A comparative study of the effects of yoga and swimming on pulmonary functions in sedentary subjects

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ABSTRACT

Context: The modality of exercise that is most beneficial and easy to perform has become a topic of research. Yogic exercises are being widely studied; however, postulated benefits of yogic exercises over other exercises must be scientifically explored. Prospective randomized comparative studies involving yoga and other endurance exercises are conspicuous by their absence.

Aim: This study was, therefore, designed to assess and compare the effects of yogic training and swimming on pulmonary functions in normal healthy young volunteers.

Materials and Methods: 100 volunteers were inducted into the study and randomly divided into two groups: One group underwent 12 weeks training for yogic exercises and other for swimming. The training and data acquisition was done in small cohorts of 10 subjects each. The subjects were assessed by studying their anthropometric parameters and pulmonary function parameters (FVC, FEV1/FVC ratio, PEF, FEF25-75%, FEF 0.2-1.2 l and MVV) both before and after training.

Results: All parameters showed statistically significant improvements after both yoga and swimming. Comparison of these improvements for different parameters statistically analyzed by unpaired t test or Mann Whitney U test depicted a statistically better improvement in FVC, FEF25-75% and MVV with swimming as compared to yogic exercises.

Conclusions: The output of this study gives slight edge to swimming as a preferred modality of exercise though either yoga or swimming can be advocated as an exercise prescription as both the modalities cause significant improvement of respiratory health. However, other factors like ability of any exercise regime to keep continued motivation and interest of the trainees must be taken into account for exercise prescription.

Key words: Lung function; swimming; yoga.

INTRODUCTION

Exercises in different forms, if performed regularly, have a beneficial effect on the various systems of the body. The modality of exercise that is most beneficial and economic for masses has now become the topic of research.[9] The conventional exercises (endurance exercises like walking, jogging, running, swimming, cycling, etc), which give stress on cardiovascular and respiratory systems and test the responses of these systems, are very popular. On the other hand, ancient yogic exercises which have been claimed to benefit human body on multiple fronts are also getting popularity all over the world.[21]

In the present study, the focus is on the effect of yoga (asanas and pranayama) and swimming on the lungs as pulmonary function has been identified as a long-term predictor for overall survival rates as well as a tool in general health assessment.[10] Both yoga and swimming have been reported to improve the pulmonary functions to a great extent as both the modalities involve physical activity as well as breathing exercise.[4,10] Efficacy of different modules must be compared as practicing any one exercise module may not be feasible by different people. The aim of the present study was, therefore, to assess the beneficial effects of these exercises and to compare the improvements in the lung functions by these two modalities of exercises. Very few cross-sectional comparative studies between yoga and other endurance exercises have been published[14] and there are no reports of prospective comparative
studies. Therefore with an aim to study and compare the improvement of lung functions by yoga and swimming, well-planned, randomized comparative prospective study was undertaken.

MATERIALS AND METHODS

Study set up
The study was conducted in Department of Physiology in Post Graduate Research Laboratory in co-ordination with Yoga Centre and Municipal Swimming Pool.

Study groups
Healthy males and females with normal physical examination and with sedentary occupations between 18 and 40 years of age were included in the study. The volunteers from the socio-cultural gathering of general populations were motivated to participate in the study by explaining plan of the study to them. The recruitment was purely on the voluntary basis. After screening and fulfilments of inclusion and exclusion criteria, volunteers were recruited in the study. Yoga group consisted of 41 subjects (\(n=41\)) out of which 16 were males and 25 females. Swimmer group comprised of 40 subjects with 18 males and 22 females. Volunteers had not been engaged in yoga practice or swimming nor were they doing any physical exercise at least during 3 years preceding the study as assessed by enquiring in detail. Smokers, alcoholics, subjects who were in non-sedentary occupations, post operative patients and subjects suffering from any hernia, pregnant females, subjects with history of any cardiovascular disorder, subjects with history of any respiratory tract infection symptoms during previous 6 weeks and subjects suggestive of any active respiratory disorder were excluded by thorough history and clinical examination.

Study protocol
The screening of subjects was done and clearance of Institutional Ethics Committee was obtained. After selection of the subjects, they were explained about the detailed plan of work and aim of present research project. The volunteers were briefed about the study protocol, they were motivated for the training and for compliance needed till the end of the study and written informed consent was obtained from them.

