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Original Research Article

# PULMONARY FUNCTIONS IN ADOLESCENT SWIMMERS PERFORMING DIFFERENT STROKES OF SWIMMING: A CROSS-SECTIONAL STUDY

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ABSTRACT

**Background:** Competitive swimming is proven to be an excellent exercise for lungs. It takes place in a medium, that presents different gravitational and resistive forces, respiratory conditions and thermal stress compared to air. Swimming comprises of four strokes namely, front crawl (FC), butterfly (BF), breast stroke (BRS) & back stroke (BS). Respiration during swimming is synchronized with swimming strokes. The present study was undertaken to compare the pulmonary functions of swimmers performing different styles of swimming.

**Methods and Materials:** 160 swimmers between the age group of 12 to 16 years were divided into four groups according to their proficiency in the swimming stroke namely front crawl, butterfly, breast stroke and back stroke. The parameters recorded were pulmonary function tests (FVC%, FEV1%, PEFR %) as baseline and after 100 meters stroke performance.

**Results:** There was no significant difference between the baseline pulmonary function tests (FVC%, FEV1%, PEFR %). Pulmonary function tests decreased significantly in front crawl and butterfly after 100-meter swim.

**Conclusion:** The present study revealed that the four strokes of swimming have equivalent influence on baseline pulmonary functions (FVC%, FEV1%, PEFR%). After 100-meter swim significant decrease was observed in FEV1%, in FC and BF. Physiological profiles observed in various swimming strokes may be utilized as a selection criteria for suitable swimming stroke.

**Key words:** swimming strokes, pulmonary functions.

## INTRODUCTION

Competitive swimming is proven to be an excellent exercise for lungs. Swimming takes place in a medium, that presents different gravitational and resistive forces, respiratory conditions and thermal stress compared to air.[18]

A swimming style is known as a stroke. "Stroke" refers to a single completion of the sequence of body movements repeated while swimming in the given style. Competitive swimming comprises of four strokes namely, front crawl (FC), butterfly (BF), breast stroke (BRS) & back stroke (BS).[1]

Front crawl, is typically swam with alternating arm strokes and a flutter kick. The butterfly stroke is accomplished with simultaneous movement of arms and legs. In the backstroke, the swimmer remains on back and movement occurs with alternate arm strokes and flutter kick. To perform breaststroke, a swimmer makes simultaneous movements of arms on a horizontal plane.

Respiration during swimming is synchronized with swimming strokes. Mechanics of breathing varies with each stroke. Respiratory responses to swimming may be expected to be different for the reasons that, the swimming is a sport performed in horizontal position in restricted ventilation. In addition, the external pressure is increased in swimming and the heat conductance of water is higher than that of air.[3,18,24] The efficiency related to various systems with special reference to pulmonary functions, play a major role in various strokes.[4]

An obvious dichotomy was observed between the alternated (Freestyle and Backstroke) and the simultaneous (Breaststroke and Butterfly) techniques. Even, in the same type of event, the performers of various strokes have been shown to differ in their metabolic as well as physiological responses.[4]

The present study was undertaken to assess the pulmonary functions of swimmers performing different styles of swimming & to compare them, to note the difference if any. It may provide guidelines for swimmers and coaches in their efforts to explore the limits of human performance. It can be utilized for the selection criteria of the swimmers, to understand the effect of training and to evaluate the training schedule. It may also provide a reference upon which talent-identification programs could be based and monitoring programs could be established.

**Aim:** To compare the pulmonary functions in swimmers performing different styles of swimming namely front crawl (FC), butterfly (BF), breast stroke (BRS) and back stroke (BS).

**Objectives**

1. To compare baseline pulmonary function tests (FVC%, FEV1% and PEFR%) in different styles of swimming namely front crawl (FC), butterfly (BF), back stroke (BS) and breast stroke (BRS).
2. To compare similar parameters after 100 meters swim of different styles of swimming (FC, BF, BS, BRS).

## MATERIALS AND METHODS

**Study Set Up**

The present study was conducted in Jawaharlal Nehru Medical College, Sawangi (M), Wardha and Hanuman Vyayam Prasarak Mandal, Amravati (M. S.).

