awareness there was a significant decrease in TMT-B time and in trail cost

(Time B minus Time A), both variables indicate better executive functions.[12] Breath awareness, mentioned here is not the same as mindfulness meditation or mindful-breath awareness. All yoga breathing practices include being aware of the breath. In yoga-based breath awareness, unlike mindful breath awareness there are no specific instructions. However as in mindful breath awareness, during the breath awareness session participants directed their attention to their experiences as they occurred while simultaneously keeping their mental state non-judgmental and accepting.[15] This mental state is known to lead to improved attention[16,17] and better associated cognitive processes.[18]

In the present study reduction in TMT-B time and in trail cost (Time B minus Time A) following breath awareness could be explained from the finding of an earlier study.[19] The earlier study investigated the effect of mindful breathing exercise compared to control condition on neural activity associated with self-monitoring processes. In the study 44 participants were either assigned to mindful breathing exercise or control condition. The participants were assessed for EEG during mindful breathing or control condition and subsequently during a stroop test. The study reported an increased alpha activity during mindful breathing exercise and enhanced error related alpha suppression during stroop test following mindful breathing. Based on this finding the authors concluded that mindful intervention may enhances attention control and self monitoring process.

Similar to performance in stroop test, TMT B requires inhibition control and shifting attention. Hence a possible way in which it may be speculated that the way in which attention was engaged resembled that of mindful breath awareness. This could explain the improvement in TMT-B performance, suggestive of better executive functions. Ideally, the participants should have been asked to describe in detail what their thoughts were during breath awareness. Not having these details limits the interpretation of the present findings about the effects of breath awareness. However breath awareness is used as a method to engage the attention and has improved the performance in tasks such as letter cancellation test[20] and the P300 task.[21] Breath awareness could also influence executive functions by down-regulating the stress response through the influence on the autonomic nervous system and on levels of epinephrine, nor-epinephrine which influence attention and recall.[22] This effect is supported by the decrease in state anxiety following breath awareness.

The main limitations of the present study are related to explaining the changes in the TMT test performance after HFYB or BAW. A detailed interaction with each participant would be useful to understand their exact mental processes during breath awareness, especially as breath awareness is also a part of HFYB. If there had been simultaneous recordings of neuro-physiological variables during the completion of the TMT it would have helped to understand the neuro-physiological processes underlying the effects.

Both HFYB and BAW practice improved the performance in the TMT; HFYB reduced the time required for TMT-A, suggestive of better cognitive processing, while BAW reduced the time required for TMT-B and decreased state anxiety, which is suggestive of better executive functions. Hence the practices complement each other and maintaining awareness on the breath during HFYB would give the best possible results.

LIMITATIONS

The findings of the study will be of maximum interest to practitioners of yoga and yoga therapists who are interested in mental health issues related to details about yoga practice. The main reason for this is the study lacks novelty. Previous longitudinal studies have shown an improvement in the Trail Making Test (TMT) performance following practice of yoga breathing, including high frequency yoga breathing (HFYB), after several weeks of practice. This study adds the detail that 18 min of HFYB improves TMT performance.

CONCLUSIONS

The immediate effect of both yoga breathing practices (i.e., HFYB and BAW), was an improvement in TMT performance. HFYB improved psychomotor speed, sustained attention and visual scanning. BAW improved flexibility in thinking, working memory and shifting strategies, while reducing state anxiety. Hence a combination of the two practices, with awareness on the breath maintained during HFYB could be expected to give the best possible results.

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Conflicts of interest:

There are no conflicts of interest.

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