One hundred volunteers were divided into cohorts of 10 subjects each and were randomly (block randomization) assigned to undergo either yogic training or swimming for a duration of 12 weeks. Before the actual training period, baseline parameters were recorded in a single day for one cohort. The subjects of that cohort were motivated for the exercise regimen they had to follow during the entire 12 weeks period. After 12 weeks exercise by all ten subjects in that cohort, all the parameters were again studied. After baseline parameters were recorded for one cohort and the training started for that cohort, the next cohort was subjected to same treatment.

Out of the 100 subjects, 9 from the yoga group and 10 from the swimmer group dropped out in due course of the study. As subjects who dropped out were non-compliant, per protocol analysis method was used to analyze the data. Thus, at the end of the study, data of 41 subjects from yoga group and 40 subjects from swimming group was analyzed (characteristics of the population shown in Table 1).

The yoga group subjects were instructed not to practice any yogic technique other than the prescribed ones and swimmer group was advised to refrain from other physical exercises during the study. We supervised the subjects early in the morning (5.00–6.00 a.m) during yoga classes and swimmers from 6.00–7.00 a.m. every day during the training period. Participants of both the groups were allowed to do their routine activities during the study period.

The subjects were taught yogasanas and pranayamas and they practised the same, 6 days/week for 60 min daily, for a total duration of 12 weeks. iyengar yoga techniques were followed by the yoga trainers. Different yogasanas (yogic postures) viz. tadasana, konasana, utkatasana, sarvangasana, halasana, chakrasana, padmasana, dhanurasana, makarasana, pashchimottanasana, vajrasana, virasana and shivasana were practiced for 40 min and pranayamic breathing exercises with purak, rechak and kumbhak, anulom-vilom, bhastrika, bhramari pranayam and kapalbhati were practised for 20 min. Swimming was practiced 6 days/week for 60 min daily. Swimming comprised freestyle in first 6 weeks (including training in first 2-3 weeks) and freestyle and breast stroke in last 6 weeks including 10 min of floating on the water. For novice swimmers, continuous swimming for 60 min is difficult; therefore, intermittent floating with deep slow breathing was introduced. It also helped to keep similarity with yoga group who practiced shivasana for 10 min (Lying still and relaxed with slow deep breathing). An important limitation of the methodology was inability to compare the intensities of two modalities of exercise during

| Table 1: Composition of both groups of intervention namely yoga and swimming |
|----------------|----------------|----------------|----------------|
|                | Yoga \(n=41\) (%) | Swimming \(n=40\) (%) | Statistical significance |
| Age (years)    | 28.439 ± 1.41   | 27.7 ± 1.35     | t test, \(P=0.7067\) |
| Height (cm)    | 159.21 ± 1.50   | 159.4 ± 1.54    | t test, \(P=0.9335\) |
| Weight (kg)    | 55.12 ± 1.80    | 58.375 ± 1.76   | t test, \(P=0.2021\) |
| Males \(n\)    | 16 (39.0)       | 18 (45)         | Chi square test |
| Females \(n\)  | 25 (61.0)       | 22 (55)         | \(P>0.05\)        |
12 weeks duration. This inability was because of the fact that unlike endurance exercise, intensity of yogic asanas and pranayama is not directly related with exercise and post-exercise heart rates.

**Pulmonary function tests**

On the day of recordings, the subjects were familiarized with the laboratory environment and their height and weight were recorded. Pre training (at the start of study) and post training (after 12 weeks of training) lung function measurements were done in the morning about 2 h after a light breakfast by single investigator. On the day of recording (both pre and post training), yoga or swimming was not done. All the lung function parameters viz. forced vital capacity (FVC), forced expiratory volume at the end of first second to forced vital capacity ratio (FEV/FVC ratio), peak expiratory flow rate (PEFR), average forced expiratory flow rate during 0.2-1.2 L of FVC (FEF 0.2-1.2 L), average forced expiratory flow rate during 25-75% of FVC (FEF 25-75%), and maximal ventilatory volume (MVV) were recorded with computerized spirometer (Helios, Recorders and Medicare Systems Pvt. Ltd., Chandigarh, India). The recordings were done during 9.30 to 10.30 a.m. in sitting position by single investigator throughout the study for all the subjects. Recommendations and guidelines of American Thoracic Society for spirometry were followed to avoid measurement bias.[7] Percent predicted values were calculated using prediction equations for Indian population.[8]

**Statistical analysis**

All the data obtained was presented group-wise by descriptive statistics using mean, and standard error of mean. For differences in sex-wise composition of two study groups, Chi-squared test was used. For each parameter in both yoga and swimming groups before and after training period of 12 weeks, data distribution was tested for normality of distribution by Kolmogorov-Smirnov test.