**Study Design**

Comparative, cross sectional study.

**Sample Size**

160 subjects were selected and divided into four groups according to their proficiency in the swimming stroke. Each group consisted of 40 swimmers expertise in specific swimming stroke.

**Study Duration**

Two years

**Study protocol**

Clearance of Institutional Ethical Committee, Jawaharlal Nehru Medical College, Sawangi (M) Wardha was obtained. The selection and screening of subjects was done at Hanuman Vyayam Prasarak Mandal, Amravati. 160 swimmers participating in the study were healthy males and females between age group of 12 to 16 years.

**These subjects were divided into four groups as follows**

| Swimming style | Male | Female | Total |
|---|---|---|---|
| Front Crawl (FC) | 27 | 13 | 40 |
| Butterfly (BF) | 25 | 15 | 40 |
| Breast stroke (BRS) | 26 | 14 | 40 |
| Back stroke (BS) | 28 | 12 | 40 |

A written consent was obtained from coach and parents of participants in the study. All the subjects were assessed through history taking and detailed clinical examination.

Inclusion criteria

1. Swimmers trained in specific swimming style for more than 2 years & practicing swimming for one & a half hour per day for five to six days per week.
2. Trained swimmers between the age group of 12-16 years.

**Exclusion Criteria**

1. Subjects with history of cardiovascular diseases and/or any respiratory disorders.
2. Subjects with deformity of thoracic cage or deformed body parts.
3. Subjects who were smokers.
4. Swimmers engaged in other athletic activities along with swimming.

All the parameters in all the four groups were recorded during morning hours between 8 am to 10 am to avoid any possible diurnal variation effect.

**Following parameters were recorded in each study group**

A) The anthropometrical parameters like age, height and weight.

B) Pulmonary function tests – Pulmonary function was assessed based on Forced Expiratory Volume in first second (FEV1%), Forced Vital Capacity (FVC%) and Peak Expiratory Flow Rate (PEFR%) expressed as percent predicted for the age, sex, height, weight at rest and after 100-meter swim of specified swimming stroke within two minutes (after swim).

Helios (Recorders and Medicare Systems Pvt. Ltd., Chandigarh, India), a computerized electronic type of PFT machine was used for spirometry.

All the criteria for a satisfactory effort for recording a forced expiratory spirogram as mentioned in the review article titled "Lung functions with spirometry" by Dixit M.B.et al. (2005) were followed during the recordings.[8]

**Statistical Analysis**

Descriptive statistics was applied like mean and standard error of mean. Study groups were compared for anthropometric parameters like age, sex, height and weight with chi square test. One-way ANOVA

and Student's 't' test were applied to the data to test the significant difference between the various swimming stroke groups. If the F-test showed significance, the differences were further verified by Multiple comparisons by Bonferroni test. The significance was tested at 5% (0.05) level of significance. All the statistical calculations were done with the help of SPSS version 17.0.

## RESULTS

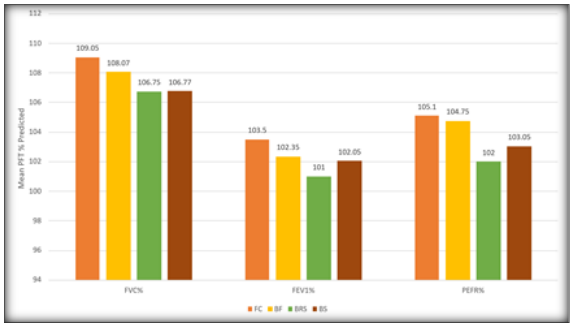


**Figure 1: Showing comparison of Baseline P.F.T. in four groups (one-way ANOVA)**

Baseline FVC%, FEV1% and PEFR% predicted was highest in front crawl, followed by butterfly, backstroke and least in breast stroke. The difference between the four groups in baseline FVC%, FEV1% and PEFR% was not significant. (Table 1, Graph 1).

