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The comparison of dynamic volumes of pulmonary function between different levels of maximal oxygen uptake

Rouholah Fatemi[1], Saeid Shakerian[2], Mohsen Ghanbarzade[2], Abdolhamid Habibi[3], Hadi Fathi Moghaddam[4*]

[1]Department of Physical Education, Islamic Azad University, Dehdasht Branch, Iran.
[2]Assistant Professor Sport Physiology Department, Shahid Chamran University, Ahvaz, Iran.
[3]Associate Professor Sport Physiology Department, Shahid Chamran University, Ahvaz, Iran.
[4]Associate Professor Department of Physiology and Physiology Research Center, Ahvaz Jundishapour University of Medical Sciences, Ahvaz, Iran.

Correspondence author: Dr. Hadi Fathi-Moghaddam, Department of Physiology, School of Medicine & Physiology Research Center, Ahvaz Jundishapur, University of Medical Sciences, Ahvaz, Iran. Post code: 61357-33118. Ahvaz, Iran. Tel 0098-61-336-7543, Fax: 0098-61- 3330074, E-mail: hfmoghaddam@ajums.ac.ir and hfmoghaddam@yahoo.com

ABSTRACT: Maximal oxygen uptake (VO_{2max}) and pulmonary function may have a close correlation, but few studies have been done in comparison of pulmonary function in different levels of VO_{2max}. The aim of this study was to compare the dynamic volumes of pulmonary function between different levels of maximal oxygen uptake. In order to achieve the purpose of the study, 51 healthy male subjects (age 19-24) participated in this study. After determination of their level of maximal oxygen uptake based on Subjects VO_{2max} levels, they were assigned to A; high (49.76 $ml.kg^{-1}.\ min^{-1}$), B; mean (39.24 $ml.kg^{-1}.\ min^{-1}$) and C; low (27.51 $ml.kg^{-1}.\ min^{-1}$) VO_{2max} groups. The study protocol used in order to measure VO_{2max} level was sub-maximal incremental Astrand–Rhyming test on Ergometr Cycle. The pulmonary function indexes that include Force Expiratory Volume in One Second (FEV1), Forced Vital Capacity (FVC), and FEV1/FVC were measured by digital spirometry. The data were analyzed through one way analyze of variance (ANOVA). Results showed that there was significant difference between FEV1, FVC and FEV1/FVC in different levels of VO_{2max} ($p<0.001$). Based on the results, it can be concluded that dynamic variables of pulmonary function are associated with VO_{2max} levels, and can limit aerobic capacity.

Keywords: Aerobic capacity, Maximal oxygen uptake, Pulmonary Function, Spirometry

Introduction

Maximal Oxygen Uptake

Maximal oxygen uptake (VO_{2max}) is defined as the highest rate at which oxygen can be taken up and utilized by the body during severe exercise.[1] The term "maximal oxygen uptake" was coined and defined by Hill et al (1924, 1966)[2,3] and Herbst in 1928s.[4]

The capability for maximum O_2 transport (or the product of arterial O_2 content blood flow) to the working locomotors muscles and, in turn, diffusion from muscle capillaries to mitochondria are major determinants of VO_{2max} in the muscle, of peripheral muscle fatigue, and, by implication, of exercise performance.[5] However it has been suggested that 70–85% of the limitation in VO_{2max} and aerobic capacity is linked to maximal cardiac output.[6,7] Then the cardio-respiratory system,[8,9,10] peripheral diffusion gradient[11] and mitochondrial content and O_2 transport capacity can limit the VO_{2max}.[12] Several studies have been observed a close relationship between poor muscle condition and maximal aerobic capacity (VO_{2peak}).[13-16]

Respiratory function is a limiting factor rigorously limiting the aerobic working capacity and VO_{2max} in those conditions that referred to obstructive airway disease, increased resistance of breathing, or inhalation of gas mixtures of higher density.[17-19]

