Effect of yoga training and detraining on respiratory muscle strength in pre-pubertal children: A randomized trial

Crystal Dalia D’Souza, Sandhya T Avadhany
Department of Physiology, St. John’s Medical College Hospital, Bangalore, India

Address for correspondence: Mrs. Crystal Dalia D’souza, St John’s Medical College, Sarjapura Road, John Nagar, Koramangala, Bangalore - 560 034, Karanataka, India.
E-mail: crys2crystal@gmail.com

ABSTRACT

Objective: To evaluate the effect of yoga on forced vital capacity (FVC), forced expiratory volume in 1st second (FEV1), peak expiratory flow rate (PEFR), FEV1/FVC ratio, and pulmonary pressures [maximum inspiratory pressure (MIP), maximum expiratory pressure (MEP)] at the end of 3 months yoga training and the detraining effect on the above parameters in 7-9-years-old school going children.

Materials and Methods: A total of 100 participants were recruited from a school in Bangalore. After baseline assessments, the participants were randomly allocated to either yoga or physical activity group. Intervention was given for 3 months, and measures of pulmonary function and pulmonary pressures were determined immediately post-intervention and at 3-months follow-up.

Results: Although significant increase was observed in FVC, FEV1, PEFR, FEV1/FVC, MIP, and MEP at post-intervention, there were no significant differences between the two study groups after adjusting for height and age post training. However, MIP increased significantly in both the groups post-intervention, but the yoga group performed significantly higher than the PE group. The effects of training did not fade off even after 3 months of detraining. In fact, the FVC and FEV1 continued to increase significantly. A trend of decrease was observed in PEFR, MIP, and MEP. However, the values did not regress to the baseline value.

Conclusions: This study suggests that practice of yoga for a short duration (3 months) of time can significantly improve respiratory muscle strength in pediatric population.

Key words: Children; pulmonary pressure; respiratory function test; yoga.

INTRODUCTION

Yoga is believed to exhibit a powerful and profound effect on the respiratory system, perhaps more than that on any other organ in the body. Studies have shown that yoga has a positive effect on the pulmonary function tests. Pranayama, the fourth limb of Ashtanga yoga, is an important component of yoga training. In yoga tradition, pranayama means “control over breathing”. Where breath is the life source of an individual. Pranayama can assume rather complex forms of breathing, but the essence of practice is slow and fast breathing.

Madannmohan et al., studied the effect of slow and fast pranayama on respiratory pressures and endurance, which is a good index of respiratory muscle strength. This study confirmed that slow and fast pranayama are effective in strengthening the respiratory muscles.

The effects of yoga training on pulmonary function have been previously studied. These studies have mainly investigated the effects of yoga training on vital capacity and peak expiratory flow rate (PEFR) in comparison with a sedentary control group. Ross in his review article compared the health benefits of yoga and exercise (walking, stationary cycling, dancing, and gentle aerobic exercises) and concluded that yoga is as effective or superior to exercise in a healthy and diseased population.
Researchers have observed that the significant change in the lung functions can be brought about even with short-term yoga training.\[10,11\] Only 3 weeks of yoga program conducted for 28 visually impaired 11-17-year-old children showed reduction in the breath rates significantly.\[12\]

We planned to undertake the present study with the objectives to determine whether 3 months yoga training produces improvements in pulmonary function test and respiratory pressures in comparison with a active control group (performing physical exercises (PE) as per the school curriculum) in the pediatric group aged 7-9 years of low socioeconomic population, where there is limited randomized trial study of an effect of physical activity interventions.\[13\] The participants of the study were comparable in their physical activity as they belonged to the same school and followed the same curriculum.

The present study aimed at assessing the following:

- Pulmonary function test-FVC, FEV1, PEFR, FEV1/FVC before and after 3 months of yoga intervention
- Respiratory muscle strength before and after 3 months of yoga intervention
- Intergroup comparison at post-intervention in all the parameters
- Detraining effect in all the parameters at the end of 3 months detraining.

