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ZAHRA HEMATI FASANI, MOHSEN GHANBAZADEH, SAEED SHAKERIAN, MASOUD NIKBAKHT, ABDOLHAMID HABIBI
Department of Sport Physiology, School of Physical Education & Sport Science,
Shahid Chamran University of Ahwaz, Iran

EFFECTS OF AEROBIC TRAINING ON AIRWAY RESISTANCE IN SMOKING AND NON-SMOKING MALES

Key words: aerobic exercise, smoking, FEV1, FVC.

ABSTRACT

The purpose of this study was to investigate the effects of a six-week aerobic training program (interval running) on such pulmonary function indexes as FEV1 (Forced Expiratory Volume in 1 Second), VC (Vital Capacity), FVC (Forced Vital Capacity) and FEV1/FVC in smoking and non-smoking male subjects. Twenty-eight male employees from the Bushehr Municipality and Alzahra Hospital, Iran took part in the study and were divided into two groups: smokers and non-smokers. The smokers had been smoking 7-20 cigarettes per day for more than 4 years. The subjects completed health level and smoking rate questionnaires, and then their body height, body mass and pulmonary factors were measured in the pre-test phase. Independent t-tests were performed regarding the pulmonary indexes at the level of statistical significance set at $p < 0.05$. The results revealed significant differences between the pre-test and post-test FEV1 and FVC in the smoking group ($p < 0.05$); a significant difference between pre-test and post-test FVC in the non-smoking group ($p < 0.05$); and no significant differences between pre-test and post-test FEV1 in the non-smoking group ($p > 0.05$). The results also showed no significant differences in post-test pulmonary variables between the two groups of subjects.

INTRODUCTION

Airway resistance is a concept used in respiratory physiology to describe mechanical factors which limit the access of inspired air to the pulmonary alveoli, and thus determine airflow. Resistance is greatest at the bronchi of intermediate size, in between the fourth and eighth bifurcation. Because airway resistance is dictated by the diameter of the airways and by the density of the inspired gas, the low density of heliox reduces airway resistance, and makes it easier to ventilate the lungs. Forced Vital Capacity (FVC) and Forced Expiratory Volume in 1 Second (FEV1) are two of the most important parameters in the airway resistance of tracheal duct. Alveolar destruction, small airways obstruction, big airways alternation and mucosal gland hypertrophy of bronchioles are harmful effects of smoking on the pulmonary system [9]. Other side effects of smoking include wheezing, sputum and hard breathing [11]. Considering the fact that the pulmonary and cardiovascular systems are the most essential systems of the human body, quitting smoking is the best way to prevent smoking-related diseases. Also appropriate exercise can be useful in decreasing the risk of pulmonary diseases [3]. It can prevent more cardiopulmonary diseases or at least delay their incidence [2].

Correspondence should be addressed to: Mohsen Ghanbarzadeh, Department of Sport Physiology, School of Physical Education & Sport Science, Shahid Chamran University of Ahwaz, Iran, tel: +98 611 3738535, fax: +98 611 3336316; e-mail: ghanbarzadeh213@gmail.com

Studies show that physical activity and regular exercise (e.g. running) lead to an improvement in the performance of ventilatory muscles and that physically inactive subjects cannot deliver an appropriate pulmonary performance [16]. De and Tribathi [18] carried out a study of pulmonary function of 10 smoking athletes, 17 non-smoking athletes and 41 non-smoking non-training subjects by means of FEV1, FVC, FIV1/FVC and Peak Expiratory Flow (PEF) assessment. In smoking subjects the test was performed before and 30 minutes after smoking two cigarettes in order to assess the acute effect of smoking on the lungs performance. No significant differences were noted between the pre-test and post-test of pulmonary variables in smoking athletes. Before smoking the cigarettes the performance of smoking athletes was lower than non-smoking athletes, however, their pulmonary performance was better than the performance of non-training smokers. Holmen et al. [10] assessed the effects of endurance training of different intensities (low, moderate and high) on pulmonary function in smoking and non-smoking subjects. They showed that with increasing exercise intensity in non-smoking subjects the FEV1 and FVC values increased as well. Their results also revealed that smoking subjects achieved higher FEV1 values in moderate intensity exercise than in low intensity exercise, and that non-smoking athletes (regardless of exercise intensity) had higher FEV1, FVC and $FEF_{50\%}$ values in comparison with non-training subjects. Goic-Barisic et al. [6] studied exposure to a smoky environment and its influence on the lung performance of athletes and found significant differences in FVC, FEV1, $FEF_{50\%}$ and $FEF_{25\%}$ between those athletes who were exposed to a smoky environment and those subjects who were not. Morton and Holmik [15] examined effects of smoking on the maximum oxygen uptake and physiological responses of elite athletes and concluded that smoking elite athletes had lower FEV1 and FVC than non-smoking elite athletes. Physical training results in an improvement in pulmonary function and protects against harmful effects of smoking.

