

Original Article

Effect of controlled deep breathing on psychomotor and higher mental functions in normal individuals

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Abstract

Objective: The present study was conducted to assess the effect of controlled deep breathing on psychomotor and higher mental functions.

Methods: 100 normal healthy subjects (52 females and 48 males, age range - 18 to 25 years) participated in the study. Each subject acted as his or her own control. Six weeks course of controlled deep breathing i.e. 5 seconds of maximal inhalation followed by 5 seconds of maximal exhalation, once a day for ten minutes, six days a week was arranged. (i) Letter cancellation test (ii) Rapid fire arithmetic deviation test and (iii) Playing card test were conducted before and after six weeks of controlled deep breathing practice for evaluating psychomotor and higher mental functions.

Results: No significant gender difference was observed on comparing baseline readings between female and male subjects. After six weeks of controlled deep breathing practice letter cancellation test time significantly reduced ($P < 0.001$), rapid fire arithmetic deviation test and playing card test scores ($P < 0.001$) significantly improved. Letter cancellation test score didn't show improvement.

Conclusion: The results suggest that a short, simple breathing practice can be helpful in improving cognitive processes.

Introduction

The diseases of modern times, such as obesity, hypertension, coronary disease, diabetes and psychological stress are rooted in a faulty lifestyle. Yoga is one of the best lifestyles ever devised by

mankind, a new way of looking at life. Therefore, since last two decades Yoga has got incorporated into modern medicine itself.

Finally, Psychoneuroimmunology (PNI) has provided a solid scientific foundation for body mind relation. Emotions may be difficult to measure but their effects on cytokine levels and natural killer cell activity can be quantified. PNI has acted as a bridge between ancient wisdom and modern science which demands quantifiable evidence. Therefore, effect of subjective emotions on objective parameters has made modern medicine accept relaxation, peace, love, hope and joy as therapeutic tools (1).

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The yogic discipline of pranayam is claimed to have a toning effect on cardiorespiratory system (2). It creates equilibrium between psychic and somatic aspects of bodily functions (3). It has also been shown to improve the vagal tone and reduce sympathetic activity (4, 5). It is helpful in reducing stress and anxiety (6) and preventing many pathological processes by improving the antioxidant status of the individual (7). Controlled deep breathing also affects frequency of premature ventricular complexes (8). Breathing through a particular nostril can alter metabolism and autonomic activities (9).

Many theories of mental health agree on the important role played by cognitive processes, which differ greatly and influence mental health in general (10).

Cognition refers to the processes through which information coming from the sense organs is attended, transformed, irrelevant information is reduced and relevant information is elaborated, recovered and used. Cognitive processes are thus the mental processes involved in knowing about the world; as such, they are important in perception, attention, abstract thinking, problem solving, memory and learning (11).

Spatial task performance was reported to enhance during left nostril breathing in both males and females and verbal task performance was greater during right nostril breathing (12). The letter-cancellation task scores significantly improved, i.e., there were fewer errors following right and alternate nostril yoga breathing (13). A brief yoga program may be beneficial in decreasing anxiety, somatization of stress and discomfort, improving health-related quality of life and self-rated sleep quality (14). Both Kapalabhati and breath awareness can improve fine motor skills and visual discrimination, with a greater magnitude of change after kapalabhati (15).

In order to validate the physiological basis of claims regarding wide ranging therapeutic benefits of yogic practices there has been a revival of interest in researches on the preventive and curative aspects of these practices.

This project was taken up to study some aspects of cognition i.e. psychomotor function (movement or

muscular activity associated with mental processes) and some of the higher mental functions like concentration, attention, short term memory in normal individuals because few scientific studies have been conducted to investigate the effects of controlled deep breathing on cognitive processes of an individual.

Methods

This study was undertaken at MGM Medical College, Kamothe, Navi Mumbai in the Department of Physiology. The study was approved by Institutional Ethics Committee.

Study design

An experimental (pre-post) study design.

Participants

100 normal healthy subjects (52 females and 48 males) of Indian origin between the age range 18 to 25 years participated in the study. They were non smokers, non alcoholic and non diabetic, having no evidence of physical and mental illness and not on any medication as inquired before including in the study. They were explained about the study procedure and their written informed consent was taken.

Intervention

Six weeks course of controlled deep breathing, once a day for ten minutes, six days a week was arranged under supervision. 100 subjects were divided into three small batches and controlled deep breathing practice was organised in three slots from 9:00 a.m. to 9:30 a.m. every day. No other physical activity such as sports or athletic training was allowed during that period of six weeks.

