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RESEARCH ARTICLE

Effect of pranayama training on vital capacity, respiratory pressures, and respiratory endurance of young healthy volunteers

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ABSTRACT

Background: There is a paucity of literature on the effects of isolated pranayam practice in particular savitri pranayam. Furthermore, no study depicts the pattern of change and variations in the effects produced. It needed to be found out whether long-term practice of Pranayama improves respiratory endurance and to what extent. **Aim and Objectives:** The aim of the study was to determine forced vital capacity (FVC), forced expiratory volume in 1stsecond, maximum inspiratory pressure, maximum expiratory pressure, and 40 mm Hg endurance of young healthy volunteers and to study the effect of pranayam on the same. **Materials and Methods:** Sixty volunteers of age group 20–30 were recruited and were divided into pranayam group and control group. After familiarizing the subjects with lab environment, the pre training values of both the groups were recorded. The parameters recorded were FVC, Forced expiratory volume in 1st s, maximum inspiratory pressure, maximum expiratory pressure, and 40 mm Hg endurance. A spirometer and a mercury manometer were used to measure these parameters. The pranayam group was given training in savitri pranayam for 12 weeks. The parameters were recorded at 4, 8, and 12 weeks of study. Data were collected and analyzed with student-*t*-test. Tests of significance were calculated by Statistical package for the Social Sciences software version 21.0. **Results:** There was a highly significant improvement ($P < 0.001$) in all the parameters among pranayam group. The control group did not showed significant improvement in any of the parameters. **Conclusion:** The improvement in respiratory efficiency in this study, though highly significant is less in magnitude. Combined practice of asan and pranayam may produce a better improvement than practicing savitri pranayam alone. The pattern of improvement in respiratory variables is not uniform. Individuals respond differently to yoga. Some showed a rapid improvement followed by a plateau, whereas for others the improvement graph appeared slow and steady. Yoga training has to be individualized and yoga therapy should be customized according to individual patient's receptivity and nature. Savitri pranayam would be an effective tool in promotion of respiratory efficiency.

KEY WORDS: Savitri Pranayam; Pranayam Training; Forced Vital Capacity; Respiratory Pressure; Respiratory Endurance

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INTRODUCTION

The World Health Organization reports air pollution responsible for around three percent of global disease burden.[1] It also says India is the main victim of indoor air pollution and 4–6% of the national disease burden is due to air pollution. Changing the environment and controlling

the threats are difficult, whereas one can modulate with relative easiness his/her immune system, and respiratory apparatus to withstand strong against these hazards. While considering the available options to improve respiratory efficiency, yoga stands out as the best intervention. Yoga is a blend of spiritual belief, scholarly philosophy, and physical techniques that helps the yogi to achieve a union of mind, body, and soul with the ultimate Divine. The Sanskrit word pranayam means extension of prana (life force). Pranayam is a vital part of any form of yoga practice. In a very recent article by D'Souza and Avadhany it was found that yoga practice for 3 months significantly improves respiratory muscle strength even in pediatric population.[2] In a study done by Ross and Thomas, it was found out that yoga may be better than common physical exercises at improving variety of health related outcome measures.[3] Although the exact neurophysiological basis of Pranayam is not known, it has been postulated in a work by Ramamurthi which says, with control of cortical higher brain centers, it is possible to get control of other basic functions.[4] Pranayam, the practice of controlled and conscious breathing forms the fourth limb of the ashtanga (eight limbs) yoga. Madanmohan *et al.* studied the effect of slow and fast pranayam on cardio-respiratory variables in which they found an increased respiratory pressures and respiratory endurance with slow pranayam.[5] While the energy spent and oxygen consumption rise with exercise and fast pranayam, Madanmohan *et al.* found a reduction in oxygen consumption with savitri pranayam.[6] Being a slow type of pranayam, anybody can practice it. In a book by Vasant lad it has been mentioned that thoughts alter rhythm of breath and breathing alter rhythm of thoughts.[7] To the best of my knowledge, the earliest scientific literature relevant to the topic of current study was by Makwana *et al.*[8] They observed the effect of 10 week training of yoga that included pranayam. They reported an increase in Forced vital capacity (FVC), forced expiratory volume in 1st s (FEV_1), maximum breathing capacity, and breath holding time. Succeeding study by Joshi *et al.* investigated a 6 week effect of pranayam alone on ventilatory functions.[9] The results were similar to the previous study. Similarity in results makes clear that pranayam practice improves ventilatory functions across diversely aged population. In an attempt to study the effect and dynamics of pranayam in the form of work done, Raju *et al.* attempted a maximal graded exercise test.[10] He reported that yoga training that included pranayam produced a reduction in minute ventilation, increase in maximal work output with a reduction in oxygen consumption per unit work. These findings suggest that with pranayam practice, a person can do more work with lesser consumption of oxygen. A study by Yadav and Das investigated the effect of yogic practice on pulmonary functions in female population.[11] They made the subjects performed prayer, asan, pranayam, and meditation. They evaluated the effect in 6th week and 12th week of training. There was an increase in both the recording with 12th week recordings exceeding 6th week results. In a comprehensive study by Madanmohan *et al.* that investigated the effect of yoga over respiratory apparatus entirely evaluated FVC, FEV_1, PEFR, respiratory pressures along with hand grip strength found a significant rise in the above mentioned parameters.[12] Godoy *et al.* in their study compared the effect of aerobics and yoga training on respiratory parameters.[13] They reported that there is no difference between the post training recordings of parameters between these two groups. It was in contradiction with a study by Prakash *et al.* conducted a year later.[14] Prakash *et al.* compared lung functions between three group of populations; yoga practitioners, athletes, and people with sedentary life style.[14] They found that people who practice yoga had better PEFR and FEV_1 than other two groups. A study by Vedala *et al.* supports the same although they have mentioned what type of asan or pranayam they have used for their subjects.[15]