The paired data before and after the exercise for both yoga and swimming groups was tested by Student’s paired ‘t’ test for parametric data with normal distribution and by Wilcoxon signed rank test for parametric data without normal distribution as well as for non-parametric data.

The change in different PFT parameters with exercise was studied by calculating delta i.e. difference in value before and after the exercise of both modalities. The percent change was also calculated for each parameter as percentage of change with respect to pre-exercise level of that parameter. Percentage increase or decrease in value of a parameter (delta) with yoga and swimming was also compared using unpaired ‘t’ test for parametric data with normal distribution and using Mann-Whitney U test for parametric data without normal distribution as well as for non-parametric data.

The statistical significance was considered at probability value less than 0.05.

The statistical calculations were done using Data Analysis tool of Microsoft Excel and Systat 12 (Systat Software, Inc. Chicago).

**RESULTS**

**Comparison between compositions of study groups**

Yoga and swimming groups showed statistical similarities for basic parameters like age, sex, height and weight [Table 1]. Even after similarities in the two groups, percentage improvements in lung function parameters after 12 weeks of training with respect to baseline level were considered for comparisons of efficacy of exercise modality. This reduced the effect of differences in the baseline parameters of two groups obtained because of sampling error.

**Effect of yoga and swimming on pulmonary function parameters**

The mean percentages of the predicted values of different parameters along with their standard error of mean before and after 12 weeks of either yogic training or swimming are depicted in Table 2. Comparison between improvements in each parameter by two modalities of exercises is depicted in Table 3.

**Table 2: Effects of yoga and swimming on pulmonary function tests**

| Parameter       | Exercise modality | Baseline (mean±SEM) | After 12 weeks (mean±SEM) | Wilcoxon signed rank test/paired ‘t’ test |
|-----------------|-------------------|---------------------|--------------------------|----------------------------------------|
| FVC % predicted | Yoga              | 78.55 ± 1.935       | 83.33 ± 1.982            | Z= -5.51****                           |
|                 | Swimming          | 78.89 ± 1.531       | 85.13 ± 1.524            | Z= -5.51****                           |
| PEFR % predicted| Yoga              | 90.33 ± 0.845       | 90.74 ± 0.704            | Z= -0.62                               |
|                 | Swimming          | 87.28 ± 1.183       | 88.63 ± 1.183            | Z= -2.97                               |
| FEF 25-75% %    | Yoga              | 77.05 ± 2.692       | 81.09 ± 2.699            | Z= -5.46****                           |
|                 | Swimming          | 79.82 ± 2.309       | 85.18 ± 2.304            | Z= -5.51****                           |
| MEF 0.2-1.2 L % | Yoga              | 70.14 ± 2.128       | 74.65 ± 2.020            | Z= -5.58****                           |
|                 | Swimming          | 73.67 ± 1.650       | 78.34 ± 1.594            | Z= -5.51****                           |
| MVV% predicted  | Yoga              | 75.57 ± 1.915       | 80.23 ± 1.841            | Z= -5.51****                           |
|                 | Swimming          | 77.87 ± 1.283       | 83.91 ± 1.421            | Z= -5.51****                           |

*P<0.01; ****P<0.0001
**Table 3: Comparison of improvement of pulmonary functions by yoga and swimming after 12 weeks of training**

| Parameter  | Improvement (change) in value | Percentage improvement (with respect to value before intervention) | Mann-Whitney U test |
|------------|-------------------------------|-------------------------------------------------------------|---------------------|
|            | Yogic exercise | Swimming | Yogic exercise | Swimming |                      |
| FVC % predicted | 4.786 | 6.258 | 6.26% | 8.063% | U=1030.5 | Z=−1.98 | P=0.047* |
| FEV1/FVC | 0.401 | 1.343 | 0.610% | 1.539% | U=922 | Z=−0.96 | P=0.337 |
| PEFR % predicted | 4.119 | 4.238 | 5.84% | 5.747% | U=793 | Z=−0.25 | P=0.802 |
| FEF 25-75% predicted | 4.041 | 5.355 | 5.485% | 6.962% | U=1067 | Z=−2.33 | P=0.019* |
| FEF 0.2-1.2 L % predicted | 4.510 | 4.675 | 6.784% | 6.548% | U=825 | Z=−0.04 | P=0.968 |
| MVV % predicted | 4.453 | 6.032 | 6.17% | 7.75% | U=1064.5 | Z=−2.3 | P=0.0214* |