Pulmonary function

Airway obstruction and narrowing, leading to abnormal ventilation distribution, could lead to the widened alveolar-arterial oxygen difference (A-aDO_2) seen during incremental exercise.[20] FEV1 is a valuable factor for the assessment of airflow obstruction if defined as a ratio of whole expiratory air; the normal rate of this ratio is 75%- 85% of FVC volume. In healthy individuals, FEV1 is more than 80% of FVC.[21] A fall of 10% or greater in FEV1 post-exercise is diagnostic for exercise-induced asthma (EIA).[22,23] Tone (1999) showed that pulmonary function variables predict 30 percent of the variance of peak exercise capacity.[24]

Dempsey (2006) states "a carefully selected combination of increased frequency and tidal volume must be achieved, taking into account the need to minimize dead space ventilation (i.e., the increase in breathing frequency should not be excessive)[25]. Decreasing in pulmonary variable levels is affected by increased airway resistance[16] that could increase the ventilation-perfusion ratio (VA/Q) in the lung and may lead to a drop in partial pressure of arterial oxygen content (PaO_2).[5,26] However no significant differences between pre and post values were observed in VO_{2max} after inspiratory muscles training.[27]

Interaction of VO2max and Pulmonary Function

The dynamic factors of pulmonary function depend on different variables such as age, physical activity level, environments pollutants, body composition and prolong disease of the lunges.[20,26,28-30] Tone (1999) showed that any increase in VO_{2max}, is due to increases in FEV1 volume.[24] It has been suggested that longitudinal changes in VO_{2peak} are associated with changes in lung function.[31] Evidence clearly supports the importance of exchanging high volumes of air (VE) to maintain PaO_2 and hemoglobin saturation.[32] Other results suggest that deterioration in lung function in children with CF might also points to a significant decrease in peak exercise capacity.[31] Athletes with respiratory system limitations experience major impairment during exercise or competitionsin hypoxic environments.[5] Kohl (1997) indicated that changes in functional respiratory after running competitions may have their roots in the fatigue of respiratory muscle, pulmonary obstruction, pulmonary edema, closing of small air ways and changes in pulmonary blood volume.[33] This type of airway remodeling combined with the presence of possible VA/Q mismatching can contribute to exercise-induced hypoxemia (EIH).[26]

Regarding to the importance of pulmonary function and VO_{2max} in athletic performance and close relationship between these variables (according to mentioned literatures) celerity this relation seems be necessary because of lack study in this area; so, the main purpose of the present study was to compare dynamic volumes of pulmonary function between different levels of maximal oxygen uptake in young people.

Materials and Methods

Subjects

Fifty one male subjects who volunteered for participation in this study were recruited as study sample initially. All subjects (age 19-24 years) were fit, physically active, healthy and nonsmoker students with no history of cardiovascular and respiratory problem that studied at Shahid Chamran University of Ahvaz in Iran. The study was approved by the University Research Ethics Board. Before the administration of the tests, subjects completed health and physical activity level forms. After determination of the levels of maximal oxygen uptake of all subjects, based on subjects VO_{2max} level, fifty one subjects were selected and assigned in to 3 groups: high VO_{2max} (49.76 $ml.kg^{-1}.min^{-1}$), mean VO_{2max} (39.24 $ml.kg^{-1}.min^{-1}$) and low VO_{2max} (27.51 $ml.kg^{1}.min^{-1}$) groups (A, B and C) according to Astrand-Ryming ranking of maximal oxygen uptake (see figure1). The chosen subjects had a mean (±SD) age of 22.1±2.4 years, a mean height of 174.4± 6.3 cm, mean mass of 72.4± 9.7 kg and a mean VO_{2max} of 38.8± 9.8 $ml.kg^{-1}.min^{-1}$. All subjects completed an informed consent form before participating and completing in this study.