Each session for ten minutes was as follows (16)

Subjects were instructed to remain fasting two hours prior to practice. They were instructed to sit erect on desk, to breathe through both nostrils with eyes closed and concentrating on breathing. The subjects were asked to do maximal sustained inhalation lasting

for 5 seconds followed by maximal sustained exhalation also lasting for 5 seconds. Thus breathing rate was controlled to 6 breaths per minute during each practice session. Verbal commands 'breathe in' and 'breathe out' were given using a stopwatch for 6 cycles per minute for a total duration of 10 minutes to synchronise the rate of breathing of all subjects.

Assessments

For evaluating psychomotor and higher functions following tests were conducted (17).

1. Letter cancellation test
2. Rapid fire arithmetic deviation test
3. Playing card test

Each subject acted as his or her own control i.e. baseline readings for all the tests were recorded once, before starting the controlled deep breathing practice sessions. The tests were conducted once again after six weeks to assess the effectiveness of intervention.

1. Letter cancellation test

Subject was given a sheet of paper having 100 small squares. Each square was filled with a single alphabet. Alphabets were written in random fashion in different squares. The subject was asked to cancel a particular alphabet from this chart with a single stroke and also told that he or she could follow a horizontal, vertical or a random path according to his or her choice. That particular alphabet was present in 10 squares but the subject was unaware of it.

Scoring system for the test

Total time taken (in seconds) and number of the particular alphabet cancelled were noted. Scoring was done out of a total score of 10. If a subject cancelled all 10 of the particular alphabet he or she would be given a score of 10 on 10. If a subject missed one or two squares with the particular alphabet then one point was deducted for each of the particular alphabet missed.

2. Rapid fire arithmetic deviation test

In this test subject was asked to keep in mind a standard two digit number with zero in one's place e.g. 30, 40, 50, 60. 10 deviations were asked from this reference number. These deviations were either in plus or minus, giving any number in such a way that final answer was not more than 100. The time allotted for each answer was 3 seconds; delayed answers were permitted upto 6 seconds.

Scoring system for the test

Numbers of correct, delayed correct and wrong answers were noted.

Correct answer in 3 seconds	2 points
Delayed correct in 6 seconds	1 point
Delayed correct beyond 6 seconds	0 point
Wrong answer	minus 1 point

3. Playing card test

It was confirmed that subjects were familiar with the playing cards. Each one was shown a set of seven cards arranged in random manner. Subject was allowed to view each card for a period of ten seconds. The cards were shown three times in succession without changing their sequence and time for viewing. The subject was then asked to recall all the cards in exactly same order of sequence.

Scoring system for the test

Errors in the order of sequence and number of cards missed were noted. Scoring was done out of a total score of 10. 7 points were for identification of 7 cards and 3 points for the correct sequence. If a subject recalled all the seven cards in the correct sequence the total score was 10. If a subject recalled all the seven cards but the sequence was incorrect total score of 7 was allotted. If a subject failed to recall some of the seven cards then 1 point was deducted for each of the missed card and no points were allotted for the sequence.

Statistical analysis

Assessments were conducted before and after six weeks course of controlled deep breathing practice. Observations were statistically analysed using SPSS 20 software. Statistical significance was set at $P < 0.05$ level.

Results

The mean age of the subjects was 18.92 ± 2.04337 years. Unpaired 't test' was used to know the gender difference by comparing baseline readings between female and male subject groups. There was no statistically significant difference ($P > 0.05$) between female and male subject groups at baseline with respect to letter cancellation test time and scores for letter cancellation test, rapid fire arithmetic deviation test and playing card test (Table I).

Therefore, Paired 't test' was used to compare the readings of all tests after six weeks of controlled

deep breathing practice with baseline readings to assess the effectiveness of intervention, irrespective of gender (Table II). Subjects showed a significant reduction in time taken for letter cancellation test ($P < 0.001$), improvement in rapid fire arithmetic deviation and playing card test scores ($P < 0.001$) but no significant improvement was seen in letter cancellation test scores ($P > 0.05$).

Finally to assess the effectiveness of intervention within male and female subject groups separately, Paired 't test' was used to compare the readings of all tests after six weeks of controlled deep breathing practice with baseline readings (Table III and IV).

Female and male subject groups showed a significant reduction in time taken for letter cancellation test ($P < 0.001$), improvement in rapid fire arithmetic deviation ($P < 0.001$) and playing card test scores ($P < 0.01$) but no significant improvement was seen in letter cancellation test scores ($P > 0.05$).