*P<0.05

All PFT parameters except FEV1/FVC improved significantly (P<0.0001) in both yoga and swimming groups. FEV1/FVC improved only slightly (P>0.05) in yoga group while it showed a statistically significant increase in swimming group (P<0.01).

The percent change in FVC % predicted was more in swimmer group than in yoga group (P<0.05). Though the change in FEV1/FVC was apparently more in swimmer group, the difference was statistically non-significant (P>0.05) amongst the two groups. The improvement in PEFR % predicted was statistically similar in both groups (P>0.05). The improvement in FEF25-75% % predicted was more in swimmers group than in yoga group (P<0.01). Improvement in FEF 0.2-1.2 L % predicted was similar after yoga and swimming (P>0.05). The change in MVV % predicted was more in swimming group than in yoga group (P<0.01).

**DISCUSSION**

All PFT parameters were improved highly significantly by both yogic training and swimming except FEV1/FVC. Statistically better improvement was seen with swimming as compared to yoga for FVC% predicted, FEF25-75% % predicted and MVV % predicted (P<0.05).

Better pulmonary functions in subjects performing yoga as well as swimming are documented.[4,5,9‑15] However, most of the studies in yoga are cross-sectional and most of the previous studies have mentioned the absolute values of different parameters of PFT, which cannot be compared because of differences in age, weight and height of the study populations. In few follow up studies, the duration of training and the age group of study population are also different. Most of the randomized controlled trials in yoga are therapeutic in nature and therefore done in some or the other diseased condition.[2] Thus, the comparison of the values obtained in the present study with the previous studies is difficult. However, significant improvements in FVC, FEV1 and PEFR have been reported in young individuals previously by some authors.[9,14]

Pranayama, a yogic practice, has beneficial effects on respiratory efficiency. It includes various exercises which involve forceful inspiration to total lung capacity (TLC) and forceful exhalation to residual volume, and all maneuvers are done through nostrils, which offer resistance by means of decreased cross sectional area and turbulence. Breathing through one nostril in Anulom-vilom pranayama further increases the resistance. Higher peak expiratory flow rates and FEV1 could be explained due to better strengthening of respiratory muscles in yogis. By yoga practice respiratory apparatus is emptied and filled more completely and efficiently which is recorded in terms of increased forced vital capacity (FVC).[9,10] Yogic breathing creates more negative pressures in both abdominal and thoracic cavity during inspiration and moves the diaphragm more than its normal excursions and helps in efficient movement of diaphragm leading to improvement in vital capacity. Removal of undue tension from the skeletal muscles in yogasanas helps the thorax to relax better than before. All these practices seem to increase expiratory reserve volume (ERV) thereby increasing the vital capacity.[11]

Skeletal muscles control many crucial elements of aerobic conditioning including lung ventilation. Repeated inspirations to TLC and breath holdings as done during pranayama can lead to increase in the maximal shortening of the inspiratory muscles which has been shown to improve the lung function parameters.[12] Yogis have significantly higher peak expiratory flow rates presumably due to respiratory muscle conditioning.[4] Increase in MEP and MIP suggests that yoga training improves the strength of expiratory as well as inspiratory muscles. Yoga postures involve isometric contraction which is known to increase skeletal muscle strength.[13] In addition to improved respiratory muscle performance, increased FEV1 in yogic practitioners may be because of improved patency of airways.[14,15] Yoga with its calming effect on the mind can reduce and release emotional stresses, hereby withdrawing the broncho-constrictor effect.[9,11,16]

Lung inflation near to total lung capacity is a major physiological stimulus for the release of lung surfactant and prostaglandins into alveolar space, which increases...
lung compliance and decreases bronchiolar smooth muscle tone, respectively.[12,14,16]