A research publication by Central Council for Research in Yoga and Naturopathy studied pulmonary function in three groups of subjects. Group one include subjects who performed only asan, subjects of group two performed asan and pranayam and the last group practiced only pranayam. They found that FVC and % FEV_1 are increased significantly in all the groups and the highest improvement is seen in subjects who performed asan and pranayam together.[16] Ahmed *et al.* in their study reported that 4 weeks of yoga training (yoga and pranayam) for subjects of age group 30 to 40 did not produce any significant improvement in FVC and FEV_1. Whereas training for another 4 weeks showed significant improvement.[17] Similar results were obtained by Shankarappa *et al.*, Mamatha *et al.*, and Chauhaun *et al.*[18-20] All the authors agree that short-term practice of savitri pranayam or equivalent forms of slow pranayams like nadhishuddhi do produce an increase in FVC and FEV_1 and other lung parameters such as BHT, PEFR, and % FEV_1. In a recent study by Kumar *et al.*, the consolidated effects of various types of pranayam on respiratory parameters were observed.[21] They also found an increase in FVC, FEV_1, PEFR, and MVV. It brings about a tremendous curiosity as how a combination of different forms of pranayam produces an effect which is similar to the effects produced when they are practiced alone.

Recently, a pilot study by Turankar *et al.*, involved yoga training for just 7 days and concluded that there is no significant improvement in FVC and FEV_1.[22] Correlating this study with other studies, we can assume that for an improvement in FVC and FEV_1 to be significant, a minimum duration of 4 weeks of training is needed. Sayyed *et al.* investigated the effects of Sudarshan Kriya Yoga.[23] Doijad *et al.* did their study with combined asan and pranayam (nadhishuddhi, bhastrika, and bhramari).[24] Santaella *et al.* investigated the effect of bhramari pranayam on old age population.[25] Kadu and Deshpande, Waghmare and Balaji and Shekhawat studied respiratory functions with anuloma-viloma and kapalbhati, bhastrika, nadhishuddhi, bhramari, and preksha meditation, respectively.[26-28] All these authors

reported an increase in respiratory parameters with yoga training. Gupta and Sawane, in their comparative study of yoga and swimming on pulmonary functions reported that they did not find any significant change in the improvement between two groups.[29] Vempati *et al.* along with above discussed mechanisms, suggested a new theory that slow and gentle breathing as done in pranayam may reduce or reverse the frictional stress that otherwise produced in forceful breathing over narrowed air passages leading to airway inflammation and obstruction.[30] In a study by Madanmohan *et al.* it was found that there is significant improvement in maximum inspiratory pressure, maximum expiratory pressure and 40 mm Hg endurance with a yoga training of 12 weeks.[31] Similarly, Coelho *et al.* in a later study reported an insignificant relationship between yoga practice and respiratory muscle strength.[32] The previous results of Madanmohan *et al.* in their short study of 6 weeks duration, found that there was a statistically significant increase in maximum inspiratory pressure in male subjects of both study as well as control groups though the absolute delta values favored yoga group.[33] Similar results in favor of improvement in respiratory muscle strength were obtained by Bhutkar *et al.* and Reddy.[34,35] Jaju *et al.* in their study that investigated the effect of pranayam training on patients of chronic obstructive pulmonary disease, it was found that the control group who were healthy normal subjects showed a statistically significant increase in maximal inspiratory pressure with pranayam training whereas the patients did not.[36] Recent research studies focusing on the effect of yoga in general or pranayam in particular were mostly supportive of the notion that says, yoga practice does produce a tremendous increase in respiratory muscle strength. Mullur *et al.* and Pandya *et al.* support this view.[37,38] A study by Desai and Jasani which compared savitri pranayam and alternate nostril breathing, concluded that there is significant rise in maximum expiratory pressure and 40 mm Hg endurance with both types of pranayam and both the types are equally beneficial.[39] Another study by Desai and Verma that evaluated the effect of savitri pranayam on respiratory variables concluded that there is a statistically significant improvement in maximum expiratory pressure and 40 mm Hg endurance with savitri pranayam training.[40]

