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# A STUDY OF PULMONARY FUNCTION OF COMPETITIVE SWIMMERS

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**Abstract :** Pulmonary Function Tests (PFT) of 45 swimmers who swam a distance of 2 to 5 kms per day regularly were compared with age, sex, height and weight matched controls. VC, IRV, FVC, $FEV_1$ and $V_{25}$ were higher in swimmers (S) than controls (NS) by 20%, 25%, 37.4%, 30.1% and 15.1% respectively. The effect of the period of training on PFT's was also analysed. Inspiratory capacity was significantly higher in Gr IS than NS probably due to a reduction in FRC, FVC and $FEV_1$ were higher in Gr. II than NS. Greater differences were seen between Gr. IV S and NS, where FVC, $FEV_1$, $V_{75}$ and PEFR were higher by 50.2%, 38.2%, 69.4% and 25% respectively in the S than NS. Probably the first parameter to increase is IC. The greater differences in PFT values of Gr. IV S and NS may be due to hypertrophy of the diaphragm which requires hard work for prolong period. Further longitudnal studies are needed to confirm these observations.

**Key words :** pulmonary function tests (PFT) swimmers sports

## INTRODUCTION

There are a number of factors on which pulmonary functions depend in normal individuals. Besides the balance between lung recoil and chest elasticity, that determine the mid-position at the end of spontaneous expiration and the coordinated neuro-muscular fnnction of maintenance of effort; the thoracic and abdominal muscle strength play an important role in most of the pulmonary functions. Since muscular strength can be increased by regular exercise, we decided to study the effect of strenuous swimming on the PFT's, as it involves both, the total body muscular activity and excessive use of chest and abdominal muscles following periods of breath holding, which is a part of training for competitive swimmers This is a cross sectional study of competitive swimmers who had undergone training for different periods of time.

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## METHODS

PFT's were performed on 45 swimmers who regularly swam a distance of 2 to 5 km, 6 days in a week. Most of the swimmers had taken part in or were being trained for competitive swimming at the State, National or Inter-national level. Age, sex, height and weight-matched controls were obtained for each child from non-swimmer children, selected from personal contacts and from schools. More than a thousand children were screened to get exact height, weight and sex-matched controls. These children were not taking part in any special sports, but were taking part in routine school sports and exercise. Any child with a respiratory or cardiac illness in the past or of recent origin was excluded from the study. Age was obtained from the school certificates. Weight was measured on a standard machine. Height was measured with a caliberated tape, the child standing against the wall with closed feet, his head and body touching the wall. PFT were performed on a portable FUKADA SPIRO-ANALYSER with computer and printer Model ST-200. The procedure of performing the PFT was fully explained to the volunteers One out of three best visual displays was printed for analysis. The data was analysed on Casio Computer Model PB410. Statistical analysis was done by applying students 't' test.

Swimmers were arbitrarily divided into 4 groups according to the period of training undergone by them. Group I (n=3) had training between 6 months to 1 year; Gr. II (N=15) had between 1 to 2 years, Gr. III (n=16) between 2 to 5 years and Gr. IV (n=11) of more than 5 years. Inspiratory capacity was obtained by subtracting ERV from VC.

Predicted values for PFT's depend on age, sex and height and were same in both swimmers (S) and controls (NS). We could not find any Indian or foreign values of IRV, ERV, $V_{75}$, $V_{50}$ and $V_{25}$ for comparison

## RESULTS

The total study group comprised of 90 volunteers between the ages of 7 and 22 years; 45 of them were swimmers and the remaining 45 were their age, sex and height matched controls. Their height varied between 119 and 182 cms with a mean of 153.69± SD 17.71. There were 64.4% (n=29) males and 35.6% (n=16) females. Table I gives the mean of the various PFT's in swimmers (S) and Non-swimmers (NS). Table II gives the PFT's of the swimmers according to their period of training.

TABLE I : Comparison of PFT's of swimmers (S) with Non-swimmers (NS).