MVV improvement might be due to improvement in respiratory mechanism and strengthening of respiratory muscles and also due to regular practice of yogasanas and yogic breathing exercises.[14]

Breathing is automatically regulated by bulbopontine respiratory control mechanisms, which are further modified by suprapontine mechanisms. The pneumotaxic centre is supposed to relay suprapontine messages which promote voluntary inspiration and expiration. During daily practice of pranayamic breathing, the basic activity of bulbopontine complex may be modified in such a way as to slow down its rhythm.[14]

A combined practice of several important asanas show considerable improvement in cardiorespiratory functions.[17] These changes might be due to specific rehabilitative effects of yogic practices on different vital organs improving their microcirculation and thus improving their functions.[18]

Increased tolerance of respiratory centers to higher $\text{PCO}_2$ and low $\text{PO}_2$ is achieved with yogic exercises, particularly with different pranayamas. Short periods of conscious control of the rate and depth of breathing as a health-promoting exercise have claimed wide human interest. In performing yoga breathing, the subject while keeping his skeletal muscles relaxed and immobile can exercise a close, continuous voluntary control over his respiratory muscles. The subject may change his ordinary rate of 15-18 respirations/minute to 1-2 respirations/minute and reduce his ventilation volume a great deal. Also this drastically lengthens his duration of expiration. In some exercises, he can use extremely rapid, shallow breathing and in others he can make each successive breath nearly equal to his vital capacity. In these prolonged efforts at controlling his respiratory muscles, he is consciously and persistently over-riding the usual stimuli of respiratory centers. These overriding stimuli may alter the sensitivity of respiratory centers thereby increasing the breath holding time or decreasing the resting respiratory rate.[15,19]

Players have higher values of lung functions compared to those not playing any games. Exercise has a facilitating effect on the lungs. Especially swimmers have the highest value of lung capabilities amongst all the sportsmen.[14]

The ability of the individual to inflate and deflate the lungs depends upon the strength of the thoracic and abdominal muscles, posture of the individual and the elasticity of lungs. Swimming increases this ability because it is performed in horizontal position compared to the vertical position in other sports. Swimming involves keeping the head extended which is a constant exercise of the Erector Spinae muscle which increases the vertical and antero-posterior diameter of the lungs and the supraspinatus which increases the antero-posterior diameter of the lungs. The sternomastoid, trapezius and the diaphragm are also being constantly exercised. Ventilation is restricted during swimming which leads to intermittent hypoxia in every respiratory cycle for one moment or the other. This intermittent hypoxia sets up the anaerobic process by which lactic acid starts accumulating in the blood leading in “lactic oxygen deficit”. This leads to the stimulation of respiratory center in the medulla therefore increasing respiration. The resultant alveolar hyperplasia may be responsible in increasing FVC, VC and number of alveoli. FVC and FEV depend on the strength of the abdominal muscles which require prolonged exercise to hypertrophy. Highest improvement in VC, FVC and FEV occurs after swimming.[13]

Swimming involves high pressure on the thorax from outside. So the respiratory muscles and the diaphragm are required to develop greater pressure as a consequence of immersion in water during the respiratory cycle, thus leading to functionally better respiratory muscles. Also the heat conductance of water is more than that of air. Regular swimming practice may tend to alter the elasticity of the lungs and the chest wall which leads to improvement in lung functions in swimmers. These factors when combined together play an important role in developing better lung functions in swimmers compared to other sportsmen.[5,12,20]

In conclusion, yogic postures and pranayama as well as swimming improve the pulmonary functions significantly within 12 weeks. Somewhat better improvement in some of the parameters, particularly FVC, FEF 25-75% and MVV, seems to give an edge to swimming over the yoga for lung function improvements. However, the present study has important limitation of not comparing the effects of these modalities of exercise on other body functions. Moreover, other factors like cost effectiveness and ability of any exercise regime to keep continued motivation and interest of the trainees should also be taken into account for exercise prescription.

In developing and poor countries, the facilities for recreational exercise and sports are not easily available and many low socio-economic group people can not afford to utilize the available resources. Some individuals with physical constraints and for other reasons like lack of training may not be able to swim, though they can undergo some yogic training. In light of these facts, yogic exercise can become the most important way of lifestyle intervention and physical activity for prevention of many diseases as prescribed by World Health Organization.[21]
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