Gaur *et al.* in their study reported a significant increase in respiratory pressures and endurance with 10 weeks of yoga practice.[41] Supportive evidence also comes from Choudhary *et al.* which confirm that yoga practices do increases respiratory pressures.[42] The molecular basis of the improvement was explained by Bhasin *et al.*[43]

Ironically, there is a paucity of literature on the effects of isolated pranayam practice in particular savitri pranayam. Furthermore, no study depicts the pattern of change and variations in the effects produced. It needed to be found out whether long-term practice of Pranayama improves respiratory endurance and to what extent. This study is started with the above mentioned background as an attempt to throw some light over the lacunae. This study is aimed predominantly to find effect of 12 week Pranayam training on FVC, forced expiratory volume in 1st s, maximum inspiratory pressure, maximum expiratory pressure, and 40 mm Hg endurance of young healthy volunteers. In an attempt, this study evaluated the effect of savitri pranayam alone on the respiratory efficiency. The results of this study would help to emphasize the role of Pranayama in improving respiratory endurance and importance of regular Pranayama practice.

MATERIALS AND METHODS

Ethical Clearance

Study approval was sought from Institutional Human Ethical Committee of Mahatma Gandhi Medical College and Research Institute. Study commenced after the approval from IHEC.

Participants

This study recruited subjects from Yoga Therapy outpatient department of Mahatma Gandhi Medical College and Research Institute.

Inclusion Criteria

Healthy young volunteers of age group 20–30 years of age were included in the study.

Exclusion Criteria

Athletes, swimmers, and patients with cardio respiratory diseases were excluded from the study.

Study Design

This is a prospective cohort study, conducted in a concurrent parallel study design. The subjects were informed about the study both in English and in local language, by the principal investigator. Informed written consent was obtained from the subjects before taking them into the study.

After obtaining consent, the subjects of both the group were taken to the Human Laboratory in the Department of Physiology, Mahatma Gandhi Medical College and Research Institute for Pre-training orientation.

Parameters and Instruments

1. FVC: It is the maximal volume of air expired forcefully after a maximal inspiratory effort. It also provides information about the airway resistance muscles
2. FVC in 1st second (FEV_1): Fraction of the vital capacity expired in 1st second of a forced expiration

Both these parameters were measured by conventional digital spirometer and were consistent with ATS/ERS guidelines. The instrument used was ndd easy one world spirometer by the manufacturer (ndd medical technology incorporation Andover, USA) that uses ultrasonic true flow measurement technology. Since this is a conventional commonly used instrument the technical specifications are omitted from description.

3. Maximum inspiratory pressure (PImax): The maximum static pressure generated during inspiration at the mouth
4. Maximum expiratory pressure (PEmax): The maximum static expiratory pressure generated at the mouth
5. 40 mm Hg endurance.

A custom designed mercury manometer was used for measuring PI_{max}, PE_{max}, 40 mm Hg endurance. All the parameters were recorded for subjects of both groups with easy one world spirometer and mercury manometer.

Method of Recording

1. FVC and FEV_1: The subjects were made to sit comfortably on a stool. The procedure was taught and demonstrated to them by the principal investigator. After satisfactory trials, the actual recording was done. The subjects were asked to sit straight and hold the spirometer in their hands. They were asked to take a maximum deep inspiration. After holding the breath, they were asked to seal their lips around the mouth piece tightly and asked to blow out the air as fast and deep (maximum)/as possible. Multiple trials were made till three successful tests with a difference of less than ten percent are obtained. The maximum of all the three values was noted as the reading for that subject
2. PI_{max}, $P_E$max: The subjects were made to sit comfortably straight on a stool placed behind the mercury manometer. The procedure was taught to them and demonstrated to them by both technicians and the principal investigator. After satisfactory trials, the actual recording was done. For $P_I$max, the subjects were asked to blow out completely to their residual volume. Then they were asked to hold the glass syringe in their mouth with lips sealed tightly over it. With a technician supporting the cheek of the subject, the subject was asked to take a full deep inspiration to the maximum of ability and to hold it at the maximum level continuously for 3 s. Multiple trials were made with a rest period of 2 min, till three successful tests with a difference of less than ten percent are obtained. The maximum of all the three values is noted as the $P_I$max reading for that subject. Similar procedure is repeated for evaluating $P_E$max. Here, the subject is encouraged to take full deep maximum inspiration and asked to blow out in to the mouth piece completely as maximum as possible and to hold it at that level for 3 s
3. 40 mm Hg endurance: The subjects were made to sit comfortably straight on a stool placed behind the mercury manometer. The procedure was taught to them and demonstrated to them by both technicians and the principal investigator. After satisfactory trials, the actual recording was done. The subjects were made to take a good breath and asked to blow in to the mouth piece of mercury manometer till forty markings. They were then encouraged to hold their breath at the same level for as much time as maximum possible and the time duration was noted. Multiple trials were made with a rest period of 2–2 min, till three successful tests with a difference of less than ten percent were obtained. The maximum of all the three values is noted as 40 mm Hg endurance.

