Indian J Med Res 120, August 2004, pp 115-121

Effect of short-term practice of breathing exercises on autonomic functions in normal human volunteers

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Received May 6, 2003

***Background & objectives*: Practice of breathing exercises like pranayama is known to improve autonomic function by changing sympathetic or parasympathetic activity. Therefore, in the present study the effect of breathing exercises on autonomic functions was performed in young volunteers in the age group of 17-19 yr.**

***Methods*: A total of 60 male undergraduate medical students were randomly divided into two groups: slow breathing group (that practiced slow breathing exercise) and the fast breathing group (that practiced fast breathing exercise). The breathing exercises were practiced for a period of three months. Autonomic function tests were performed before and after the practice of breathing exercises.**

***Results*: The increased parasympathetic activity and decreased sympathetic activity were observed in slow breathing group, whereas no significant change in autonomic functions was observed in the fast breathing group.**

***Interpretation & conclusion*: The findings of the present study show that regular practice of slow breathing exercise for three months improves autonomic functions, while practice of fast breathing exercise for the same duration does not affect the autonomic functions.**

Key words Autonomic functions - breathing exercises - parasympathetic activity - sympathetic activity

It is known that the regular practice of breathing exercise (*pranayama*) increases parasympathetic tone, decreases sympathetic activity, improves cardiovascular and respiratory functions, decreases the effect of stress and strain on the body and improves physical and mental health[1-3]. It has been demonstrated that yoga training that includes pranayama, improves autonomic and pulmonary functions in asthma patients[4].

Regular practice of breathing exercise is shown to improve autonomic functions by decreasing sympathetic activity or by increasing vagal tone[1,2,5]. Different types of pranayamas either increase sympathetic or decrease parasympathetic activity[6-10]. It has been observed that *surya anuloma viloma pranayama and kapalabhathi* type of breathing exercise increase sympathetic tone or decrease vagal tone[5,7]. Practice of short *Kumbhak pranayamic* breathing at slow rate increases oxygen consumption and metabolic rate[10], and other slow breathing exercises reduce chemoreflex response to both hypoxia and hypercapnia but increase baroreflex sensitivity[11]. Practice of slow breathing has also been advocated for the treatment of anxiety disorder as it attenuates cardiac autonomic responses in such patients[12].

There has been no systematic study to assess the scientific basis of improvement of health following practice of breathing exercises, and to compare the differences in autonomic functions between fast and slow types of breathing exercises. Therefore, this study was designed to assess the effects of slow and fast breathing exercises on various autonomic functions in normal healthy medical students in the age group of 17-20 yr.

Material & Methods

The study was conducted in the Department of Physiology, Jawaharlal Institute of Postgraduate Medical Education & Research (JIPMER), Pondicherry, on 60 male undergraduate medical student volunteers of first year. A routine health examination was performed before the study was started. All subjects were non-smokers and free from major health problems. The age was between 17-20 yr (17.65±0.15 yr), body weight between 46-65 kg (53.72±2.28 kg) and height between 146-173 cm (168.5±1.12 cm).

The volunteers were briefed about the study protocol and informed consent was obtained from them. Clearanceof ethics committee of JIPMER was obtained.The subjects the were asked to take food only from their mess (medical college hostel mess) during the entire study period. They were also instructed not to practice any yogic techniques other than the prescribed one and other physical exercises during the study period. The volunteers were randomly divided into slow breathing (n=30) and fast breathing (n=30) groups.

Slow breathing group: Subjects of this group were randomly subdivided into study group (n=15) and control group (n=15). Study group volunteers were given training to learn and perform slow breathing exercises for 15 days. After the successful completion of training, they were instructed to perform breathing exercise for half an hour in the morning between 6 and 7 am and half an hour in the evening between 5 and 6 pm under the guidance of an expert for a period of 3 months. Various autonomic function tests were performed and the values were recorded before and after the study. The volunteers were instructed not to take tea, coffee or any drinks 1 h before and any food 2 h before the recording. This was done to exclude the effects of food and water intake on the recording. All the recordings were performed in the evening (between 4 and 6 pm) in the Department Polygraph Laboratory.

Slow breathing exercise was done with subjects in sitting posture in a well-ventilated room, and it was ensured that there was no nasal obstruction. The exercise was perform in the following steps:

(i) The volunteer was asked to close one of his nostrils (*e.g.*, left nostil) by his thumb and slowly breath in through the opposite nostril while counting 1 to 6 in his mind in 6 seconds.

(ii) He was asked to close his other nostril by the index finger (now both nostrils closed) and hold his breath for 6 seconds and then open the left nostril to slowly exhale in 6 seconds.