TABLE I: Comparison of baseline readings between female and male subject groups.

Tests	Sex	Mean \pm S.D.	P value
Letter cancellation test time (seconds)	Females	18.6954 \pm 5.3622	>0.05
	Males	19.5156 \pm 5.4465	
Letter cancellation test score (out of 10)	Females	9.7885 \pm 0.4124	>0.05
	Males	9.5208 \pm 0.8989	
Rapid fire arithmetic deviation test score (out of 20)	Females	13.0769 \pm 4.0865	>0.05
	Males	14.6667 \pm 4.1428	
Playing card test score (out of 10)	Females	7.6346 \pm 2.4175	>0.05
	Males	7.0208 \pm 2.5969	

Data presented are means \pm S.D. * $P < 0.05$ - significant, ** $P < 0.01$ - significant, *** $P < 0.001$ - highly significant.

TABLE II: Comparison of baseline readings with readings after six weeks of intervention (n=100).

Tests	Readings	Mean \pm S.D.	P value
Letter cancellation test time (seconds)	Baseline	19.0891 \pm 5.3912	<0.001***
	After 6 weeks	14.5364 \pm 3.9586	
Letter cancellation test score (out of 10)	Baseline	9.6600 \pm 0.6995	>0.05
	After 6 weeks	9.6200 \pm 0.6784	
Rapid fire arithmetic deviation test score (out of 20)	Baseline	13.8400 \pm 4.1699	<0.001***
	After 6 weeks	17.5000 \pm 2.8087	
Playing card test score (out of 10)	Baseline	7.3400 \pm 2.5114	<0.001***
	After 6 weeks	8.4300 \pm 2.0264	

Data presented are means \pm S.D. * $P < 0.05$ - significant, ** $P < 0.01$ - significant, *** $P < 0.001$ - highly significant.

TABLE III: Comparison of baseline readings with readings after six weeks of intervention (Females, n=52).

<i>Tests</i>	<i>Readings</i>	<i>Mean±S.D.</i>	<i>P value</i>
Letter cancellation test time (seconds)	Baseline	18.6954±5.3622	<0.001***
	After 6 weeks	13.6729±2.7958	
Letter cancellation test score (out of 10)	Baseline	9.7885±0.4124	>0.05
	After 6 weeks	9.6154±0.7182	
Rapid fire arithmetic deviation test score (out of 20)	Baseline	13.0769±4.0865	<0.001***
	After 6 weeks	17.4231±2.7321	
Playing card test score (out of 10)	Baseline	7.6346±2.4175	<0.01**
	After 6 weeks	8.7308±1.9715	

Data presented are means±S.D. *P<0.05 - significant, **P<0.01 - significant, ***P<0.001 - highly significant.

TABLE IV: Comparison of baseline readings with readings after six weeks of intervention (Males, n=48).

<i>Tests</i>	<i>Readings</i>	<i>Mean±S.D.</i>	<i>P value</i>
Letter cancellation test time (seconds)	Baseline	19.5156±5.4465	<0.001***
	After 6 weeks	15.4719±4.7756	
Letter cancellation test score (out of 10)	Baseline	9.5208±0.8989	>0.05
	After 6 weeks	9.6250±0.6399	
Rapid fire arithmetic deviation test score (out of 20)	Baseline	14.6667±4.1428	<0.001***
	After 6 weeks	17.5833±2.9160	
Playing card test score (out of 10)	Baseline	7.0208±2.5969	<0.01**
	After 6 weeks	8.1042±2.0549	

Data presented are means±S.D. *P<0.05 - significant, **P<0.01 - significant, ***P<0.001 - highly significant.

Discussion

In this study three different tests were employed to assess different components of cognition. Letter cancellation test assessed eye-hand coordination and attention. Rapid fire arithmetic deviation test assessed mental calculation ability, concentration, attention and short term memory. Playing card test assessed short term memory and sequential or linear learning.

An Individual's performance on cancellation tests (paper-pencil tests) often depends on their vigilance, motivation and arousal as they visually scan the array and select appropriate responses while suppressing inappropriate ones (18). Cancellation task requires visual selectivity and repetitive motor response i.e. good eye-hand coordination. They not only require sustained attention, concentration but also visual scanning and activation and inhibition of rapid responses i.e. response speed (19, 20).