Pranayam Training: Technique and Design

The subjects of the pranayam group were asked to come to the practicing hall by 10 am in the morning, 2 ½ h after a light breakfast. They were instructed to wear loose and comfortable clothes, not tight around the thorax and abdominal region. The yoga tutors taught savitri pranayam in the 1st week. From 2nd week onwards the subjects practiced savitri pranayam under the supervision of the yoga tutors. The technique is slow deep focused inspiration to the full maximum level to a count of six, holding the breath at the maximal inspiratory level with attention for a count of three, slow deep exhalation to the maximal level for a count of six, and holding the breath at the maximal expiratory level for a count of three. The same technique is repeated for a period of 10 min. After a break of 3 min, again the procedure is repeated for two more rounds. Thus, each subject in the study group got practicing time of 30 min a day, 5 days in a week for 12 weeks.

Data Collection

The subjects of both the groups were made to come to the laboratory and the data were collected before the pranayam training and at the end of 4th, 8th, and 12th weeks of training. The recording was taken in one sitting by four technical staffs of our laboratory under supervision of the principal investigator.

Statistical Analysis

The statistical analysis was done with Statistical package for the Social Sciences version 21.0 and the mean, standard deviation, standard error mean, confidence interval, and *P*-value are calculated by employing student's *t*-test.

RESULTS

Subjects

The pranayam group consisted of eight male subjects (26.7%) and 22 female subjects (73.3%) whereas the control group consisted of five male subjects (16.7%) and 25 female subjects (83.3%). This study had preponderance of female

subjects both in pranayam group as well as control group. The anthropometric details of the subjects are given in Table 1.

FVC

The pre training FVC value for the pranayam group was 2.66 ± 0.57 (expressed as mean ± SD). After 4 weeks of training there was an increase in value by <1%. The next 4 weeks of training brought an increase in the values by 4.1%. By the end of 12 week training, the values increased again by 7.5% to 2.78 ± 0.55. The pranayam group showed a steady increase in the FVC values over the period of training. In the control group, it was 2.88 ± 0.56 at the beginning of training. Recording the values after 4 weeks showed an increase in less than 1% similar to the pranayam group. By the end of 8 weeks, an increase in the values by 1% was recorded. End of 12 week recording displayed a decrease in FVC by 1.5%. The level of FVC among the control group showed a very minimal variation. The pranayam group showed a gross variation with readings differed around 7.5%. As the training went on, the pranayam group showed statistically significant rise in FVC values by 8th and 12th weeks, whereas the change in values for control group was not statistically significant [Tables 2-4 and Figure 1].

Table 1: Anthropometric data of subjects

Parameters	Control group		Pranayam group	
	Mean	SD	Mean	SD
Age (years)	22.97	1.75	22.63	1.63
Height (m)	1.60	0.06	1.60	0.05
Weight (kg)	56.60	7.75	56.27	7.53
BMI (in kg/m^2)	22.20	2.58	21.87	2.51

m: Metre, kg: Kilogram

Table 2: Significance testing: pre, mid, and post-training recordings of pranayam group

Parameters	Groups compared	*P*-value	Difference of mean (group 1 minus group 2)	95% confidence limit of the difference
	0 week	0.3256	0.01	0.02–0.05
	4 weeks			
FVC (l)	0 week	<0.0001		
	8 weeks		0.12	0.09–0.15
	0 week	<0.0001		
	12 week		0.33	0.24–0.42
	0 week	<0.0001	0.18	0.11–0.25
	4 weeks			
FEV_1 (l)	0 week	<0.0001	0.27	0.20–0.34
	8 weeks			
	0 week	<0.0001	0.44	0.35–0.53
	12 week			
	0 week	0.0711	0.60	0.05–1.25
	4 weeks			
P^Imax (mm Hg)	0 week	<0.0001	3.07	2.42–3.71
	8 weeks			
	0 week	<0.0001	2.60	1.79–3.41
	12 week			
	0 week	0.0258	0.80	0.13–1.47
P^Emax (mm Hg)	4 weeks			
	0 week	<0.0001	2.93	2.23–3.63
	8 weeks			
	0 week	<0.0001	2.40	1.77–3.03
	12 week			
	0 week	0.0005	1.23	0.59–1.87
40 mm Hg endurance (s)	4 weeks			
	0 week	<0.0001	1.90	1.23–2.57
	8 weeks			
	0 week,	<0.0001	2.30	1.48–3.12
	12 week			

