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Original Article

Duration of Swimming Practice Among Elite Swimmers Exerts Differential Effect on Large and Small Airway Function

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Abstract

The effect of swimming on large and small airway functions among elite swimmers with varying intensity and duration of practice is addressed in this study. This is a comparative study evaluating the pulmonary function tests (PFT) among healthy young elite male swimmers of age between 20-30 years belonging to two groups who were matched for their age but significantly differ in their years of intense swimming practice i.e group 1 - 3.80±1.93 years, group 2 - 5.58±1.24 years.

ANOVA of Pulmonary function tests variables showed a significant decrease in Vital capacity (VC) (p=0.02), peak expiratory flow rate (PEFR) (p=0.03) and forced vital capacity (FVC) (p=0.03) among group 2 when compared to group 1.

Thus intensive training with increased duration of swimming practice showed decrease in large airway functions like VC, PEFR and there was no significant changes seen among smaller airway pulmonary functions like MMEF.

Introduction

Swimming as an elusive sport has its greatest influence on pulmonary function tests (PFT) when compared to any other sport. Swimming has an immediate effect on improving the indicators of large airway functions like vital capacity (VC), forced vital capacity (FVC), forced expiratory volume at first second (FEV_1) (1). There are reproducible evidences from studies across the globe including our country demonstrating higher pulmonary volume and

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capacities among swimmers when compared to sedentary and other athletes (1-6). However, the duration and intensity of swimming practice is the major determinant to which the extent of functional capabilities is modulated.

Increased practice of swimming is known to bring about significant enhancement of larger airway caliber estimated in terms of peak expiratory flow rate (PEFR), forced expiratory volume at first second (FEV_1), vital capacity (VC) and also caliber of small airways as measured by maximum mid expiratory flow volume (MMEF) (7, 8). One year of intense swimming exercise among prepubertal girls, increases both static and dynamic lung functions, improvement in conductive properties and isotropic lung growth of both small and large airways and of alveolar lung spaces (9). However, there are contrasting reports about the effect of high intensity swimming practice on functional modulations of large and small airways (10). In our country, the assessment of PFT among elite swimmers is quite sparse and probably till date to the best of our knowledge only two studies are reported. In the first study, swimmers who were recruited, only few were trained for the national standards (2), in an another study (11), 45 elite swimmers were evaluated demonstrating higher lung functions when compared to non swimmers. However, the swimmers of the later study were heterogeneous in nature as far as their age range (7-22 years) is concerned and also the duration of swimming practice varied from 6 months to more than 5 years. These two confounding factors i.e. age and duration of practice that determines the pulmonary functions should be considered while interpreting the observations. Therefore, to decipher the discrepancies over the influence of duration of intense swimming practice on large and smaller airways, PFT evaluation is warranted among professional elite swimmers with variable duration of swimming practice of comparable age group.

The present study aims in addressing this issue by evaluating PFT among elite male swimmers of comparable age but with varying duration of training aiming towards participating in the national/ international competitions.

Material and Methods

This is a comparative study carried out at Sports Physiology laboratory at Sports Authority of India (SAI) among healthy young male elite professional swimmers of age between 20-30 yrs who intend to participate at various national / international level swimming competitions. They practiced regularly for 5 days/week and covered 2000-4000 m distance. The swimmers were selected from SAI, Bangalore. Subjects who were practicing aerobic exercises, yoga and users of tobacco in any form were excluded. If the participants found to have any acute or chronic medical disease conditions on medical examination they were excluded. The subjects were informed about the procedure and written informed consent was obtained, the protocol was approved by ‘Institute Human research ethics committee’.

Total of 50 swimmers were selected for the study. The range of years of swimming practice varied between 3–6 years. The median value of 4 years of practice was considered as cut off value to categorize the swimmers into two groups based on their years of swimming practice. Group 1 (n=24) less than four years of practice and group 2 (n=26) more than four years of practice.