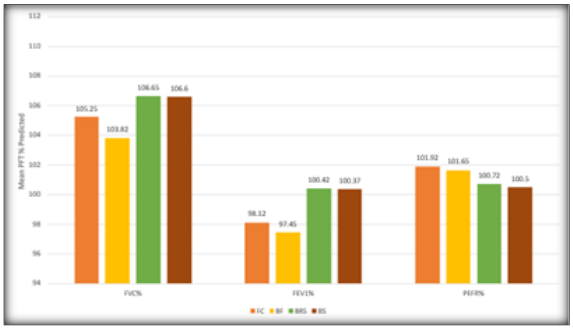


**Figure 2: Showing comparison of P.F.T. after 100-meter swim between four groups (one-way ANOVA)**

There was no significant difference in FVC% predicted and PEFR% after 100-meter swim between four groups. (Table 2, Graph 2).

The study showed significant difference in FEV1% after 100-meter swim amongst four swimming strokes. Therefore, multiple comparisons Bonferroni test was done. There was significant difference between 1) front crawl with breast stroke, 2) butterfly with breast stroke and back stroke (Table 3).

**Table 1: Showing comparison of Baseline P.F.T. in four groups (one-way ANOVA)**

| Parameter | Group | Mean ±SD | ±SEM | F | p-value |
|---|---|---|---|---|---|
| FVC% Pred. | FC | 109.05±5.62 | 0.88 | 1.480 | 0.222 NS,p>0.05 |
| | BF | 108.07±6.32 | 0.99 | | |
| | BRS | 106.75±5.64 | 0.89 | | |
| | BS | 106.77±5.51 | 0.87 | | |
| FEV1% Pred. | FC | 103.50± 4.62 | 0.73 | 2.04 | 0.110 NS,p>0.05 |
| | BF | 102.35±5.29 | 0.83 | | |
| | BRS | 101.00±4.38 | 0.68 | | |
| | BS | 102.05±3.91 | 0.61 | | |
| PEFR% Pred. | FC | 105.10±6.13 | 0.96 | 2.00 | 0.116 NS,p>0.05 |
| | BF | 104.75±6.13 | 1.16 | | |
| | BRS | 102.00±2.75 | 0.43 | | |
| | BS | 103.05±8.39 | 1.32 | | |

**Table 2: Showing comparison of P.F.T. after 100-meter swim between four groups (one-way ANOVA)**

| Parameter | Group | Parameter Mean±SD | ±SEM | F | p-value |
|---|---|---|---|---|---|
| FVC% Pred. | FC | 105.25±4.73 | 0.74 | 2.799 | 0.052 NS,p>0.05 |
| | BF | 103.82±5.35 | 0.84 | | |
| | BRS | 106.65±5.28 | 0.83 | | |
| | BS | 106.60±5.28 | 0.76 | | |
| FEV1% Pred. | FC | 98.12±4.29 | 0.67 | 8.814 | 0.000 S,p<0.05 |
| | BF | 97.45±4.07 | 0.64 | | |
| | BRS | 100.42±4.07 | 0.64 | | |
| | BS | 100.37±3.84 | 0.60 | | |
| PEFR% Pred. | FC | 101.92±4.19 | 0.66 | 0.486 | 0.692 NS,p>0.05 |
| | BF | 101.65±6.91 | 1.09 | | |
| | BRS | 100.72±4.88 | 0.77 | | |
| | BS | 100.50±8.31 | 1.31 | | |

**Table 3: Showing comparison of FEV1% Pred. after 100-meter swim in 4 groups: (Multiple Comparisons by Bonferroni test)**

| Group | | Mean Difference (I-J) | Std. Error | p-value | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| FC | BF | 0.67 | 0.86 | 1.000 NS,p>0.05 | -1.64 | 2.99 |
| | BRS | -3.17 | 0.86 | 0.002 S,p<0.05 | -5.49 | -0.85 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | BS | -2.25 | 0.86 | 0.063 NS,p>0.05 | -4.56 | 0.06 |
| BF | BRS | -3.85 | 0.86 | 0.000 S,p<0.05 | -6.16 | -1.53 |
| | BS | -2.92 | 0.86 | 0.006 S,p<0.05 | -5.24 | -0.60 |
| BRS | BS | 0.92 | 0.86 | 1.000 NS,p>0.05 | -1.39 | 3.24 |