VC=vital capacity, ERV=Expiratory reserve volume, IRV=Inspiratory reserve volume, TV=Tidal volume, FVC=forced vital capacity, $FEV_1$=forced expiratory volume at 1 sec., MMEF=maximum mid-expiratory flow rate, PEFR=peak expiratory flow rate, PEFR=peak expiratory flow rate, V75, V50, V25=flow rates at 75%, 50% and 25% of FVC.

| *PFT L/min* | | *Mean* | *SD* | *SEM* | "*t*" |
|---|---|---|---|---|---|
| VC | S | 3.19 | 1.09 | 0.16 | 2.13 |
| | NS | 2.7 | 1.09 | 0.16 | |
| ERV | S | 1.17 | 0.55 | 0.08 | 0.87 |
| | NS | 1.06 | 0.66 | 0.1 | |
| IRV | S | 1.0 | 0.39 | 0.06 | 2.26 |
| | NS | 0.8 | 0.44 | 0.07 | |
| TV | S | 1.03 | 0.42 | 0.06 | 0.22 |
| | NS | 1.01 | 0.48 | 0.07 | |
| FVC | S | 2.72 | 1.17 | 0.17 | 3.01 |
| | NS | 1.98 | 0.8 | 0.12 | |
| $FEV_1$ | S | 2.68 | 1.18 | 0.18 | 2.91 |
| | NS | 2.06 | 0.82 | 0.12 | |
| MMEF | S | 3.4 | 1.15 | 0.17 | 0.29 |
| | NS | 3.48 | 1.31 | 0.2 | |
| PEFR | S | 5.79 | 2.39 | 0.36 | 1.47 |
| | NS | 5.11 | 1.95 | 0.29 | |
| V75 | S | 5.42 | 2.41 | 0.36 | 1.21 |
| | NS | 4.86 | 1.94 | 0.29 | |
| V50 | S | 3.97 | 1.42 | 0.21 | 0.26 |
| | NS | 4.05 | 1.52 | 0.23 | |
| V25 | S | 2.14 | 0.97 | 0.14 | 1.7 |
| | NS | 2.52 | 1.09 | 0.16 | |

TABLE II : Comparison of PFT's of swimmers (S) and Non-swimmers (NS) according to the period of training for swimming. Gr. I to IV represent the four groups according to their period of training.
"t"=Students t test. VC=Vital capacity, ERV=Expiratory reserve volume, IRV=Inspiratory reserve volume, FVC=Forced vital capacity, PEFR=Peak expiratory flow rate, $FEV_1$=Forced expiratory volume at 1 sec., $V_{75}$. $V_{25}$=Flow rates at 75 and 25% FVC.