Inspiratory and expiratory pressures, l: Litre, mm Hg: Millimetres of mercury. S: Seconds

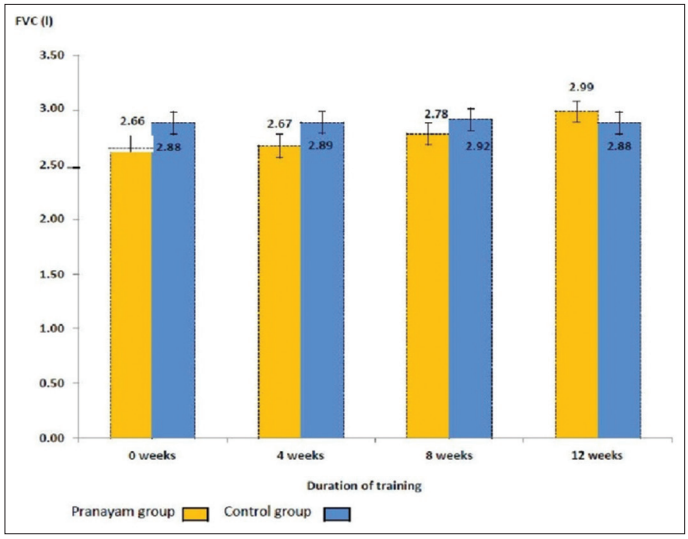

Figure 1: Forced vital capacity expressed in mean±standard error mean

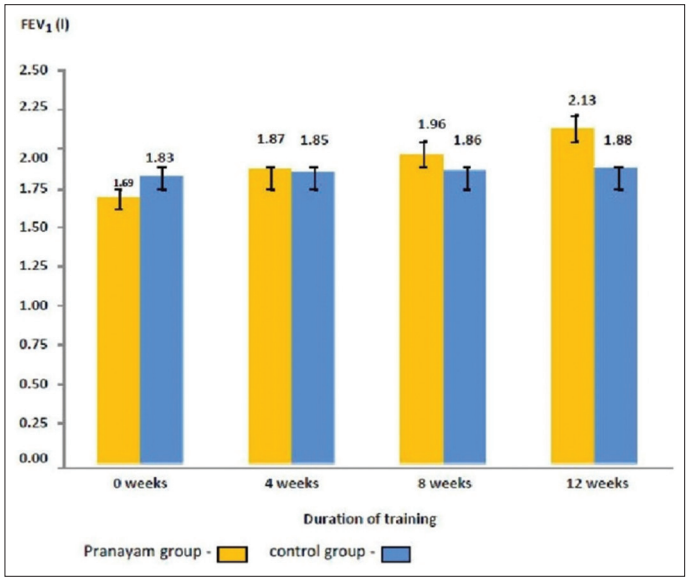

Figure 2: Forced expiratory volume in 1st second expressed as mean±standard error mean

Forced Expiratory Volume in 1st s

Pre training values for pranayam group were 1.69 ± 0.42. After 4 weeks of training it was increased by 10.65%. The next 4 weeks of training produced a 4% increase from the previous values and the last 4 weeks of training produced values 8.7% more than the previous readings reaching to 2.13 ± 0.43. The control group value by the beginning of the study was 1.83 ± 0.44. There was 1% increase by 4th week and further 1% increase by 8th week of study period among the control group. By the end of 12 weeks, control group reached a value of 1.88 ± 0.44 an improvement of 1.7% from 8th week recording and a 2.7% increase from pre training values, whereas the total improvement shown by pranayam group was 26%. The significance calculation showed a significant rise in values ($P = 0.05$) among the control group