Anthropometric measurements [Height (cm) and weight (kg)] were obtained and BMI (kg/m^2) was calculated. Resting supine pulse rate and blood pressure was obtained. Measurement of lung volumes and capacities were performed using computerized multifunctional Spirometer (Erich, Jaeger) 1994 model, at Physiology laboratory, SAI, Bangalore. Before performing the test, flow calibration was set in via a calibration syringe with volume of 1 liter. After subjects were accustomed to the sports physiology laboratory, the pulmonary function tests (PFT) was performed in sitting posture facing opposite to the PFT monitor. Nose clip was placed and mouth piece of spirometer was placed in the mouth. After maximal inhalation through the mouth piece, subjects were instructed to seal their lips around the mouth piece and were asked to exhale with maximum force as hard and as fast as possible. They were encouraged to continue exhaling for at least one second. Three recordings were obtained at intervals of 5 minutes and the best value was considered.

The following variables were recorded:

- Vital capacity (VC), Forced vital capacity (FVC)
- Forced expiratory volume at first second (FEV_1)
- Peak expiratory flow rate (PEFR)
- Mid Maximum Expiratory Flow Rate (MMMEF)

Maximum expiratory flow rate at 25% (MMEF25), 50% (MMEF50), 25/75% (MMEF25/75).

- Forced inspiratory volume in first second (FIV_1)
- FVC/FEV_1 ratio was calculated

The data between two groups was compared using ANOVA with p value < 0.05 as level of significance.

Result

In the present study, pulmonary function tests was evaluated and compared among healthy male regular elite swimmers with varying years of intense practice. Swimmers of both the groups were matched for their age [group 1 - 23.26±1.3 years, group 2 - 23.70±2.31 years, p=0.41]. Group 2 swimmers had a significantly increase duration of their practice in terms of years [group 1 - 3.80±1.93, group 2 - 5.58±1.24, p=0.00], hours/day of practice [group 1- 1.75±0.62, group 2 - 2.25±0.51, p=0.003]. However, their practice as far as number of days a week was comparable [group 1-5.96±1.31, group 2 - 6.41±0.77, p=0.1]. Comparison between Age, anthropometric measurements, resting heart rate and blood pressure between the two groups are depicted in Table I.

Pulse rate was less among group2 swimmers when compared to group1 swimmers [group 1 = 75.61±5.9, group 2 = 72.75±5.58, F (1,50), 21.06, p=0.08]. Anthropometric measurements and both systolic and diastolic blood pressures were comparable between both the groups. However, pulmonary function tests (Table II) showed a significant decrease in VC[F=(1,50), 23.4, p=0.02], FVC [F=(1,50), 28.68, p=0.03) and PEFR [F=(1,50), 30.12, p=0.03) among group2 when compared to group1. Other PFT variables, FEV_1 [F=(1,50), 9.65, p=0.68], MMEF25 [F=(1,50), 10.87, p=0.64]. MMEF50 [F=(1,50), 7.82, p=0.93] and MMEF25/75 [F=(1,50), 15.68, p=0.38], FEV_1/FVC ratio [F=(1,50), 10.86, p=0.98] were comparable between the two groups.

In summary, our results demonstrated that increased duration of swimming practice leads to decrease in VC, FVC and PEFR that are functional indicators of large airways, but, no change was seen in MMEF25,

TABLE I: Comparison of Age, Anthropometric measurements, Resting Heart rate and Blood pressure between group1 and group2 swimmers.

Anthropometric measurements	*Group 1 (n=24)*	*Group 2 (n=26)*	*P value*
Age (years)	23.26±1.3	23.70±2.3	0.41
Height (cm)	174.19±5.59	173.91±4.08	0.84
Weight (kg)	69.38±4.9	68.75±5.65	0.67
Body mass index BMI (kg/m^2)	24.06±1.79	23.57±1.64	0.32
Pulse Rate (beats/min)	75.61±5.9	72.75±5.58	0.08
Systolic blood pressure (mm of Hg)	102.76±4.38	101.25±3.37	0.17
Diastolic blood pressure (mm of Hg)	69.23±4.7	68.25±5.38	0.49

Data is expressed in mean±SD.