| *PFT* | *VC* | *(l)* | *ERV* | *(l)* | *IRV* | *(l)* | *FVC* | *(l)* | *$FEV_1$* | *(l)* | *PEFR* | *(l/min)* | *$V_{75}$* | *(l/sec)* | *$V_{25}$* | *(l/sec)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *GR. I* | *S* | *NS* | *S* | *NS* | *S* | *NS* | *S* | *NS* | *S* | *NS* | *S* | *NS* | *S* | *NS* | *S* | *NS* |
| GR. I S | | | | | | | | | | | | | | | | |
| Mean | 1.7 | 1.3 | 0.47 | 0.3 | 0.47 | 0.27 | 1.13 | 1.2 | 1.17 | 1.17 | 2.97 | 3.17 | 3.17 | 3.07 | 1.87 | 1.43 |
| SD | 0.61 | 0.26 | 0 31 | 0.1 | 0.12 | 0.06 | 0.38 | 0.17 | 0.32 | 0.12 | 0.55 | 0.6 | 0.35 | 0.4 | 0.58 | 0.5 |
| SEM | 0.35 | 0.15 | 0.18 | 0.06 | 0 07 | 0.03 | 0.22 | 0.1 | 0.18 | 0.07 | 0.32 | 0.35 | 0.2 | 0.23 | 0.3 | 0.3 |
| "t" | 0.85 | | 0.73 | | 2.19 | | 0.23 | | 0.01 | | 0.35 | | 0.26 | | 0.79 | |
| GR. II S | | | | | | | | | | | | | | | | |
| Mean | 2.51 | 2.21 | 0.84 | 0.89 | 0.86 | 0.69 | 2.2 | 1.68 | 2.2 | 1.7 | 4.76 | 4.08 | 4.53 | 3.82 | 1.93 | 1.73 |
| SD | 0.65 | 0.57 | 0.24 | 0.5 | 0.39 | 0.31 | 0.82 | 0.53 | 0.83 | 0.44 | 1.65 | 1.37 | 1.79 | 1.35 | 0.99 | 0.89 |
| SEM | 0.17 | 0.15 | 0.06 | 0.13 | 0.1 | 0.08 | 0.21 | 0.14 | 0.21 | 0.11 | 0.43 | 0.35 | 0.45 | 0.35 | 0.24 | 0.23 |
| "t" | 1.27 | | 0.31 | | 1.3 | | 2 | | 2 | | 1.19 | | 1.2 | | 0.4 | |
| GR. III S | | | | | | | | | | | | | | | | |
| Mean | 3.43 | 2.73 | 1.3 | 1.01 | 0.99 | 0.74 | 2.46 | 2.06 | 2.52 | 2.09 | 5.44 | 5.19 | 4.81 | 5.01 | 2.86 | 2.38 |
| SD | 0.94 | 1.06 | 0.44 | 0.6 | 0.31 | 0.38 | 0.8 | 0.7 | 0.76 | 0.69 | 1.72 | 1.9 | 1.74 | 1.9 | 1.24 | 0.88 |
| SEM | 0 24 | 0.26 | 0.11 | 0.15 | 0.08 | 0.09 | 0.2 | 0.17 | 0.19 | 0.17 | 0.43 | 0.48 | 0.44 | 0.48 | 0.31 | 0.22 |
| "t" | 1.92 | | 1.49 | | 2.01 | | 1.45 | | 1.63 | | 0.38 | | 0.3 | | 1.24 | |
| GR. IV S | | | | | | | | | | | | | | | | |
| Mean | 4.19 | 3.62 | 1.65 | 1.58 | 1.4 | 1.08 | 4.04 | 2.69 | 3.79 | 2.74 | 8.65 | 6.92 | 8.15 | 6.17 | 3.08 | 2.53 |
| SD | 0.83 | 1.12 | 0 55 | 0.71 | 0.53 | 0.6 | 0 81 | 0.98 | 0.66 | 1.02 | 1.96 | 1.5 | 1.98 | 1.1 | 0.69 | 1.07 |
| SEM | 0.25 | 0.34 | 0.17 | 0.22 | 0.16 | 0.18 | 0.24 | 0.29 | 0.2 | 0.3 | 0.59 | 0.45 | 0.6 | 0.33 | 0.19 | 0.32 |
| "t" | 1.3 | | 0.26 | | 1.26 | | 3.34 | | 2.73 | | 2.23 | | 2.76 | | 1.41 | |

## DISCUSSION

There are a number of factors on which PFT's are dependent; included amongst them are body size, age, sex and weight (1, 2, 3, 4) PFT peaked at 18 years in males (2, 3) and between 14 to 16 years in females (2, 3). Following this peak at which they stabilise for a short interval, they start declining (1). Since our study consisted of swimmers whose PFT's could be below peak, at peak or on the decline depending on the age of the child, we selected age, sex and height matched controls. We also matched them for weight because an initial increase in weight raises PFT's due to a muscularity effect and a later increase in weight decreases PFT's due to an obesity effect (4). However, we could not do away with the fact that smaller children and adolescent females vary widely in their willingness to exert maximum effort (2).

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 (5) and the elasticity of lungs. Swimming increases this ability by a number of factors. It involves keeping the head extend which is a constant exercise of the Erector Spinae muscle which increases the vertical and the antero-posterior diameter of the lungs and the supraspinatus which increases the antero-posterior diameter of the lungs. The sternocleidomastoid, Trapezius and the diaphragm are also being constantly exercised.