Methods and Protocols

Each subject performed two protocols (incremental exercise test on ergometer cycle to measuring the VO_{2max} and spirometery test for measuring pulmonary variables values). Tests were performed in the laboratory maintained at 24-26°C between 10 and 12 AM. The subjects had no history of any major

diseases and were not under physical training program and/or any medications. All were informed about the purpose, requirements and the experimental protocol of the investigation. Experimental procedures were demonstrated to allay their apprehension. Height and weight of the subjects were measured with the help of height measuring stand and weighing machine (Krups Company Manufacture by Dr Beli Ram and Sons, 17 Asaf Ali Roads, New Delhi). Body weight was measured to an accuracy of ± 0.25 kg and height to an accuracy of ± 0.5 cm.
Dynamic variables of pulmonary function (FEV1, FVC and FEV1/FVC) were measured by digital spirometery (Digital Spirometery, model JAEGER, USA). To measure FVC, each subject bellowed into the instrument with maximum force after full inspiration; three readings were taken and the best was recorded. The volume of air that expired in first one second of FVC is defined as FEV1 (see figure2). Spirometry included FEV1, FVC and FEV1/FVC were done before Astrand-Rhyming test.

The standard exercise protocol for this study was submaximal Astrand-Ryming protocol on monark cycle. Duration time of this test, according to the subjects' heart rate, was at least 6 minutes while it might last more than 6 minutes. The initial load to beginning the test on cycle was 98/1 watt. In the case that in the first 2minute, heart rate was less than 60% heart rate maximum (HRmax), the load increased 49 watt per 2 minute; whereas if heart rate was in 60-70% HRmax, the load increased 24.5 watt per 2 minutes. If heart rate rose above 70% HRmax, test lasted without load change until the heart rate reached steady state and test finished.

Statistical Analyses

Group results are presented as Mean±SD. Spirometric data were presented as a liter and percent values. Statistical analysis was performed using correlation Spearman coefficient for determining of relationship between pulmonary variables and VO_{2max}. One Way Analysis of Variance (ANOVA) used for the comparison of these parameters in three levels of VO_{2max}. Values of $p<0.05$ were considered significant. Statistical analyses were performed using the SPSS version 17 for Windows.

Results and Discussion

All enrolled subjects agreed to participate and successfully performed the tests. There was no exclusion or complication in this series. In this study, in order to highlight the relation between pulmonary function and maximum oxygen uptake, we decided to select subjects with wide ranges of VO_{2max} (min, 22.52 $ml.kg^{-1}.min^{-1}$; max, 55 $ml.kg^{-1}.min^{-1}$). Results are shown as mean ± SD. Table 1 summarizes the characteristics of the study group.

