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Original article

Duration Of Swimming Practice Has Differential Effect On Airway Caliber And Muscular Efficiency

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ABSTRACT

Swimming, by increasing the airway caliber and muscular efficiency brings about enhanced pulmonary function. However, the effect of duration of swimming practice on these effects is sparsely evaluated and the present study attempts to address this aspect. Pulmonary function test was conducted among healthy male (20-30 years) volunteers who were regular swimmers (n=51) and was compared with controls (n=51)who practiced athletic events but not swimming. Swimmers (23.52 ±1.87 years) were significantly younger than controls (24.39 ± 2.22 years) with 5.33±1.82 years of swimming practice. Swimmers exhibited increased VC, FVC, FEV_1, PEFR, MEF25%, MEF50%, MEF25/75% than controls. Swimmers demonstrated a significant positive correlation between duration of swimming practice and airway caliber (FEV_1, MEF25%, MEF50%, MEF25/75%), whereas, muscular efficiency (VC and PEFR) did not demonstrate any correlation. This demonstrates that, airway modulation takes place proportionately with duration of swimming practice. Contrary, muscle efficiency did not showed such behavior, thereby, a ceiling effect on skeletal muscle efficiency could be expected with prolonged duration of swimming practice.

KEYWORDS: Swimming, Pulmonary function, airway caliber, skeletal muscle efficiency.

INTRODUCTION

Development, growth and functions of respiratory system are influenced by both genetic and environmental factors. The critical period where the peak functional changes are brought about is from adolescent to adult age. During this period of life, nutrition and physical activity imparts a strong influence on lung functions [1,2].

Swimming is considered to be the most elusive sporting activity that has a greater impact on pulmonary functions [1,3]. This sporting event is unique in itself where all the group of muscles are recruited, and their synchronized action brings about an optimal effect on various physiological functions of which pulmonary system is influenced most. Hence, swimming is considered to have a stronger effect on various lung volumes and capacities than any other sport [4,5]. Swimming practiced from early age is known to bring about changes in anthropometric features and muscle characteristics. There is a report demonstrating that regular swimming for 10 weeks increases the myosin type 1 fibers and decreases type II fibers thereby enhancing the endurance and muscular efficiency [6]. Further, better coordination between movement of ribs, abdominal muscles, diaphragm during swimming helps to develop an optimized breathing pattern [7,8]. Thereby, lung volumes and capacities tend to be at higher range among swimmers than athletes or individuals practicing any other sports and yoga [9,10].

The efficiency of swimming practice on various lung functions depends on the duration and intensity of practice. If the practice started at an early age the effect seems to be more. Indicators of larger airway caliber like peak expiratory flow rate (PEFR), forced expiratory volume at first second (FEV_1), vital capacity (VC) and indicator of small airway caliber i.e, maximum expiratory flow volume (MEF) increases considerably during the period of growth [12,13,14]. Swimming practice at this critical period of life is known to bring significant enhancement in peak flow rates than the athletic training. Therefore, swimming seems to be useful even among children suffering from asthma [15,16].

However, due to intense practice the remodeling of airways is proposed to be a factor for the beneficial effect of swimming [16,17]. In the present study, pulmonary function was evaluated between swimmers and non swimmers with the hypothesis that the duration of swimming practice has a differential effect on airway caliber and muscular efficiency.

MATERIALS AND METHODS

This is a comparative study done to evaluate the effect of swimming on lung functions in healthy male individuals of 20-30 years. A total of 102 healthy male were divided into 2 groups i.e, Controls (n=51) and swimmers (n=51). Controls were healthy male who practiced other athletic sports in leisure but not swimming. Swimmers practiced swimming regularly for 5 days/week for at least 4 weeks and covered 2000-4000m distance. Recruitment of subjects was from Sports Authority of India (SAI) Bangalore. Subjects from either group who were practicing aerobic exercises, yoga, tobacco smokers were excluded. Participants on medical examination if found to have any skeletal, muscular weakness/deformities, acute or chronic medical disease conditions 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'.

Anthropometric measurements [Height (cm) and weight (kg)] were obtained and BMI (kg/m^2) was calculated. Resting pulse rate and blood pressure was obtained. Measurement of lung volumes and capacities were performed using computerized multifunctional Spirometer (Erich, Jaeger) 1994 model. Before performing the test, flow calibration was set in via a calibration syringe with volume of 1 liter.