TABLE II: Comparison of pulmonary function test (PFT) variables of large airway and small airways between group1 and group2 swimmers.

Pulmonary function testsvariables	*Group 1 (n=26)*	*Group 2 (n=24)*	*P value*
Vital capacity VC(L)	5.89±1.73	4.65±0.66	0.02*
Forced vital capacity FVC(L)	5.28±1.54	4.68±0.71	0.03*
Forced expiratory volume in first second FEV_1(L)	4.41±1.25	4.26±0.64	0.68
Peak expiratory flow rate PEFR(L)	11.59±2.9	9.87±2.71	0.03*
Forced inspiratory volume infirst second FIV_1 (L/sec)	3.86±1.75	3.73±0.9	0.76
FEV_1/ FVC ratio	0.80±0.18	0.91±0.07	0.98
Maximum expiratory flow rate at 25% MMEF25 (L/sec)	2.73±1.29	2.90±1.16	0.64
Maximum expiratory flow rate at 50% MMEF50 (L/sec)	5.54±2.73	5.59±1.91	0.93
Maximum expiratory flow rateat middle 50% MMEF25/75 (L/sec)	4.55±1.9	5.03±1.89	0.38

Data is expressed in mean±SD. * p value <0.05

Group 2 swimmers showed significantly less VC,FVC and PEFR when compared to group 1swimmers

MMEF50, MMEF25/75 that are the predictors of small airway caliber and in FEV_1/FVC ratio.

Discussion

Swimming is an endurance activity has an enormous positive influence on somatic and systemic growth. It has been shown that swimming, even for short duration of practice exerts significant influence on pulmonary function, while endurance training in land based athletes even for one year failed to produce any significant effect (12). Whereas, training with combination of both endurance and resistance exercise even for couple of months is known to greatly influence lung functions (13). Co-ordination between the movement of ribs and various groups of muscles makes swimming an endurance exercise and overcoming the resistance offered by water makes swimming a resistance exercise. Hence, swimming forms a unique sporting activity wherein both endurance and resistance form of training is imparted, which enables to enhance the muscular strength. Increased practice of this sport causes hypertrophy of the diaphragm thus augmenting the swimmers ability to inflate and deflate the lungs at higher volumes. Thereby, pulmonary function variables like VC, FVC, PEFR, FEV_1 is enhanced in swimmers (14).

Among PFT parameters, more specifically PEFR, indicates patency of large airway and the strength of the respiratory muscles and various mid expiratory flow rates (MMEF) indicates the functionality of smaller airways especially with internal diameter less than 2 mm (15, 16). The effect of swimming on PFT depends on the intensity and duration of practice. As mentioned earlier, as far as Indian studies are concerned, there are no studies evaluating PFT among elite swimmers who are competitive enough towards participating in National/International competitions. However, there are only two studies (2, 11) demonstrating higher PFT values among elite swimmers than controls. But, both these studies have limitations, wherein swimmers were ranging from children to adults with wider age groups and lesser number of participants. The strength of the present study is that all the elite swimmers were adults, with considerable duration of intense practice (3-6 years) and probably this is the first study comparing the effect of duration of swimming practice among Indian elite swimmers on PFT.

In a study (7), with large number (n=459) of swimmers and athletes, authors have reported higher FEV_1 levels among swimmers when compared to other athletes. Further, they have also demonstrated that swimmers satisfying the national standards show higher FEV_1 than non national standard swimmers. We have also reported earlier that elite swimmers show higher FVC, VC, PEFR and FEV_1 when compared to other athletes (4). The range of FVC, PEFR and FEV_1 values of elite swimmers in the present study is in accordance with earlier reports (5, 17), but, higher than other elite swimmers reported of our country (11). The higher age and longer duration of practice of our elite swimmers could be the explanation for finding this difference. However, the elite swimmers with longer duration of practice, in the present study, showed significant decrease in indicators of large airway functions i.e VC, FVC and PEFR when compared to their counterparts with lesser duration of practice. The ceiling effect of swimming on pulmonary function is also reported (18). However, interestingly, the FEV_1 and functional indicators of small airway ie. MMEF rates were comparable between the two groups.