(iii) He was instructed to breath in through the left nostrils (with right nostrils closed) over a period of 6 seconds and then to close the left nostril (now both nostrils closed) and hold his breath for 6 seconds and then to open the right nostril and exhale over a period of 6 seconds.

These 3 steps completed one breathing cycle, and these cycles were repeated continuously for half an hour (about 40 cycles) in the morning and half an hour in the evening.

Volunteers of control group were not allowed to practice slow breathing exercise. However, autonomic function tests were carried out in both study and control groups before and after the study period. The following autonomic function tests were performed following the procedures described by Banister and Mathias[13].

Heart rate response to standing: Before the test was performed, the subject was allowed to lie down for 5 min in supine position. ECG leads were connected for recording of lead II ECG (Nihon Kohden multichannel polygraph; UK). The basal (in lying posture) heart rate (HR) of the subject was noted from the heart rate counter in the polygraph.

The subject was asked to stand up immediately and changes in the heart rate were noted in the polygraph. As this polygraph gives a continuous monitoring of heart rate with beat-to-beat variation, all the changes in heart rate in response to standing were recorded. The maneuver was repeated three times at an interval of 5 min between each and the mean of the three taken for recording.

Heart rate response to deep breathing (deep breathing difference, DBD) : This was done with subjects in sitting posture with ECG leads attached to polygraph. The subject was allowed to sit on a chair till his heart rate was stabilized. Then he was asked to take a deep breath (maximum possible deep inspiration followed by maximum possible deep expiration) and heart rate changes during these respiratory phases were recorded from the polygraph. The subject was asked to perform this test three times at an interval of five minutes between each. The best of the three (the one with the maximum difference) was taken for calculating DBD.

Valsalva ratio (VR): Valsalva ratio is a measure of the change of heart rate that takes place during a period of forced expiration against a closed glottis or mouth piece (Valsalva maneuver). The subject was allowed to sit in erect posture in a chair with a rubber clip over the nose. ECG leads were connected and he was asked to breathe forcefully into a mouthpiece (with a small leak in the side) connected to a mercury manometer and maintained the expiratory pressure of 40 mm of Hg for 15 sec, during which the HR was recorded in the ECG recording of the polygraph. VR was calculated by dividing the longest interbeat interval recorded after the maneuver by the shortest interbeat interval during the maneuver.

Each volunteer performed this maneuver three times separated by 5 min. The highest ratio from these three successive attempts was considered in the VR.

Bradycardia ratio: This was calculated from the ECG recording of Valsalva maneuver.

$$\text{Bradycardia ratio} = \frac{\text{Longest R-R interval shortly after the strain}}{\text{Mean R-R interval of the period of 30 sec before the strain}}$$

Tachycardia ratio:

$$\text{Tachycardia ratio} = \frac{\text{Shortest R-R interval during the strain}}{\text{Mean R-R interval of the period of 30 sec before the strain}}$$

Fast breathing group

Volunteers of this group were randomly subdivided into study group (n=15) and control group (n=15). Following the training to perform fast breathing exercise for 15 days, the subjects of the study group were allowed to perform the breathing exercise for half an hour in the evening and half an hour in the morning for a period of 3 months. The autonomic function tests were performed as in the slow breathing group and the values were recorded before and after the study.

Fast breathing exercise was done with subject in sitting posture in *padmasan* (with erect spine) in a well-ventilated room. They were instructed to take a deep and fast inspiration and expiration for one minute following which they were given three minutes rest. The procedure was repeated 8 to 10 times over a period of 30 min. Subjects of control group were neither given training for breathing exercise nor were they allowed to practice the exercise.

Statistical analysis was done by Students 't' test and ANOVA. $P<0.05$ was considered statistically significant.

Results

All volunteers completed the study. There was no dropout.

Slow breathing group

Basal heart rate following slow breathing exercise was significantly reduced ($P<0.05$) in the volunteers of study group compared with the pre-exercise value, as well as the control group (Table I).

Heart rate response to standing: The heart rate response to standing in study subjects of slow breathing group was significantly altered. Immediately on standing the maximum heart rate attained in the study subjects after practicing the breathing exercise was significantly less ($P<0.05$) in comparison to their pre-exercise value, and also the mean heart beat at which this maximum rise was attained was significantly less ($P<0.001$) in comparison to the pre-exercise value and the values of control group (Table I). Though there was a decrease in the minimum heart rate in the study subjects, the decrease was not statistically significant in comparison to their pre-exercise value, but the decrease was significant compared to the post-three months value of control group ($P<0.01$). The time in which the minimum heart rate was achieved was also significantly less ($P<0.001$) in post-exercise study subjects in comparison to their own pre-exercise values and values of control subjects.