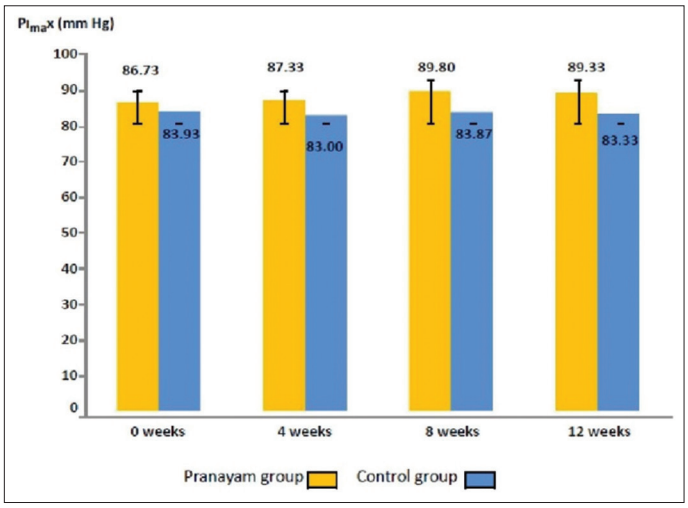

Figure 3: Maximum inspiratory pressure expressed as mean± standard error mean

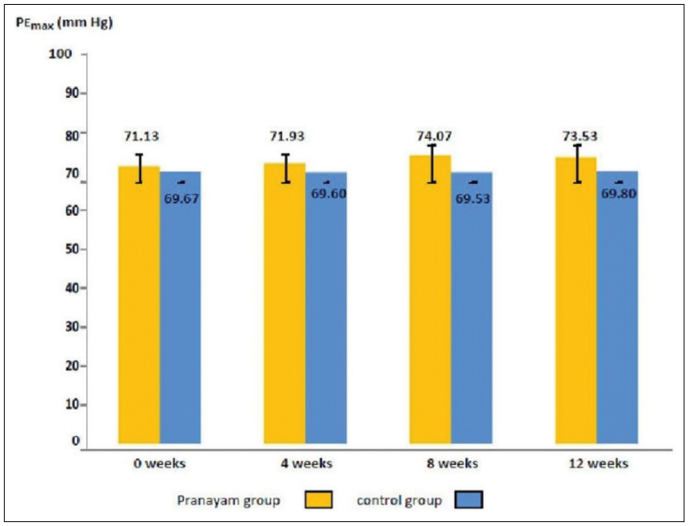

Figure 4: Maximum expiratory pressure expressed as mean± standard error mean

and a very high significance ($P < 0.0001$) among pranayam group [Tables 2-4 and Figure 2].

Maximum Inspiratory Pressure

The pranayam group showed a highly significant improvement between pre and post training recordings and the control group did not show any. To begin with, the values of maximum inspiratory pressure in pranayam group and control group were 86.73 ± 18.63 and 83.93 ± 11.58, respectively. By the end of 4 weeks, the pranayam group showed an improvement of less than 1 %, whereas in the control group, there was a decrease in value by less than 1%. After 8 weeks, the pranayam group improved by 2.8% reaching a value of 89.90 ± 19.08. The 12th week recording showed a decrease in values for both the groups by 0.5%. The end of study comparison between pre- and post-training values of control group showed a decrease in value by 0.7%.

Table 3: Significance testing: pre, mid, and post-training recordings of control group

Parameters	Groups compared	*P*-value	Difference of mean (group 1 minus group 2)	95% confidence limit of the difference
	0 week	0.33	0.005	<0.00–0.01
	4 weeks			
FVC (l)	0 week	0.34	0.034	0.037–0.104
	8 weeks			
	0 week	0.92	0.001	0.018–0.02
	12 week			
	0 week	0.12	0.024	<0.00–0.05
	4 weeks			
FEV_1 (l)	0 week	0.05	0.036	<0.00–0.07
	8 weeks			
	0 week	0.01	0.053	0.01–0.09
	12 week			
	0 week	0.04	0.930	0.04–1.83
	4 weeks			
P^Imax (mm Hg)	0 week	0.89	0.070	0.88–1.02
	8 weeks			
	0 week	0.26	0.600	0.46–1.66
	12 weeks			
	0 week	0.77	0.070	0.39–0.53
P^Emax (mm Hg)	4 weeks			
	0 week	0.87	0.130	1.49–1.76
	8 weeks			
	0 week	0.87	0.130	1.52–1.79
	12 week			
	0 week	0.87	0.070	0.79–0.92
40 mm Hg endurance (s)	4 weeks			
	0 week	0.36	0.430	0.52–1.38
	8 weeks			
	0 week,	0.57	0.270	0.68–1.21
	12 weeks			

Inspiratory and expiratory pressures, l: Liter, mm Hg: Millimeters of mercury. S: Seconds

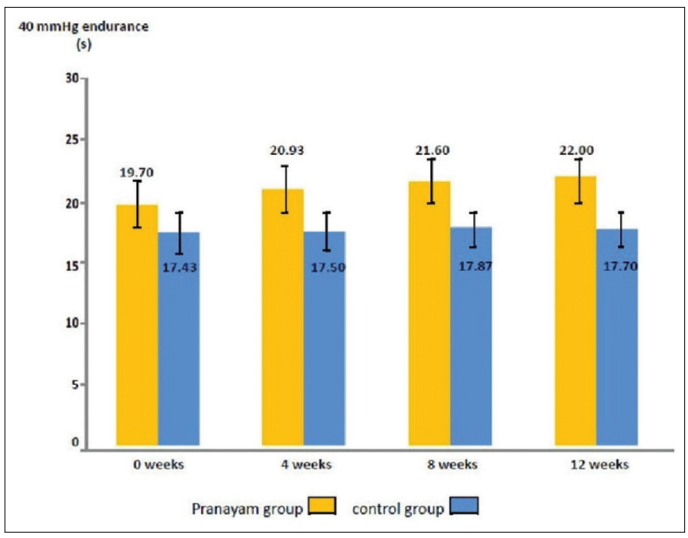

Figure 5: 40 mm Hg Endurance test expressed as mean± standard error mean

The pranayam group showed an overall 3% increase in value from the beginning of study to the end of study. Significance testing showed a very highly significant change ($P < 0.0001$) between pre and mid, post training values within the pranayam group. The control group showed no significance ($P = 0.89$, $P = 0.26$) among its pre and, mid, post-test values [Tables 2-4 and Figure 3].