The purpose of this study was to investigate the effects of a six-week aerobic training program on such pulmonary function indexes as FEV1 (Forced Expiratory Volume in 1 Second), VC (Vital Capacity), FVC (Forced Vital Capacity) and FEV1/FVC in smoking and non-smoking non-training male subjects. It also aimed to determine whether aerobic exercise had a greater effect on smokers' or non-smokers' pulmonary function.

METHODS

Subjects

Twenty-nine non-training male employees of the Municipality and Alzahra Hospital of Bushehr in Iran, aged 40.79 ± 1.12 years, with the mean body height of 173.21 ± 5.26 cm and mean body mass of 75.06 ± 1.12 kg took part in the study. The sample was divided into a smoking group (n = 14) and a non-smoking group (n = 15). The smoking group included men who had been smoking about 7-20 cigarettes per day for more than 5 years. Data was gathered by means of a questionnaire and quantity measures. The questionnaire provided information about participants' injury history, number of cigarettes smoked a day, cigarette types, history of smoking and individual characteristics.

Spirometry

Spirometric tests were performed in a laboratory in a temperature of 24 to 26° C, between 7 and 8 pm. Following spirometric calibration and entering individual data to the measuring device (Digital Spirometer, Jaeger, USA), FVC, FVE1 and FEV1/FVC were calculated. Three readings were taken from each subject and the best one was recorded.

Training protocol

The training protocol was a six-week aerobic training program. Each session included a 5-10 min warm-up, 25-35 min of jogging and interval running, 10-15 min of light exercise and a cool down period. The protocol was administered 2 sessions per week for 6 weeks.

Statistical analysis

The results in both groups of participants were presented as mean values ± SD. Statistical analysis used a dependent t-test in order to compare pre- and post-test values, and an independent t-test to compare the results in the two groups after the training protocol. The level of statistical significance was set at $p < 0.05$. SPSS ver. 16 for Windows was used for all statistical calculations.

Table 1. Characteristics of smoking and non-smoking subjects

Body height (cm)	M	SD	f	Min.	Max
Smokers	172.43	4.38	14	164	182
Non-smokers	173.93	6.02	15	159	182
Body mass (kg)	M	SD	f	Min.	Max
Smokers	72.42	1.04	14	57	93
Non-smokers	77.53	1.18	15	60	97
Age (years)	M	SD	f	Min.	Max
Smokers	42.14	4.28	14	32	48
Non-smokers	39.53	3.75	15	34	47

Table 2. Pulmonary function variables in smokers and non-smokers

Smokers		Non-smokers	
Variable	Mean ± SD	Variable	Mean ± SD
FVC	5.54 ± 0.60	FVC	6.08 ± 1.04
FVC%	73.70 ± 2.09	FVC%	66.80 ± 1.43
FEV1	4.63 ± 0.55	FEV1	5.20 ± 1.10
FEV1%	82.25 ± 2.24	FEV1%	74.55 ± 1.50

Table 3. Comparison of pre-test and post-test FVC, FEV1 in smokers and non-smokers

Pulmonary Function	Stages	Mean	SD	*t*	*df*	*p*
FVC/Smokers	Pre-test	5.14	0.59	9.88	13	0.001
	Post-test	5.54	0.60			
FVC/Non-smokers	Pre-test	5.74	1.03	7.52	14	0.001
	Post-test	6.08	1.04			
FEV1/Smokers	Pre-test	4.63	0.55	2.39	13	0.033
	Post-test	4.46	0.50			
FEV1/Non-smokers	Pre-test	4.63	0.55	2.00	14	0.065
	Post-test	5.20	1.10			