Memory starts with a sensory input from the environment. This input is held for a very brief time-

several seconds at most- in a sensory register associated with the sensory channels (vision, hearing, touch and so forth). Information that is attended to and recognized in the sensory register may be passed on to short term memory that holds information received from the sensory register for upto about 30 seconds (21).

Short term memory has a very limited storage capacity. This capacity is estimated to be about 7 items, plus or minus 2 as suggested by George Miller (1956) in Miller's Law. Seven is also known as magical number. However, recent studies point towards a capacity limit of three to four objects that can be reliably stored. However, the number of items would differ with each individual due to their ability to chunk or group number of objects together (22).

There could be some hypothetical probable mechanisms underlying improvement in cognitive processes after controlled deep breathing practice.

Oxygen is essential to brain function, although brain

amounts to only 2% of the body's weight it consumes 25% of body's oxygen intake. Deliberate enriching the brain's supply of oxygen can also reverse any apparent deterioration of function in old people. Brief periods spent in an oxygen chamber can lead to a remarkable intellectual revitalisation. Patients given short treatments twice a day for just fifteen days have been found to become more active and more alert (23).

Controlled deep breathing practice in our study could have improved oxygen supply to brain leading to overall improvement in all the cognitive processes. Also, there is an enormous latent potential in the human brain that can become unfolded due to rich supply of oxygen resulting into synthesis of required neurotransmitters.

So far some neurotransmitters like phenylethylamine (PEA), dopamine and noradrenaline have been studied that are known to cause improvement in the cognitive processes. Phenylethylamine also acts as the releasing agent of norepinephrine and dopamine (24). It is a monoamine and supposed to be the neuronal substrate for attention. It is a major modulator of reticular activating system responsible for behaviour and cortical arousal. Therefore, it plays important role in wakefulness and arousal (25). Endogenous PEA has been identified in human brain. This endogenous PEA partly originates in situ and partly taken up from the blood. The blood levels of PEA are controlled by lungs (26).

Inactivation of monoamines was the first pharmacokinetic property of the lungs to be identified. There are two types of monoamine oxidase enzymes, MAO A and MAO B. MAO A enzyme inactivates 5-HT and noradrenaline whereas MAO B enzyme inactivates phenylethylamine. PEA inactivation is limited not by uptake but by intracellular MAO B activity (26, 27).

Prolonged inflation of the lungs or any atmospheric agent may cause inhibition of MAO activity. So far changes during oestrous cycle, anaesthetic agents and some atmospheric pollutants are shown to cause such effect. Probably, controlled deep breathing causes MAO inhibition and results therefore, in decreased inactivation of PEA by the lungs which in

turn would increase blood levels of PEA.

Controlled deep breathing also increases corticosteroid activity in the body. Corticosteroids are shown to decrease activity of MAO in brain, heart, liver and spleen. So, probably they would also decrease MAO activity in lungs thereby causing increased blood levels of PEA. This would increase PEA levels in the brain (28).

Blood levels of neurotransmitters may get affected by controlled deep breathing as it decreases the rate and increases the depth of breathing. It allows greater excursion of the lungs during prolonged inhalation and prolonged exhalation thereby increasing the surface area for exchange of neurotransmitters.

Stress is known to modulate the activity of autonomic nervous system and central nervous system in a way so as to cope up with the stress to get adapted to it. In stressful states with preponderance of sympathetic activity, controlled deep breathing practice can lead to a state of reduced sympathetic activity shifting the autonomic balance towards relative parasympathetic dominance (29).

During controlled deep breathing practice subject concentrates on breathing. This regular training of the cortex probably improves the ability to concentrate. It is also supposed to cause relaxation and calmness. It is reported to cause stabilizing effect on nervous system as shown by synchrony of alpha waves in EEG.

Controlled deep breathing reduces anxiety and reduced anxiety can improve performance on tasks requiring sustained attention (30, 31).

To summarise, controlled deep breathing is effective in improving and maintaining cognitive processes. In future, studies with long term practice of controlled deep breathing ranging from 3 months to 1 year are required to further validate the study findings. Other cognitive domains can be assessed by using different cognitive tests e.g. six letter cancellation test to increase the chances of making mistakes by increasing the level of difficulty, trail making test, stroop task, digit span task etc.

Conclusion

This study suggests that a short, simple breathing practice can be helpful in improving concentration, attention, memory, eye-hand coordination, mental calculation ability, sequential or linear learning etc. This may help to improve one's cognitive processes and if continued in adult and old age may also help to retard the process of cognitive decline that occurs with aging.

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