Maximum Expiratory Pressure

Pranayam group showed a highly significant improvement between pre and post training and the control group did not The mean PE_{max} of pranayam group was 71.13 ± 16.74. The control group was having 69.67 ± 8.36 as their mean. After 4 weeks, the pranayam group showed an increase by 1.1%. The control group showed decrease in their value by 0.5%. The 8th week recording of pranayam group showed a further increase by 3% from the 4th week value whereas the control

Table 4: Significance testing: pranayam and control group

Parameters	Week	Control group			Pranayam group			P value
		Mean	SD	SEM	Mean	SD	SEM	
FVC (l)	0	2.88	0.56	0.10	2.66	0.57	0.10	0.13
	4	2.89	0.56	0.10	2.67	0.59	0.11	0.15
	8	2.92	0.56	0.10	2.78	0.55	0.10	0.35
	12	2.88	0.56	0.10	2.99	0.52	0.09	0.45
FEV_1 (l)	0	1.83	0.44	0.08	1.69	0.42	0.08	0.23
	4	1.85	0.43	0.08	1.87	0.46	0.08	0.58
	8	1.86	0.44	0.08	1.96	0.45	0.08	0.38
	12	1.88	0.44	0.08	2.13	0.43	0.08	0.02
P^Imax (mm Hg)	0	83.93	11.58	2.12	86.73	18.63	3.40	0.49
	4	83.00	11.82	2.16	87.33	18.95	3.46	0.29
	8	83.87	11.46	2.09	89.80	19.08	3.48	0.15
	12	83.33	11.23	2.05	89.33	18.93	3.46	0.14
P^Emax (mm Hg)	0	69.67	8.36	1.53	71.13	16.74	3.06	0.67
	4	69.60	7.97	1.46	71.93	16.29	2.97	0.48
	8	69.53	8.97	1.64	74.07	16.16	2.95	0.18
	12	69.80	8.89	1.62	73.53	16.36	2.99	0.28
40 mm Hg endurance (s)	0	17.43	9.75	1.78	19.70	10.42	1.90	0.39
	4	17.50	8.47	1.55	20.93	10.39	1.90	0.16
	8	17.87	8.19	1.49	21.60	9.98	1.82	0.11
	12	17.70	8.20	1.50	22.00	10.38	1.89	0.08

FVC: Forced vital capacity, FEV_1: Forced Expiratory Volume in 1st second. PI_{max}, PE_{max}: Maximum. Inspiratory and expiratory pressures,.
l: liter, mmHg: millimeters of mercury. S: seconds. SD: standard deviation, SEM: Standard error mean

group showed a further decrease by 0.1% from their 4th week value. The 12th week recording for pranayam group was 73.53 ± 16.36 which was a 3.3% increase when compared with pre training value and a 0.7% decrease when compared with the 8th week value. The control group showed a 0.3% increase in their 12th week value with a mean of 69.80 ± 8.89. It was a 0.1% increase when compared with pre training values. The change within pranayam group from pre training to 4th week of training was significant ($P = 0.02$) and from pre-training to end of training was highly significant ($P < 0.0001$). There was no significant change among the values of control group at different phases of study period [Tables 2-4 and Figure 4].

40 mm Hg Endurance

A steady significant improvement was seen in the pranayam group over the duration of training whereas there was not so in control group. The baseline pre-training recording was 19.70 ± 10.42 for the pranayam group and 17.43 ± 9.45 for the control group, respectively. The pranayam group showed a 6.2% improvement with 4 weeks of training whereas the control group showed a 0.4 % increase in values. After another 4 weeks, the pranayam group improved by another 3.2% whereas the control group showed a improvement of 2%. When the study period is over, the pranayam group has improved by 1.8%, mean being 22.00 ± 10.38 from its previous values whereas the control group showed a decrease by 0.9% reaching a value of 17.70 ± 8.20. The values within the pranayam group were highly significant while comparing pre training with post training values ($P < 0.0001$) whereas in case of control groups there was no significance shown between the values ($P = 0.57$) [Tables 2-4 and Figure 5].

DISCUSSION

There was a highly significant rise in FVC, FEV_1, PI_{max}, PE_{max}, 40 mm Hg endurance from baseline values to post-training values in the study group who practiced savitri pranayam. There was no significant change in the above mentioned parameters in the control group over the time duration of the study. On comparing the post-training final results of all the parameters between study group and control group, the difference was found being statistically significant.