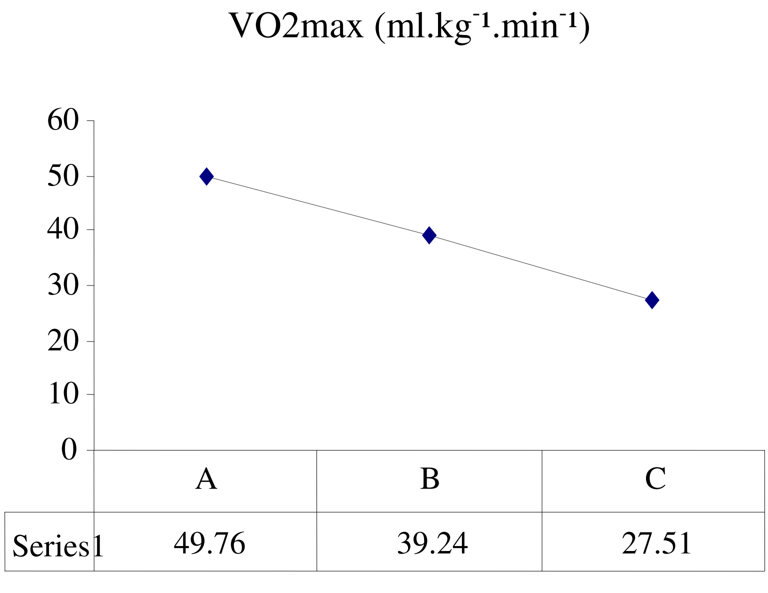

Figure1.Comparison of VO_{2max} between three groups

The results showed that the difference between FEV1/FVC and FEV1/FVC in three levels of VO_{2max} is statically significant with 4.03, 3.34 and 2.88 liter FEV1 in A, B and C groups respectively. Also 4.36, 3.92 and 3.60 liter FVC and 0.83, 0.72, 0.70 liter FEV1/FVC were recorded respectively for A, B and C groups (Table 2, Figure 3). However we observed that differences were larger between A and C group and were smaller between B and C group.

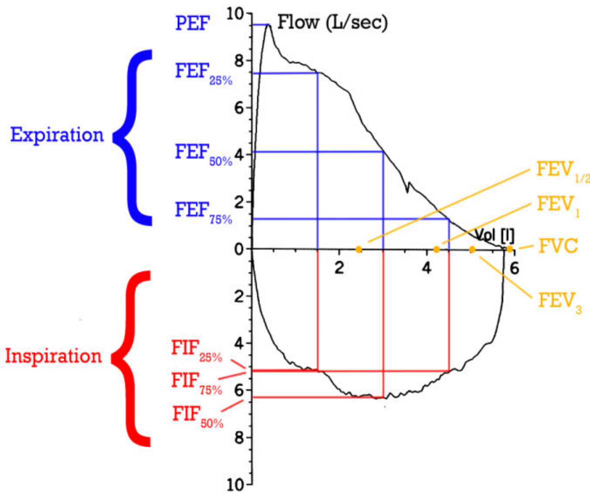

Figure2. Diagram of Forced FVC and FEV1.

Table1. Subject characteristics and pulmonary function

Variables	*mean ± SD*
Age, yr	22.1± 2.47
Weight, kg	72.48± 9.72
Height, cm	174.44± 6.38
FEV1, lit	3.41± .66
FEV1, % predicted	87.66± 8.78
FVC, lit	3.96 ± .56
FVC, % predicted	75.28± 8.33
FEV1/FVC, lit	.84± 5.91
VO_{2max}, ml.kg^{-1}.min^{-1}	38.83± 9.80

FVC=Forced vital capacity; FEV1=Forced expiratory volume in one second; VO_{2max} =Maximal oxygen consumption

Table2. Values of pulmonary variables of three groups

Subjects / Variables(mean ± SD)	A	B	C
FEV1.lit	4.03±0.40	3.34±0.45	2.88±0.54
%FEV1	93.46±9.35	88.20±7.46	81.70±5.05
FVC.lit	4.36±0.41	3.92±0.44	3.60±0.55
%FVC	83.01±7.45	72.60±6.33	70.08±4.50
FEV1/FVC	90.78±4.32	82.83±3.68	80.00±3.48
VO2MAX. ml.kg^{1}.min^{-1}	27.51	39.24	49.76