MATERIALS AND METHODS

Design

This study was a randomized control trial. Eligible students were randomly assigned to one of the two study groups. Treatment group assignments were made for the entire cohort at the same time, which allowed subjects to begin physical exercise (PE) versus yoga simultaneously. Stratified randomization was done by gender using RALLOCC software. Before randomization, baseline data for demographic variables and pulmonary functions for all children were collected.

Interventions

Interventions were given by trained yoga qualified teachers and physical education-trained teachers.

The subjects were randomly assigned to either a yoga or a PE group. Both the interventions were given for 45 min simultaneously in the afternoon, 2 hours post lunch at two different locations on the school premises. The sequence of the yogic techniques practiced by the yoga group and the exercises performed by the PE group are summarized in Tables 1 and 2 respectively. The interventions were given for 3 months daily, except on Saturdays, Sundays and scheduled school holidays. In the yoga group, children were taught various yoga practices in a phased manner spread over 3 months. In the first month, the children were mainly taught stretching yogic exercises, which were easy to learn, and, in the second month, Surya namaskara was introduced, followed by various Asanas, Pranayama, and Dharana (concentration). The duration and components of yoga techniques were selected based on recommendations for 7-9 year-old school going children.\[14\] The PE group

Table 1: The yogic techniques, their sequence, and the number of repetitions practiced by the yoga group

| Yoga Techniques | Duration | Repetitions |
|----------------|----------|-------------|
| Pranayama      | Prayer 5 min | 3 repetitions |
| Mukh-bhastrika |          | 5 repetitions |
| Bhramari pranayama |          | 5 repetitions |
| Nadi shuddhi pranayama |          | 3 repetitions |
| Ujjayi (breathing with a hissing sound) |          | 3 repetitions |
| Kapalabhati    |          | 5 repetitions |
| Ushtrasana     |          | 5 repetitions |
| Tratakay-eye   |          | 3 repetitions |

Table 2: The physical exercises, their sequence, and the number of repetitions practiced by the PE group

| Physical Exercises                  | Repetitions |
|-------------------------------------|-------------|
| Standing exercises                 | 5 repetitions |
| Neck rotation                       |            |
| Hand rotation (back to front, circular movements, flex and extend) |            |
| Hip rotation                        |            |
| Knee rotation                       |            |
| Feet rotation                       |            |
| Leg exercises (back and forward, leg rotation) |            |
| Leg to hand exercise                |            |
| Body twist with hands straight      |            |
| Leg to hand cross touch             |            |
| Forward and backward bending        |            |
| Leg stretch                         |            |
| Sitting exercises                   |            |
| Bending with hands on the head      |            |
| Sideway bending                     |            |
| Slow jump                           |            |
| Fast high jump                      |            |
| March fast                          |            |
| Static fast run                     |            |

PE = Physical exercises
did both passive stretching and aerobic exercises such as running, and the attendance in both the interventions was >90% across both groups. We would like to mention that the physical activity levels of both the groups were identical.

At the school, color-coded (white button–yoga and black button–PE) buttons stitched on to school uniforms identified the assignment of the participating children to avoid the contamination of the study subjects.

To assess the sustained effect of intervention, the intervention was suspended for 3 months, where none in the groups followed any structured activity nor did they attend any structured intervention; they played for fun or for keeping themselves busy or going out for vacations.

Training was stopped at the end of 3 months of training, just before their final exams commenced, after which the children went out for their summer vacations. Assessments were done immediately after children rejoined the school after vacations.