## DISCUSSION

Competitive swimming comprises of four strokes, the alternated front crawl and back stroke, and the simultaneous butterfly and breast stroke. These swimming events have been shown to differ regarding their physiological responses. As the energy expenditure, O2 consumption rate, body movements, i.e. arm & leg movements differ with each stroke the lung function status, mechanics of breathing & cardiac status have to cope up with the stroke techniques. Respiration during competitive swimming is synchronized with swimming strokes.[3] Mechanics of breathing varies with each stroke. Respiratory responses to swimming may be expected to be different for the reasons that, the swimming is a sport performed in horizontal position in restricted ventilation. In addition the external pressure is increased in swimming and the heat conductance of water is higher than that of air.[3,18,24] The efficiency related to various systems with special reference to pulmonary functions, play a major role in various strokes.[4] Therefore, the present study was undertaken to compare the pulmonary functions of swimmers performing different styles of swimming.

The four groups (FC), (BF), (BRS), (BS) were analyzed for basic parameters like age, sex, height and weight. The difference in composition of the four groups was statistically not significant in respect of age, sex, height and weight of the swimmers.

Swimming is reported to increase pulmonary functions to a great extent as it involves physical activity as well as breathing exercise. Swimmers have the highest values of lung capabilities amongst all the sportsmen.[7,9,12,13,14] 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. The physiological responses have been shown to differ in various strokes depending upon the pattern of breathing in the strokes.[14]

The analysis of pulmonary function tests viz. FVC%, FEV1%, PEFR% showed that there was no significant difference in the baseline mean FVC%, FEV1% and PEFR% between all four groups.

The baseline values of pulmonary functions reported by P. Vaccaro et al,[7] and J. Armour,[10] are little higher. This may be attributed to the higher age and average duration of training (6.5years) of swimmers in comparison to our study.

It has been suggested that increased respiratory muscle strength and perhaps alveolar expansion or hyperplasia are responsible for the increase in lung volume. In swimming, there is a large amount of upper body work. Considering the hypoxic nature of swimming and the enhanced growth hormone release with arm exercise, it is very possible that intensive swim training over the adolescent growth spurt, is capable of eliciting a lung growth response of alveolar multiplication and enlarging chest cavity.[12] Intensive swimming training enhances static and dynamic lung volumes and improves the conductive properties of both the large and the small airways. The larger values for vital capacity seen in swimmers.[13] might result from both training during the growth period and genetic endowment.[22]

The study showed significant difference in FEV1% after 100-meter swim amongst four swimming strokes. There was significant difference between 1) front crawl with breast stroke, 2) butterfly with breast stroke and back stroke (Table 3).

In literature the maximum data available analyzing pulmonary functions is chiefly in front crawl.[9,11,14] However our findings correlated with C. Kesavachandran et al., 2001. They compared pulmonary functions in different swimming strokes at baseline and after 100-meter swim. They reported significant decrease in FVC% and FEV1% after 100-meter swim in front crawl and butterfly. But they found no change in back stroke and insignificant increase in breast stroke.[3]

The studies in literature suggested, the whole body endurance exercise causes end-organ fatigue, i.e., at the level of diaphragm.[23] Several factors which influence the inspiratory muscle and diaphragmatic fatigue include failure of neural transmission in the diaphragm, breathing frequency, trans diaphragmatic pressure generation during exercise. The unifying quantity common to all these mechanical determinants of respiratory muscle fatigue may be lesser availability of oxygen to the respiratory muscles.[14] However, earlier studies showed that ventilation decreases rapidly towards baseline quickly after the exercise.[15]

## CONCLUSION

Thus the present study revealed that the four strokes of swimming have equivalent influence on baseline pulmonary functions (FVC%, FEV1%, PEFR%). The flow volumes are affected by 100-meter swim of FC and BF mainly, while they are not affected by 100-meter swim of BS and BRS.

**Utility**

**"Physiological profiles" observed in various swimming strokes may be utilized**

1. As a selection criterion for suitable swimming stroke.
2. To provide training schedule for improvement in specific stroke performance.
3. To characterize the current weaknesses of the competitors.
4. To detect exercise induced bronchospasm.[19,20]

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