Though the steady state heart rate of study subjects in the post-exercise state was less, it was statistically not significant. However, when compared with the post-three months value of control subjects it was found to be significantly less ($P<0.01$). Also, the time for achieving the steady state was significantly less ($P<0.001$), in post-exercise subjects in comparison to their own pre-exercise value and with the value of pre- and post-three months recordings of control subjects.

Heart rate response to deep breathing: There was a significant rise in DBD ($P<0.001$) in slow breathing group in comparison to their pre-exercise value and the values of the control group (Table II).

Valsalva ratio, bradycardia ratio and tachycardia ratio: There was no significant change in Valsalva ratio, bradycardia ratio between pre-and post exercise values of study group subjects, and also between the values of

Table I. Heart rate response to standing in control and study subjects of slow breathing group

	Control		Study	
	Pre-3 months	Post-3 months	Pre-exercise	Post-exercise
Basal HR (per min)	71.86±10.36	74.08±9.61	73.61±10.69	65.02±8.02*
Imm Max HR	104.03±11.30	105.11±10.96	108.28±9.36	101.18±8.45*
(mean beat)	(12.99±1.48)	(12.5±1.61)	(12.11±1.54)	(9.73±1.25)**
Min HR	85.23±11.57	88.68±12.94	83.90±13.89	75.84±10.69†
(time in sec)	(121.33±4.99)	(117.33±4.70)	(118.67±5.43)	(90.27±3.28)††**
Steady State HR	89.77±11.35	93.84±11.88	89.83±11.57	81.82±9.90†
(time in sec)	(236.66±9.90)	(231.06±7.57)	(232.93±8.51)	(154.43±7.63)††**

Values are mean±SD; n=15 in each group

P* <0.05 **<0.001 compared to pre-exercise value

P †<0.01 ††<0.001 compared to control (post 3 months) values

Basal HR: Mean basal heart rate in supine posture after 5 min of rest; Imm Max HR (mean beat): Immediate mean maximum rise in heart rate after standing (the mean beat at which this was achieved); Min HR (time in seconds): Mean minimum heart rate observed after standing (the time in seconds at which this was achieved); Steady state HR (time in seconds): Mean heart rate in standing position after reaching a steady state (the time in seconds at which this was achieved; Pre-3 months: before three months of study period; Post -3 months: after three months of study period in controls

Table II. Heart rate response to deep breathing in control and study subjects of slow breathing group

	Control		Study	
	Pre-3 months	Post-3 months	Pre-exercise	Post-exercise
Basal	74.4±8.48	76.4±7.18	75.0±8.32	71.6±8.22
Maximum	84.67±7.35	84.73±6.79	84.53±7.18	84.2±6.53
Minimum	73.8±7.66	73.9±6.94	73.27±7.79	69.5±7.04
DBD	10.86±1.68	10.81±1.26	11.27±1.53	14.73±1.71***

Values are mean±SD, n=15 in each group

***$P<0.01$ compared to pre-exercise value

Basal: Heart rate in sitting posture after 5 min of rest; Maximum: Maximum heart rate observed during deep inspiration; Minimum: Minimum heart rate observed during deep expiration; DBD: Difference in heart rate between the maximum during inspiration and the minimum during expiration; Pre-3 months: before three months of study period; Post-3 months: after three months of study period in controls control and study subjects of slow breathing group (Table III).

Fast breathing group

No significant change was observed in basal heart rate, heart rate response to standing, heart rate response to deep breathing, VR, BR and TR in study and control subjects of fast breathing group.

Discussion

In normal resting subjects the heart rate is determined mainly by background vagal activity. The basal heart rate is therefore the function of parasympathetic system[14]. In our study, there was a significant decrease in basal heart rate in slow breathing group after three months of practice of slow breathing exercise. This indicates that the practice of slow breathing exercise improves vagal activity. No significant change in basal heart rate was observed in fast breathing group. So, it can be presumed that there was no change in parasympathetic tone following the practice of fast breathing exercise for three months.

On immediate standing there occurs an increase in heart rate, which reaches a maximum between 10 to 15th beat. Following this, the HR falls to a minimum in 1 to 2.5 min and then rises again to stabilize (the steady state heart rate) in 2.5 to 4 min[13]. In our study, the heart rate was increased significantly on standing from supine position. It was observed that the maximum increase in heart rate was significantly less in subjects of post-exercise slow breathing group (compared with their own pre-exercise value and with the pre-and post-three months values of control group). However, it may be argued that the maximum increase in heart rate was less in this group because their basal heart rate was less. Since, in post-exercise study subjects, the maximum rise in heart rate on immediate standing was attained in significantly less number of beats in comparison to their pre-exercise value and the values of the control group, it suggests that the vagal tone was increased following three months practice of slow breathing exercise.