Participants

The study included 100 7-9-year-old clinically healthy (as assessed by medical professionals) school going children hailing from a socioeconomically disadvantaged background. All participants were recruited from a single school in Urban Bangalore, India. From a total of 200 participants who were a part of a larger interventional study on the effects of yoga practices on cognitive performance, 100 participants with even screening number were assessed for lung functions and pulmonary pressures. The school also provided written permission to conduct the study on its children on the school premises. The study was approved by the Institutional Ethical Review Board of St. John's National Academy of Health Sciences. Parents of all children aged 7-9 years were invited for a meeting, and the study procedures were explained. Consent form, drafted as per the policy guidelines of the Indian Council of Medical Research, was read out to parents because majority of them were illiterate, and their responses were entered by trained research assistants. The targeted enrollment was 25 subjects rounded off to 50 in each arm with an estimated 90% and 1% level of significance. The sample size estimation \((N = 100)\) was based on forced vital capacity (FVC) changes.\(^\text{[14]}\)

Participants underwent a physical examination and apparently healthy participants with no history of chronic diseases, physical or mental handicap, and not severely undernourished \((\pm 3\ SD\ for\ weight\ for\ age\ and\ \pm 3\ SD\ height\ for\ age\ z\ scores\ of\ the\ National\ Center\ for\ Health\ statistics/WHO\ standards)\(^\text{[16]}\)\ were invited to participate in the study.

Assessments

Sociodemographic information was obtained from school record. There were no significant differences in any of the sociodemographic characteristics between the groups. Majority of parents were employed as daily wage earners. The mean total family income was 4964 ± 1471 Indian rupees (equivalent to US $100). Approximately one-third of the mothers were uneducated.

Anthropometry

At baseline, a trained research assistant recorded anthropometric measurements in duplicate. The body weight was recorded with subjects wearing their school uniform to the nearest 0.1 kg using a digital weighing scale (Salter kent England), while height was recorded to the nearest 0.1 cm using a locally made and validated stadiometer (Biorad, India).

Pulmonary function test

The assessment of pulmonary function test and pulmonary pressure was done in a quiet room on the school premises. Assessments were done in the morning between 09.30 AM to 12:00 PM. Repeat assessments at the end of the intervention and at 3-months follow-up were done around the same time in the morning. Participants were called in batches and were explained and demonstrated the correct technique to the subjects how to perform the test.\(^\text{[17]}\) Disposable mouth piece given to children and were asked to practice to blow into the mouth piece. An antiseptic procedure was followed by the children to insert the mouth piece. Care was taken to teach the participants on closing the lips around the mouth piece and on placing of the nose-clip during the procedure.

Participants were asked to perform the test by blowing into the mouth piece connected to a Laptop-based Micro-Quark PC (computer) based Spirometer (COSMED–Italian Company) used for pulmonary function tests. The system was calibrated everyday with a 600-ml syringe. In the event, the recordings had to be aborted, which were interrupted due to coughing during the measurement, inadequate effort or lack of understanding about the procedure, and the measurements were repeated.

Each subject was provided 15-20 trials, of which 3 best trials were selected and, among the 3 highest readings, the best (highest) was selected as the representative of that test.

Pulmonary pressures

Maximum inspiratory pressure (MIP) was obtained by asking the participant to stand and to breathe out fully and then inhale maximally from the mouthpiece connected to
Digital peak respiratory pressure (DPRP) monitor (pressure transducer device developed at St John’s biomedical department). Maximum expiratory pressure (MEP) was determined by asking the participant to take in a full breath and blow forcefully into the mouthpiece of the DPRP monitor. 3 measures were performed for both MEP and MEP and the maximum pressure that was maintained for at least 3 seconds was noted and used as the representative value.

Statistical analysis

All analyses were performed using SPSS version 18.0 (SPSS Inc., IL, Chicago, USA). Data were expressed as mean ± SD for both the groups. Intergroup comparisons at baseline were done using independent t-test and within group comparisons by paired t-test.

Our study consists of three time points (baseline, post-intervention, and follow-up (this period had no intervention). Paired t-test was used to assess the effect of intervention in both the study groups separately. Intergroup comparisons were done using ANCOVA, immediately after training, controlling for covariates (baseline values, age and height). Similarly, paired t-test was used to assess the sustained effect of the intervention at follow-up from post-intervention in both the groups. Probability <5% was considered as statistically significant.