Higher prevalence of upper (74%) and lower (76%) airway disorders has been reported among elite swimmers and athletes as well (19, 20). Mechanical stress of high order, increased airflow, changes in viscosity and tonicity of the fluid lining the airway epithelium are the factors that initiates inflammatory response in the large airways among athletes including elite swimmers (21). This inflammatory response recruits inflammatory cells (22) as exercise hyperventilation causes modulation of airway neutrophils through airway hyperosmolarity which triggers the neutrophil chemotactic factors and shedding of adhesion molecules .Thus, maintaining a low grade of systemic upper airway inflammation due to intense training (20) thereby, blunting the function of upper airways. In addition to this, swimmers have added environmental factor towards inflammation of upper respiratory tract which is well studied. Swimming in the indoor swimming pools wherein the chlorine is used to maintain the pool hygiene will react with organic matter, releasing high amounts of chloramines. Repeated inhalation of chloramines for longer duration among elite swimmers is known to induce epithelial injury of large airways, development of atopy and asthma or asthma like response (23, 24). These mechanisms could be the reasons for our finding of reduced upper airway functions indicated with significantly less VC, FVC and PEFR.

The smaller airways, to the intense training of swimming for longer duration responds by becoming more hyperresponsive, initially to provocative stimuli which progress gradually even in the normal resting conditions (17). But, few studies have not reported such hyperresponsiveness to the intense training (25). The reasons for these discrepancies are not understood. Increased oxidative stress and reduced antioxidant capacity in airway of elite swimmers are the proposed mechanism towards developing the airway hyperresponsiveness which in long run may develop a specific phenotype of asthmatic airway (26). There are bronchial biopsy evidences showing that airway changes in elite swimmers are almost similar to non athlete asthmatic patient (25). The MMEF flow rate and FEV_1/FVC ratio among two groups of elite swimmers in the present study were comparable. The values of FEV_1/FVC ratio in either group were above the lower limit of normality (> 0.75) (27). Therefore, smaller airways of our swimmers at least in the basal non provocative condition were neither hyperresponsive nor showed susceptibility to be asthmatic. However, estimation of MMEF and FEV_1/FVC ratio to provocative stimuli probably would have provided greater insight into the subclinical hyperresponsiveness of the smaller airways. But, the reasons for resistant in altering the function of smaller airway for the given duration and intense of swimming practice in the present study needs to be explored.

There are evidences demonstrating gender differences in Physiology of small airways, wherein, the smaller airways are more susceptible to collapse rather than getting inflamed in males and vice versa in females (28, 29). All the elite swimmers in the present study were males. Therefore, it only could be hypothesized that for the given intensity and duration of swimming practice in our elite male swimmers, probably, the defense mechanism of smaller airways would have been efficient enough to mitigate the inflammatory process, hence, no differences in the functions of smaller airways was observed. However, this statement needs to be validated with studies involving more technical sophistication. More insight will be obtained if the PFT is carried out with provocation.

In conclusion, the duration of intense swimming practice among elite swimmers cannot reduce or increase the airway functional capabilities and thus will differentially influence the functions of large and small airway (30, 31). Attenuation of large airway functions is expected at the earliest, probably which will be followed by changes in functions of smaller airway. However, the physiological and clinical significance of these findings seems to remain indefinite and needs to be explored more with long term follow up PFT studies with various other parameters like bronchial biopsy, bronchial lavage, hyperresponsiveness to provocation. Further evaluation of PFT among swimmers and its more systematic way of interpretation can be a guiding parameter towards individual risk assessment in developing respiratory disorders.

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