Table 4. Comparison of post-test FVC and FEV1 between smokers and non-smokers

Pulmonary Function	Stages	Mean	SD	*t*	*df*	*p*
FVC/Smokers vs. Non-smokers	Pre-test Post-test	5.54 6.08	0.60 1.04	1.69	27	0.102
FEV1/Smokers vs. Non-smokers	Pre-test	4.63	0.55	1.75	27	0.09

RESULTS

Tables 1-4 present the test results. The results show that the six-week aerobic training (interval running) resulted in a significant improvement in FEV1 and FVC in the smoking subjects ($p < 0.05$). The results also revealed that the FVC of non-smoking subjects increased significantly after the test ($p < 0.05$). However, no significant differences were found in FEV1 in non-smoking subjects between the pre-test and post-test values ($p > 0.05$). No significant differences were noted in post-test FEV1 and FVC between the smoking and non-smoking groups ($p > 0.05$).

DISCUSSION

McCully and Faulkner [13] studied the force-length relationship in excised diaphragmatic muscle bundles from five male species and demonstrated that the relationship for the diaphragm is essentially similar to that for limb muscles. The force developed by a skeletal muscle bundle during isometric contraction in vitro is well known to vary as a function of the length of the muscle. Specifically, as the length of the muscle bundle increases, active force increases gradually until a maximum is reached, and it then decreases again; the length corresponding to the maximum active force is usually referred to as the optimal length (L_o). The force developed by the diaphragm in vivo cannot be measured directly. Instead, it is usually evaluated by measuring the pressure difference between the abdominal side (Pab) and the pleural side (Ppl) of the muscle, i.e., trans-diaphragmatic pressure (Pdi) [17].

The results of the present study show that aerobic exercise results in a significant increase of FVC in smoking and non-smoking subjects. These results are in agreement with the findings of Mickleborough, Gupta, Alberti, Cheng, Adegoke, MacAuley, Tripathi, Hagberg and Ghosh. FEV1 is one of main indices of expiratory airway resistance and lung capacity and it is related to the lung elastic and airway resistance. According to the findings, lung compliance, airway resistance between alveolar branches and the narrowed region are the main physiological factors affecting airflow in this phase. It seems that the post-exercise increase in FVC is related to an increase in lung capacity and elasticity. In addition, the power of intercostal muscles also affects FVC, thus the improvement in the power and endurance of these muscles leads to an increase in FVC. Aerobic exercise also increases the power and endurance of ventilatory muscles [14, 7, 2, 4, 1, 12, 18, 8, 5].

Other findings of the present study show that a six-week aerobic exercise program causes a significant increase in FEV1 in smoking subjects. The non-smokers' FEV1 also increased after exercise; however, this change was non-significant. These results correspond to those of Mickleborough, Gupta, Alberti, Cheng, Adegoke, MacAuley, Tripathi, Hagberg and Ghosh. Lung elasticity and compliance, airway and elastic resistance between alveolar branches and the narrowed region are the main physiological factors affecting airflow in this phase. These mechanisms increase elastic tension, decrease resistance, and increase the airflow rate in definite volume [14, 7, 2, 4, 1, 12, 18, 8, 5].

Aerobic training does not only improve lung capacity but also increases lung elasticity. Moreover, because of the improvement in the intercostal muscle power, the forced expiratory volume increases as well. It seems that all these parameters and mechanisms have a major effect on the increase in FEV1 and FVC in smoking subjects. The findings of the study indicate that physical activity can improve pulmonary function by affecting the nervous system, ventilatory muscles endurance and power, increasing lung dimensions, decreasing the stiffness of lung walls and preventing obesity and accumulation of fats on lung tissues. In addition, aerobic training decreases the amount of toxic materials caused by smoking that remain in the airways, through increasing ventilatory diffusion, and thus recovering the ventilatory system in smokers. However, the role of the nervous system in pulmonary function through aerobic training still requires further research.

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