RESULTS

Of the 100 participants enrolled in the study, 91 completed assessments at all the 3 time points; both genders were almost equally distributed (boys = 46, girls = 45). The mean age of the subjects was 7.9 ± 0.9 years. The mean height, weight, and body mass index (BMI) of the sample were 1.21 ± 0.06 m, 20.5 ± 3.1 kg, and 13.8 ± 1.1, respectively [Table 3]. There were no significant differences in any of the baseline pulmonary function tests and pulmonary pressures between the two groups.

There were no significant differences between the two study groups in FVC, FEV1, PEFR, FEV1/FVC, and MEP at post-intervention after controlling for height and age at baseline measure [Table 4]. However, MIP increased significantly in both the groups, but yoga group performed significantly better than the PE group.

The sustained effect of intervention was assessed for both the study groups 3 months after stopping the intervention. This study observed significant increased in FVC and FEV1 in both the groups even after the cessation of the intervention. Although a reduction was observed in PEFR, MIP, and MEP, the values did not regress to the baseline values. In our study, the males and females did not have significant difference in their pulmonary measures.

DISCUSSION

The effect of aerobic training on the lung function is well known. Yoga, an ancient Indian exercise, has gained much accolades in the field of health and fitness. Since most studies are conducted on the adolescent and adult population, the effect of yoga in children is unknown. Our interest lies in the less explored age group of middle childhood (7-9 years) and also to quantify the sustained effect of yoga.
Respiratory function depends on several factors, including chest expansion, lung dimensions, respiratory muscle strength, airway resistance and alveolar surface area. Pranayama, one of the limbs of Asthanga yoga, is known to have profound effect on the pulmonary function than any other part of the human system. Pranayama consists of different kinds of breathing patterns such as alternate nostril breathing, Mukha bhashrika pranayama, and Bhrahmari pranayama. Pranayama is essentially a breathing exercise against resistance, and its positive effects on lung functions is well documented.[11,3,21]

The FVC is an index of the volume of the respiratory apparatus, whereas the FEV1 is a reflection of the expiratory flow resistive properties. PEFR is the rate of air flow during expiration, measured in litres per minute. Yogasanas and pranayama exercises are performed by consciously altering the respiration. Studies have shown that breathing exercises open the small airways in the lungs and reduces the airway resistance.[11]

Studies have revealed that even short-term (2 weeks) yoga training is sufficient to improve the lung function.[10] In the present study, although significant increase was observed in FVC, FEV1, and PEFR in 7-9-year-old children in both the groups at the end of 3 months training, there was no significant difference between the yoga and the PE group post-intervention, expect for MIP.

In a study conducted on adolescents, 84 subjects were randomly allocated to 4 groups: Yoga and pranayama group, fast Suryanamaskara group, slow Suryanamaskara group, and sedentary control group, and each group was trained for 6 months in their respective regime. Significant improvement was observed in FVC, FEV1, and PEFR in 7-9-year-old children in both groups. In all of the above mentioned studies, the control group was sedentary.[9,24,21] except for[6] where the yoga group was compared with athletes apart from the sedentary group. All three groups significantly differed in FEV1 and PEFR, and yogis performed the highest in these parameters. The present study is inconsistent with the above-mentioned studies and suggests that yoga is at par with PE in improving the pulmonary functions.