After subjects were accustomed to the lab, the pulmonary function tests (PFT) was performed in sitting posture with a nose clip in place and mouth piece of spirometer held in one hand. After maximal inhalation, subjects were instructed to seal their lips around the mouth piece and were asked to exhale with maximum force as hard and fast as possible. They were encouraged to continue exhaling for at least one second and 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 in one second (FEV_1)

Peak expiratory flow rate (PEFR)

Mid Maximum Expiratory Flow Rate (MMEF)

Forced inspiratory volume in first second (FIV_1)

Maximum expiratory flow rate at 25% (MEF25), 50% (MEF50), 25/75%(MEF25/75)

Statistics

Statistics was carried out using SPSS version 18. Unpaired 't' test was used to compare PFT variables between swimmers and controls. Pearson's correlation was carried out to correlate the relationship between height, weight, BMI and duration of swimming with PFT variables. p value <0.05 was considered significant.

RESULTS

In the present study, pulmonary function tests was evaluated and compared between healthy male regular swimmers of 20-30 years age group and age, gender matched controls. Swimmers had a mean of 5.33 ± 1.82 years of regular swimming practice for an average 6 ± 0.8 days a week with 2.29 ± 0.6 hours of practice/day. The total hours of practice /week were about 13.82 ± 3.77 hours.

Age, anthropometric measurements, resting heart rate and blood pressure between the two groups and their comparison are depicted in Table 1. Swimmers were significantly younger than controls. Anthropometric measurements like height, weight and BMI were comparable between both the groups. Resting heart rate (beats/min) was significantly less among swimmers than controls. Whereas, systolic and diastolic blood pressures were comparable.

Comparison of pulmonary function test is given in Table 2. Unpaired 't' test showed significantly higher VC, FVC and FEV_1 among swimmers than controls. Peak expiratory flow rate PEFR (L) in swimmers was almost two times more than controls. It was 4.32 ± 3.78 L in controls and 10.72 ± 2.90 L in swimmers (p = 0.000). Whereas, FIV_1 was comparable between the groups. MEF50 (L/sec) was evaluated to assess the functionality of small airways which was significantly more among swimmers when compared with controls (p=0.000). MEF 25 (L/sec), and MEF25/75 (L /sec) was also significantly more in swimmers (p=0.029).

In the present study, swimmers were significantly younger than controls. There are two important factors which could have resulted in the significant changes in PFT. One, could be swimming practice, two, could be age itself. Therefore univariate analysis of variance test was carried out to assess the contribution of swimming (group difference), age and their interaction towards the observed changes in PFT.

The values of univariate analysis of variables are given in Table 3. Univariate analysis of pulmonary function tests showed a significant group difference across all the parameters except FIV_1. Whereas, none of the parameters demonstrated a significant dependency on age, and group×age interaction also did not showed any significant value. Therefore, this result has demonstrated that the differences of PFT among swimmers when compared to controls could be attributed to swimming practice rather than that of age.

Pearson's correlation was estimated between anthropometric and PFT variables in both the groups. In addition, correlation between the duration of swimming practice and PFT variables was assessed among swimmers. Controls showed a significant negative correlation of MEF50 with BMI (r=-0.34, p=0.0031). Swimmers demonstrated a significant positive correlation between weight and vital capacity (r=0.27, p=0.048) and PEFR (r=0.30, p=0.031). Duration of swimming practice significantly correlated positively with FEV_1 (r=0.48, p=0.001), MEF25 (r=0.304, p=0.04) and MEF25/75 (r=0.35, p=0.01). However, no other PFT variables including VC and PEFR which indicates the strength of respiratory muscles correlated significantly with duration of swimming practice.

Table 1: Comparison of Age, Anthropometric measurements, Resting Heart rate and Blood pressure between controls and swimmers.

Anthropometric measurements	Controls (n=51)	Swimmers (n=51)	t value	p value
Age (years)	24.39 ± 2.22	23.52 ±1.87	1.03	0.037*
Height (cm)	173.23 ± 5.92	174.03 ± 4.83	0.75	0.455
Weight (kg)	68.00 ± 7.37	69.05 ± 5.22	0.83	0.405
Body mass index BMI (kg/m^2)	23.75 ± 2.65	23.82 ± 1.71	0.14	0.888
Heart Rate (beats/min)	74.90 ± 5.95	72.00 ± 0.00	3.48	0.001†
Systolic blood pressure (mm of Hg)	102.86 ± 4.47	102.00 ± 3.93	1.03	0.304
Diastolic blood pressure (mm of Hg)	67.88 ± 5.31	68.78 ± 4.96	0.88	0.378

Data is expressed in mean ±SD .*p value<0.05, † p value<0.001 . Swimmers were significantly younger and showed significantly decreased heart rate when compared to controls.