IRV (inspiratory reserve volume) reflects muscle strength, thoracic mobility and the balance between lung and chest elasticity. The muscles involved are the diaphragm and the accessory muscles of respiration. IRV was 25% higher in S than NS. This difference was statistically significant (P=<0.05).

This can be explained on better functions of the inspiratory muscles and improved thoracic mobility.

ERV (expiratory reserve volume) depends on the strength of the abdominal muscles ERV was 10% higher in S than NS. This difference was not statistically significant. The muscles of expiration probably required prolonged exercise to hypertrophy, as mentioned later.

The initial part of an expiratory FVC (forced vital capacity) curve depends on non-brochopulmonary factors like neuromusclar factors and mechanical equipment factors eg. inertial distortion. The terminal portion of the curve is relatively variable due to factors like maintenance and co-ordination of efforts, which are, to some extent exercise dependent. The middle portion is relatively free. Our FVC was higher by 37.4% ($P=<0.01$), $FEV_1$ by 30.1% ($P=<0.02$), $V_{25}$ by 15.1% ($P=<0.05$) and $V_{75}$ by 11.5% ($t=1.21$) in S as compared to NS. Except for $V_{75}$ all the differences were statistically significant. Comroe (8) mentions that the first 20% of the FVC is affected by non-bronchopulmonary factors. Our $V_{75}$ is probably out of this range and has therefore shown lesser improvement. We may have to evaluate $V_{80}$ instead of $V_{75}$ to find out the effect of swimming on the initial part of the FVC curve. MMEF (maximum midexpiratory flow rate) and $V_{50}$ which measure the middle part of an FVC were not different in the two groups. PEFR (peak expirator flow rate) which measures large airway obstruction was 13.3% higher in S than NS. Tidal volume (TV) was high in both the groups probabaly due to apprehension caused by the testing procedure.

We further analyzed the effect of the duration of swimming on the PFT. In Gr. I, only IC (inspiratory capacity) was higher in S than NS ($P=<0.05$). Therefore we presume that IC may be the first parameter to improve with swimming probably due to the improved strength of the accessory muscles of respiration, which according to Campbell's (9) electromygraphic studies do not contract during quiet breathing and are inactive but are exercised during severe muscular exercise. Further as ERV was not significantly different in the two groups, the improvement in IC was probably due to reduction in the FRC. Further studies are needed to confirm this observation.

In group II swimmers who had a training of 1-2 years, FVC and $FEV_1$ were significantly higher by 31% and 29.4% ($P=<0.05$) than NS respectively. In this group, PEFR and $V_{75}$ were 16.7% and 18.6% higher in S than NS respectively but the difference was not statistically significant. Values of $V_{25}$ were also not different in the two groups. In group III, VC, ERV, FVC, $FEV_1$ and $V_{25}$ were higher by 25.6%, 28.7%, 19.4%, 20.6% respectively in S than NS. PEFR and $V_{75}$ were not different. However greater differences were seen between gr. IV S and NS, where FVC, $FEV_1$, and PEFR were significantly higher in the swimmers by 50.2% ($P=<0.01$), 38.2% ($P=<0.01$), 69.4% ($P=<0.02$) and 25% ($P=<0.01$) respectively. This later improvement in the PFT values could be due to hypertrophy of the diaphragm which requires hard work for prolonged periods of time (7).

Thus in our study swimmers had better values of VC, IRV, FVC, FEV and $V_{25}$ than controls. IC is the first pulmonary function to improve after 6 to 12 months of regular swimming, probably due to reduction in FRC, FVC, $FEV_1$ and to a lesser extent $V_{75}$ and PEFR improve after 1 to 2 years. The greater increase in PFT after 5 years of swimming may be due to hypertrophy of the diaphragm. MMEF and $V_{50}$, which are mainly dependent on bronchopulmonary factors were not different than controls. Further longitudnal studies are required to confirm these findings.

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