In another study, Godoy et al., conducted a comparative study on the effect of aerobic exercise and yoga on FVC, FEV1, and MIP. Adults between the age of 18-40 years were recruited and trained in aerobic exercise and yoga separately for 1-2 times a week for 3 months. No significant improvement was observed in FVC and FEV1. In a cross-sectional study, pulmonary function was compared among professional yogis, athletes, and sedentary people. Yogis—subjects who practiced yoga for at least 1 h everyday for 6 months. Athletes—marathon runners running at least 2 km everyday for 6 months, and sedentary subjects—who did not participate in physical activity at least 2-3 times week for 6 months. FVC and FEV1 values were similar in both yogis and athletes compared to the sedentary group and the highest PEFR was observed in yogis as compared to the other two groups. The author presumes that the improvement in the PEFR is due to the toned respiratory muscle. The forceful inhalation until total lung capacity (TLC) and forceful expiration until residual volume, both performed through the nostrils, offering resistance during the maneuvers, strengthens the respiratory muscles. The effect of resistance exercise on skeletal muscles is well known.[8]

Although the improvement in MIP was statistically insignificant, the absolute delta value of MIP was more pronounced in the yoga group than in the aerobic exercise group (yoga = 18.6% versus aerobic = 2.8% in males; yoga = 20.8% versus aerobic = 4.1% in females).[21] The present study observed a significant increase in MIP than in the PE group.

Maximum respiratory pressures are simple, non-invasive, and accurate indices of respiratory muscle strength, which is important for the maintenance of the respiratory mechanics[21] and can be easily measured and evaluated, as any change in the values are evident before any alterations in other commonly measured pulmonary function tests.[10] Thus, evaluation of pulmonary pressures becomes important physiologically and clinically. Respiratory pressures obtained in patients or healthy subjects are the combined result of the tension (force) generated by the muscle, which is dependent on the lung volume at which the maneuver is obtained and the chest wall and lung mechanics;[24] thus, this parameter should not be considered to be a measure of respiratory muscle strength only.

Studies conducted by Madanmohan et al., suggests that 6 months of yoga training has favourable effect on the respiratory muscle strength in adolescent subject.[9,11]
Our findings are consistent with the above study in that 3 months of yoga can improve the respiratory muscle strength in pre-pubertal children. Improved muscle strength helps increasing the lung dimension and chest expansion,[21] improving the breathing capacity.[4]

Studies have shown that the effect of training significantly decreases by 4 weeks of detraining and that the rate of detraining is independent of the duration of the training, although the improvement observed does not regress to the baseline values.[25] Our study, which is one of its kind, observed the detraining effect of yoga and PE after 3 months of the cessation of the training. In contrast to the previous studies, our present study presents a different picture. The effects of training did not fade off even after 3 months of detraining. In fact, the FVC and FEV1 continued to increase significantly (P <0.005) in both the groups. After 3 months of detraining, a trend of decrease was observed in PEFR, MIP, and MEP. However, the improvement observed did not regress to the baseline value, which is in accordance with the results reported in other studies.[25,26] Literature suggests that physical inactivity in humans can cause decrease in muscle mass within 4 weeks.[25] However, this is not applicable to respiratory muscles as they cannot remain inactive. In addition, middle childhood is an active phase of life, where children tend to be independent and physically active, which may tend to promote respiratory muscle strength. This could explain the continued beneficial effect on the pulmonary function test after the cessation of the intervention.

Metabolic investigations in yoga practitioners suggest that performing yoga is equivalent to physical exercise of low aerobic intensity.[27,28] In light of our observations, we can conclude that at least 3 months of yoga training is as effective as the PE to bring changes in the pulmonary functions and pulmonary pressures in the pediatric group and the beneficial effect continues even after the cessation of training.

**Strength and limitations of the study**

The study was conducted on a middle childhood group (7-9 years), which is sparsely explored. Although the immediate effect of 3 months of yoga training is known, the detraining effect of yoga has been mostly unknown. Thus, our study contributed to the pool of knowledge, the minimum duration of yoga training required to show a significant improvement in the respiratory muscle strength, and respiratory functions as well as the detraining effect of yoga. Further validation is required in this arena with a true control group, which was lacking in our study.

**Contributors**

STA and CD conceived and designed the study and revised the manuscript for important intellectual content. CD collected, analyzed the data, and drafted the paper. The final manuscript was approved by all authors.

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