Table 2: Comparison of pulmonary function test (PFT) variables between controls and swimmers

Pulmonary function tests variables	Controls (n=51)	Swimmers (n=51)	t value	p value
Vital capacity VC(L)	4.33 ± 1.26	5.31 ± 1.45	3.64	0.000†
Forced vital capacity FVC(L)	3.47 ± 1.86	5.02 ± 1.24	4.9	0.000†
Forced expiratory volume in first second FEV_1(L)	2.38 ± 0.89	4.22 ± 0.99	9.74	0.000†
Peak expiratory flow rate PEFR(L)	4.32 ± 3.78	10.72 ±2.90	9.58	0.000†
Forced inspiratory volume in first second FIV_1 (L/sec)	3.45 ± 1.49	3.80 ± 1.40	1.03	0.304
Maximum expiratory flow rate at 25% MEF25 (L/sec)	1.69 ± 0.79	2.81± 1.20	4.40	0.000†
Maximum expiratory flow rate at 50% MEF50 (L/sec)	2.59 ± 1.71	5.55 ± 2.11	7.51	0.000†
Maximum expiratory flow rate at middle 50% MEF25/75 (L/sec)	3.23±4.61	4.78±1.90	2.21	0.029*

Data is expressed in mean ±SD. *p value<0.05,† p value<0.001. Swimmers showed significantly higher VC (L), FVC(L), FEV_1(L), PEFR(L), MEF25 (L/sec), MEF50 (L/sec) and MEF25/75 (L/sec) than controls.

Table 3: Details of Univariate Analysis and Group×Age Interaction of Pulmonary Function Test Variables.

Pulmonary Function Test Variables	Group	Age	Group×Age Interaction
Vital Capacity (VC) (L)	F=(1,102)=12.61,p=0.001	F=(1,102)=6.59,p=0.997	F=(1,102)=3.73,p=0.056
Forced Vital Capacity (FVC) (L)	F=(1,102)=22.48,p=0.000	F=(1,102)=0.91,p=0.763	F=(1,102)=1.55,p=0.215
Forced Expiratory Volume In First Second (FEV_1) (L/Sec)	F=(1,102)=90.03,p=0.000	F=(1,102)=0.00,p=0.999	F=(1,102)=0.21,p=0.644
Peak Expiratory Flow Rate (PEFR) (L)	F=(1,102)=8.05,p=0.000	F=(1,102)=0.08,p=0.775	F=(1,102)=0.043,p=0.835
Forced Inspiratory Volume In First Second (FIV_1) (L/Sec)	F=(1,102)=0.949,p=0.333	F=(1,102)=0.030,p=0.862	F=(1,102)=2.70,p=0.105
Maximum Expiratory Flow Rate At 25% (MEF25) (L/Sec)	F=(1,102)=29.75,p=0.000	F=(1,102)=0.481,p=0.490	F=(1,102)=0.080,p=0.778
Maximum Expiratory Flow Rate At 50% (MEF50) (L/Sec)	F=(1,102)=50.62,p=0.000	F=(1,102)=0.665p=0.417	F=(1,102)=0.868,p=0.354
Maximum Expiratory Flow Rate At 25/75% (MEF25/75) (L/Sec)	F=(1,102)=3.69,p=0.058	F=(1,102)=0.82,p=0.365	F=(1,102)=1.55,p=0.215

Univariate analysis showed significant group effect but interaction between group and age did not showed any significant interaction.

DISCUSSION

In the present study, PFT was compared between healthy male (age between 20-30 years) swimmers and controls. Swimmers demonstrated a significantly higher VC, FVC, FEV_1, PEFR, MEF25%, MEF50%, and MEF25/75% when compared to controls. Interestingly, duration of swimming practice showed a significant positive correlation with FEV_1, MEF25%, MEF25/75% whereas, VC and PEFR did not. Swimmers were younger than controls, therefore age and swimming practice could be two contributing factors for the observed differences in various flow rates. However, no significant interaction between age and group was observed.

This authenticates that the observed differences in lung functions among swimmers is due to swimming practice and not due to statistical difference in the age when compared to controls. Swimming as an endurance activity has enormous positive influence on somatic and systemic growth, where the skeletal features typical to swimmers like being tall for their body mass, increased bi-acromial breadths appear with swimming practice at an early age [3,4,5,6]. In the present study, the average age of swimmers was 23.52 ± 1.87 years with 5.33 ± 1.82 years of swimming practice i.e, they started swimming after puberty. Therefore, we couldn't find significant differences in height between swimmers and controls in our study. However, both static and dynamic lung volumes and flow rates were significantly higher among swimmers than controls.