Though the fall in heart rate to the minimum following standing in post-exercise study subjects was not statistically significant, the time taken to achieve the minimum was significantly less. This means that fall in heart rate was achieved in less time. Similarly, though the rise in heart rate to the steady state was not statistically significant, the steady state heart rate was achieved in significantly less time. These findings indicate the improvement in parasympathetic activity. Our findings corroborate with the observations of Bhargava *et al* that *pranayamic* breathing decreases baseline heart rate and blood pressure by improving vagal tone and by decreasing sympathetic discharge[1]. However, other workers suggested that *pranayamic* breathing practiced exclusively in right nostril (right nostril *pranayama*) increased sympathetic activity[2,8]. It was also observed that left nostril breathing decreased sympathetic discharge[8]. Slow breathing exercise performed in alternate nostrils in the present study showed an increase in parasympathetic activity. This suggests that practice of either left nostril slow breathing or alternate nostril slow breathing improves parasympathetic and decreases sympathetic activity.

Heart rate response to standing is a function of autonomic nervous system[13]. A rise in heart rate

Table III. Valsalva ratio (VR), bradycardia ratio (BR), tachycardia ratio (TR) in control and study subjects of slow breathing group

	Control		Study	
	Pre-3 months	Post-3 months	Pre-exercise	Post-exercise
VR	1.57±0.26	1.54±0.27	1.59±0.26	1.64±0.46
BR	1.17±0.18	1.18±0.23	1.18±0.18	1.18±0.15
TR	0.71±1.10	0.65±0.10	0.71±0.06	0.72±0.13

Values are mean±SD; n=15 in each group

Pre-exercise: Before practice of three months of slow breathing exercise; Post-exercise: After practice of three months of slow breathing exercise; Pre-3 months: before three months of study period; Post-3 months: after three months of study period in controls observed when a person assumes standing posture from the supine position, is mediated by baroreceptor reflex, which assesses the integrity of autonomic nervous system[14]. In our study in slow breathing group, the immediate rise in heart rate in response to standing was achieved at a lower beat. The maximum fall in heart rate and stabilization of heart rate in less time in response to standing indicate an improvement in autonomic functions.

A significant increase in DBD was observed in slow breathing group after the practice of three months of the exercise. During inspiration, vagal activity decreases and sympathetic activity increases[14]. Therefore, the heart rate rises during inspiration. Opposite mechanism operates in expiration and heart rate decreases. This difference in heart rate in different phases of respiration is called as sinus arrhythmia[14]. This phenomenon of arrhythmia is accentuated in deep breathing. DBD decreases with increasing age[13]. Normally, in adults the DBD varies from 10-15 and a value less than 10 is regarded as abnormal. A significant rise in DBD in slow breathing group post-exercise in the present study indicates an increase in vagal activity, as the change in heart rate during breathing is mainly due to the change in vagal activity[14].

It has been suggested that well-performed slow yogic breathing decreases sympathetic activity during altitude-induced hypoxia, by increasing oxygenation without altering minute vantilation[15]. In slow and deep breathing, oxygenation of blood increases without changing minute ventilation, as alveolar ventilation increases[14]. It has been suggested earlier that *pranayamic* type of slow breathing increases oxygen consumption that improves autonomic functions[10]. Also slow type of pranayamic breathing like *nadisuddhi*-breathing decreases sympathetic activity and fast type of pranayamic breathing like *kapalabhati*-breathing increases sympathetic activity[7]. The breathing exercise practiced in slow breathing group in our study was slow and deep breathing type. The improvement of parasympathetic activity following practice of slow breathing exercise in our study may possibly be due to increased oxygenation of tissues. As oxygenation does not improve in fast breathing due to decreased alveolar ventilation, no significant change in autonomic activity was observed in fast breathing group. Though others have reported increased sympathetic activity by practicing fast breathing exercise[7], no such change was observed in our study, which may possibly be due to different pattern and duration of fast breathing exercise practiced in our study.

During and after Valsalva maneuver, changes in the cardiac vagal efferent and sympathetic vasomotor activity occur, resulting from stimulation of carotid sinus and aortic arch baroreceptors and other intrathoracic stretch receptors[13]. In our study, no significant change was observed in VR in slow and fast breathing groups. This may be due to the less duration of practice of breathing exercise, which was not adequate enough to cause changes in the sensitivity of baroreceptors and intrathoracic stretch receptors to affect VR. As BR and TR are calculated from the ECG recording of Valsalva maneuver, no significant change was observed.

It could thus be concluded that regular practice of slow breathing exercise for a minimum of three months improves autonomic functions. The practice of fast breathing exercise for the same duration does not affect the autonomic functions. As subjects of the present study were from various social, environmental, cultural and religious backgrounds, result of this study should be widely applicable.

Acknowledgment

The authors thank Smt. Bharathi Balakumar, Technical Assistant, Department of Physiology, for assisting in recording the autonomic function tests.

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