Thus comparing with few other studies, the report of some authors like Godoy *et al.* and Ahmed *et al.*, this study also finds no statistical significance in FVC and FEV_1 when the study group is compared with control group.[13,17] This study is in agreement with literatures [8-12] that reports significant improvement in FVC and FEV_1 in subjects practicing either alone or in combination with asan and in disagreement with studies[15,18] that reported a significant change when the study group is compared with control goup; where in the control

groups were prevented from doing any other forms of yoga, aerobics, or any other exercises. Answering to the research question of this present study, yes, savitri pranayam practice alone does improve FVC and FEV_1. Addition of asan could produce a better increase in dynamic lung functions. It is in agreement with the research publication by Central Council for Yoga and naturopathy.[16]

Study by Makwana *et al.* and Joshi *et al.* postulated various hypotheses that could explain the improvement in lung function.[8,9] Conversion of autonomic tone from sympathetic dominance to parasympathetic dominance in yoga practice may produce a decrease in the bronchoconstrictor effect of sympathetic system. This could reduce airway resistance, thus airways get opened up and could able to transmit more air with an increased force leading to increase in FVC and FEV_1. By this mechanism, thoracic cage can contract and relax better and quicker producing an increase in FVC and FEV_1. While Joshi *et al.* proposed another theory in addition to the previous one. In Pranayam, breathing fully to total lung capacity stimulates surfactants and prostaglandins release from bronchial epithelium that increases the lung compliance and reduces bronchial smooth muscle tone. This might decrease airway resistance and increase FVC and FEV_1.[9] In spite of these many attempts, still the exact mechanism and the biology behind the beneficial effects of Yoga on dynamic lung functions are unclear. It is evident that pranayam as an exercise will improve the muscle strength proportionately with the duration of practice. The molecular basis of the improvement was explained by Bhasin *et al.*[43] They have reported that with yoga practice, there occurred an upregulation of genes encoding enzymes of mitochondrial energy pathway like mitochondrial ATPase, thereby improves mitochondrial energy production and also utilization. There was an additional mention which directly explains the results of this study. Certain genes like CACNA1C, a calcium channel gene that mediates calcium entry in to cells. This action is responsible for many functions like gene expression, neurotransmitter release, muscle contraction and so on. Thus with pranayam practice, there is a evidence supported definite improvement in respiratory muscle strength. However, the psychological and spiritual influence on these improvements was beyond the scope of explanation. The results of this study are in agreement with a research article by CCYRN which says practicing asan and pranayam will produce a better improvement than practicing either one of them alone. Desai *et al.*[39,40] in their study reported a significant increase in maximum expiratory pressure and 40 mm Hg endurance with practice of savitri pranayam alone. The results obtained from this study make this study in disagreement with the previous reference. With the results of this study it becomes evident that savitri pranayam practice improves respiratory muscle strength and endurance, not to the level of improvement by combined practice of asan and pranayam.

Limitations of the Study

Answering to the research question of this present study, yes, savitri pranayam practice alone does improve FVC and FEV_1. But to get a better improvement, savitri pranayam alone is not sufficient. Addition of asan could produce a better increase in dynamic lung functions. It has also shown that though there appears to be an improvement in parameters among control group, it was purely due to chance as there does not exists a parallel relationship among the functions that gets improved. The significance of the present study lies in recognizing the pattern of change in FVC and FEV_1. Thus, this study makes it clear that the improvement in yoga is not generalized. It is highly individualized. Some person may need a longer time of practice to show benefit while gets improved within weeks. Thus, while applying Yoga as therapy; the regimen cannot be made common for all the patients. It has to be made individualized, customized for each patient.

CONCLUSION

This present study has thrown light on the pattern of change and improvement found in the yoga practicing subjects. Respiratory efficiency which includes dynamic lung functions (FVC, FEV_1) and static respiratory muscle strength (PI_{max}, PE_{max}, and 40 mm Hg endurance) can be improved by 12 week practice of savitri pranayam. The improvement in respiratory efficiency in this study, though highly significant is less in magnitude. Combined practice of asan and pranayam may produce a better improvement than practicing savitri pranayam alone. The pattern of improvement in respiratory variables is not uniform. Individuals respond differently to yoga. Some showed a rapid improvement followed by a plateau, whereas for others the improvement graph appeared slow and steady. Yoga training has to be individualized and yoga therapy should be customized according to individual patient's receptivity and nature. Savitri pranayam would be an effective tool in promotion of respiratory efficiency. This can very well be advised for patients of chronic respiratory disorders as well respiratory muscular disorders. More studies are needed to compare the effect of practicing pranayam alone and a combination of yoga and pranayam on respiratory efficiency.

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