Static lung functions like VC, FVC are the predictors of muscular efficiency [4,14]. Increase in muscular efficiency among swimmers is attributed to hypertrophy of the diaphragm, which brings about a better co-ordination between rib motion and variations of thoracoabdominal volumes, thus augmenting the swimmers ability to inflate and deflate the lungs. In addition, swimmers have broad chest with increased chest diameter and long trunk which helps to maintain their buoyancy in water [1].

This suggests that swimming practice leads to the formation of an optimized breathing pattern which explains for higher lung volumes found among swimmers when compared to athletes of any other sports and also individuals who practice yoga [8,18]. Our observation of increased static lung functions among swimmers is in accordance with all these studies. Dynamic lung volumes like FEV_1, MEF 25, MEF 50 and MEF 25/75 which are the predictors of airway caliber [1] were also significantly higher among swimmers when compared to controls. Further, PEFR which reflects the strength of respiratory muscles[14] thereby contributing to muscular efficiency in addition to large airway caliber and the degree of airflow limitations was also more among swimmers.

Swimming practice in both adolescent and in adults at least for minimum of 3 months to one year of duration showed increase in PEFR and long duration of practice prevents the age associated attenuation of PEFR and other lung volume and capacities [17,18,19]. Thus, our observation is in accordance to these reports.

Indicators of small airway functions by various mid expiratory flow rates (MEF25%, 50% and MEF25/75%) was also more among swimmers than controls. Similar observation is also reported earlier [16]. Thus, as per earlier reports [20,21] our observations have also shown that both static and dynamic lung volumes are more in swimmers than non swimmers. However, the unique observation was that the indicators of airway function showed significant positive correlation with duration of swimming practice.

Mid expiratory flow rates among swimmers seems not to change until 3 months of swimming practice [15] unlike other indicators of pulmonary functions. This is to infer that MEF is dependent on duration of swimming practice. In the present study, swimmers were practicing for at least 2 hours a day since 5 years. Therefore, increase in duration of swimming practice in our subjects could have had beneficial effect by showing increase in MEF and is corroborated with our correlation results. On the other hand, PEFR and VC, the indicators of muscular efficiency did not show any correlation with duration of swimming practice. Similar observations has been reported earlier, where, irrespective of duration of swimming practice, PEFR was higher among swimmers but significant changes in peak flow rates was observed only after practicing swimming for a minimum of 45 minutes, twice a week for 5-6 weeks [20].

This demonstrates that small airway caliber may be influenced earlier than muscular efficiency. One year of intense swimming practice in prepubertal girls have shown to improve both static and dynamic lung volumes by enhancing the conductive properties of both large and small airways [21]. However, intense training is known to affect and cause maximum remodeling of smaller airways. Animal models and human studies have shown that endurance training is associated with increased inflammatory cells in smaller airway but not the inflammatory activation. This adaptive response with influx of inflammatory cells and apoptosis to increased ventilatory demand aids in remodeling of smaller airways but have no detrimental effect on pulmonary function [22,23]. In addition, increase airway smooth muscle stretch and inflation of lung due to high intensity training remodels the airway smooth muscles by breaking actin-myosin cross bridges and thereby improves small airway caliber [16,23], thereby, causing changes in viscosity, tonicity, or amount of the airway lining fluid. Smaller airway is more elastic in nature than cartilagenous larger airways.

Remodeling of these elastic tissue with swimming practice seems to be more efficient among swimmers than controls and other athletes [16,23] and changes of these elastic tissue takes minimum of 3 months of swimming practice [15]. Thus these observations in animal and humans have demonstrated that elastic tissue of smaller airways gets remodeled with duration of swimming practice. However, the influence of duration of swimming practice on airway caliber among humans is not much studied and the present preliminary observation has shown that duration of swimming practice correlates positively with indicators of small and large airway function.

Therefore, it could be hypothesized that indicators of muscular efficiency undergoes a ceiling effect after certain duration of swimming practice. Whereas, airway caliber is more dependent on duration of swimming practice. However, more longitudinal studies are needed to assess the temporal influence of swimming practice on various factors influencing lung function and the underlying physiological mechanism needs to be elucidated further.

CONCLUSIONS

Though swimming has its beneficial effect on pulmonary functions, it is the airway caliber that seems to change proportionately with the duration of swimming practice. However, muscular efficiency do not increase as swimming practice continues, thereby, a ceiling effect could be expected after certain duration of swimming. Thus, it could be hypothesized that changes brought by long duration of swimming aid in better physiological adaptation for aquatic environment may be for efficient gaseous exchange. However, more studies are warranted for conclusive evidences.

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