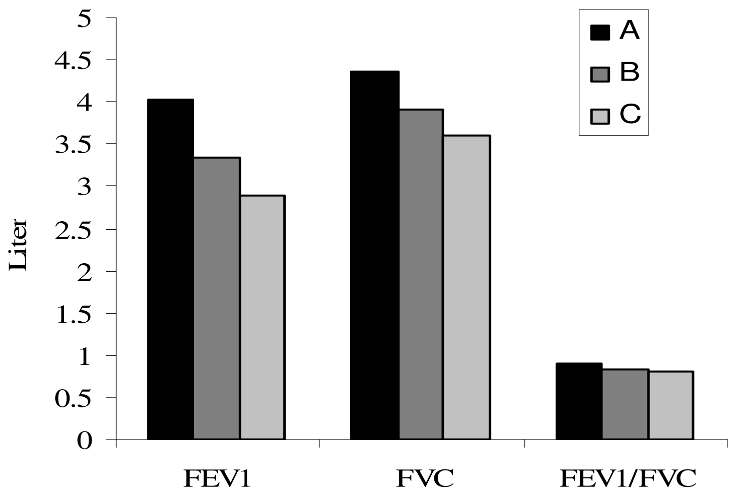

Figure3. Comparison of pulmonary variables between three groups

There are not many studies available that clear relationship between pulmonary function and VO_{2max} and compare the dynamic variables of pulmonary function in various sport fields. The aim of this study was to compare the dynamic volumes of pulmonary function between different levels of maximal oxygen uptake. Various factors such as genetic predisposition, air pollution, occupational exposure, airway hyper-responsiveness, asthma, atopy, or chronic mucus hyper-secretion have also been associated with an increased risk for decrease in dynamic ventilatory parameters and increasing airway resistance.[34,35] The most salient finding of our study is the significant difference between dynamic parameters of pulmonary function and VO_{2max} in young subjects. Researchers should be cautious in making immediate conclusions, for such variables as relatively smaller lung sizes would inevitably alter statistical analyses. Such subjects would have smaller airways and blood vessels which could accentuate any regional homogeneities differences in the distribution of air and blood flow.[36] A direct relation between the decrease in maximum aerobic capacity and FVC has also been reported.[37]

In addition to these findings, some researchers demonstrated that improvement in ventilatory system, aerobic capacity and VO_{2max} showed after surgery in emphysema and Cystic Fibrosis (CF), patients and poor lung function in these conditions is associated with reduced aerobic performance.[38-40] However, Moorcroft and colleagues (1997) reported a decline in absolute and predicted values of FEV1 in adult patients with CF not associated with aerobic capacity.[41]

According to the findings of Daniel (2008), the ability to ventilate large volumes of air at maximal exercise is important in attaining high VO_{2max} values.[42] It was demonstrated that high VE becomes a necessity because of the widening of the alveolar-arterial oxygen difference, thus creating a greater demand for alveolar ventilation to maintain arterial O_2 pressure and saturation.[5] Oxygen demands of exercising muscle may exceed the ability of the lungs to maintain arterial O_2 pressure, resulting in hemoglobin desaturation,[43] so ventilator system may effect on aerobic capacity.

Williams et al (2002) showed that specifically training the respiratory muscles using a Power lung resistance device lead to improvement of aerobic enzymes consequently improvement in aerobic performance.[44] Most aerobic athletes have very well trained respiratory muscles from their sport alone. These findings were supported by other studies.[45-47] However this studies find no significant increasing in VO_{2max} following respiratory muscles training. May be the short time of their time period of training was inadequate for change inVO_{2max} as their pulmonary muscles are already developed. Dempsey et al (1984) showed that elite athletes are more likely to undergo arterial O_2 desaturation during maximal work compared with average individuals.[48] Pulmonary limitation in highly trained athletes can be overcome with O_2-enriched air.[49]

It has been clear that exercise training inducement influences pulmonary function, as well as VO_{2max}.[20,31,50] It has also been observed that physical conditioning improves the FVC and Inspiratory Capacity (IC) of patients, and positively influences the maximum aerobic capacity with improvement.[37]

In spite of divergent scholarly views, it had been documented that higher FEV1/FVC ratios equate to lower airway resistance and better pulmonary function. Fatemi (2010) has shown that aerobic exercise

can leads to the presenting bronchospasm.[16] Furthermore, such a condition may result in differences in aerobic capacity for endurance athletes, which gives rise to inherent advantages for that athletes.[51-53]
This study emphasizes the fact that dynamic pulmonary variables have close interactions with maximal oxygen uptake and they are different in levels of VO_{2max} and these parameters may predict the level of aerobic performance of individuals. Our results support the hypothesis that pulmonary limitation can limit the aerobic capacity and athletic performance.

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