ejpmr, 2018,5(8), 182-187

SJIF Impact Factor 4.897

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Research Article

ISSN 2394-3211

EJPMR

DOES CIGARETTE SMOKING AFFECT PULMONARY FUNCTION RESPONSE TO AEROBIC EXERCISE TRAINING?

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Article Received on 15/06/2018 **Article Revised on 05/07/2018** **Article Accepted on 25/07/2018**

ABSTRACT

Objective: Impaired pulmonary functions in cigarette smokers have been clearly evident. Aerobic exercises are known to improve pulmonary functions in nonsmokers. The aim of the present study was to determine the impact of cigarette smoking on pulmonary functions after aerobic training. **Materials and Methods:** Twenty-three cigarette smokers and twenty-five nonsmokers from Prince Sattam bin Abulaziz University students were divided into two groups. The Group A subjects included 23 cigarette smokers and group B included 25 nonsmokers. Subjects in both groups underwent an 8-week aerobic exercise program at 70-80% of maximum heart rate. Pulmonary functions, peak oxygen consumption (VO_{2peak}) and anthropometric measures were assessed at baseline and at the end of the program. **Results:** Group A subjects showed no significant differences between baseline and post-test values of pulmonary functions, VO_{2peak} or anthropometric measures except for maximum voluntary ventilation (MVV) that showed significant increase ($p<0.05$). Group B subjects showed significant differences between baseline and post-test values of pulmonary functions and VO_{2peak}. Also, there was a significant positive correlation between MVV and VO_{2peak} in both groups. **Conclusion:** Cigarette smoking counteracts the beneficial effect of aerobic exercise training on pulmonary functions in sedentary healthy smokers. Our data suggest that cigarette smokers are advised to quit smoking immediately in order to avoid further pulmonary damage and to benefit from exercise programs.

KEYWORDS: Aerobic; Exercise; Lung function, Smoking.

INTRODUCTION

Tobacco use and particularly cigarette smoking is an offensive attitude that has spread worldwide as the plague.[1] The global mortality due to smoking may reach 10 million annually by 2030 with about two thirds of this figure is taking place in the developing countries. About 13.5% of Saudi university students are cigarette smokers while they are about 17.5% in the general Saudi population.[2] Taking into consideration the so many dangerous diseases related or directly caused by smoking, these figures are quite frightening.

Pulmonary functions are considered as an indicator of general health assessment. It has been shown that lung growth and function are decreased due to smoking as smokers usually begin this disgraceful habit when they are adolescents.[3,4] The risk for decreased pulmonary functions is related to number of cigarettes smoked per day with the decline in $FEV_1$and the FEV_1/FVC ratio directly related to the smoking index. There is an evident association between impaired pulmonary functions and increased mortality and morbidity in smokers.[5]

Aerobic exercise has been defined as "any activity that uses large muscle groups, can be maintained continuously, and is rhythmic in nature." It is an important component in pulmonary rehabilitation programs for patients with lung diseases. When muscles are exercised aerobically, they depend on the process of aerobic metabolism to get ATP from different metabolic sources. Walking, jogging, swimming, cycling, and dancing are the most common aerobic exercises.[6]

Improvement in lung function after exercise training could be due to improved development of the respiratory musculature. Several studies reported a positive association between pulmonary functions and exercise training.[7] Pulmonary function decline in smokers has been found to be attenuated by regular training.[8,9] Forced vital capacity was shown to be increased in physically active young subjects between the ages of 13–27 years. Middle aged male smokers have been found to have greater lung function decline during a seven year study than counterpart nonsmokers.[10]

Several studies reported improvement in pulmonary functions in response to aerobic training in both normal subjects[10] and in patients with different lung diseases including COPD,[11] bronchial asthma[12,13] and cystic fibrosis.[14] However, previous studies on the effect of exercise on pulmonary functions especially in smokers are infrequent.

Studying the pulmonary function responses to exercise training in smokers and nonsmokers is essential in setting the rehabilitation programs for smokers whether they are apparently healthy or patients with cardiopulmonary diseases.[15] Therefore, the aim of this study was to determine the impact of cigarette smoking on pulmonary functions in university students.

MATERIALS AND PROCEDURES

Subjects

This study made use of 80 smoking and nonsmoking male university students. Subjects were recruited from Prince Sattam bin Abdulaziz University during October and November 2017. All subjects were basically examined by a physician to evaluate general health, past medical history and anthropometry. Sixty-eight subjects were enrolled according to the eligibility criteria. All subjects were sedentary meaning they were not exercising more than 30 min and not more than 2 days per week. Subjects aged 17 to 23 years. Smoking subjects were moderate smokers (20-40 cigarettes per day). Smoking subjects were advised to maintain their smoking rate during the study period. Exclusion criteria included obesity, respiratory, cardiac, neurological or orthopedic disease that may limit the subject's ability to perform aerobic exercise. Subjects provided informed consent after procedures and also the study risks were explained to them. Subjects were assigned to smokers group (group A) comprised 34 smoking subjects and nonsmokers group (group B) comprised 34 nonsmoking subjects.

Procedure

Anthropometric measurements

A weight and height scale (Detecto, made in USA) was used to measure heights and weights of all subjects. Weights were measured in kilograms and to the nearest 0.1 kg. Heights were measured in centimeters and to the nearest 0.5cm. After calculating BMI for each subject, only those with BMI less than 25 kg/m^2 were selected.

Lung function

Spirometric tests were performed to assess forced vital capacity (FVC), forced expiratory volume in in the 1st (FEV_1), forced expiratory volume in the 1st second/forced vital capacity FEV_1/FVC%, forced expiratory flow at 25% and 75% of forced vital capacity (FEF_{25-75}) and maximum voluntary ventilation (MVV) using a stationary CPET system (Quark CPET, COSMED, Italy).

Each subject has to place a mouthpiece into the subject's mouth and tightly closing lips around it. A nose clip was used while a subject in an erect sitting position during the test maneuvers. All tests were carried out for all subjects at baseline and after the intervention period. FVC and MVV maneuvers were performed for all subjects according to standardized parameters.[16]

Aerobic function

To determine VO_{2peak} modified Balke protocol was performed for each subject using a CPET system (Quark CPET, COSMED, Italy) with a motorized treadmill (h/p/cosmos, Pulsar 4.0, Nussdorf-Traunstein, Germany). The system flow sensor was calibrated using a 3-L syringe, and CO_2 and O_2 sensors were calibrated against known gases before each test. Maximal effort was ensured by reaching volitional exhaustion. Verbal encouragement was used for all subjects throughout the test. VO_{2peak} was recorded if O_2 plateau is reached or heart rate reached 10 b/min within the expected maximum level or respiratory exchange ratio $\geq$1.10.[17]

Aerobic exercise program

All subjects performed 3 sessions per week for 8 weeks. The session started with 10 minutes warming-up, 10 minutes cooling down with the main session component included 30 minutes of continuous aerobic exercise on a treadmill (Runrace 900, Technogym, Gambettola, Italy) at 70%-80% of the subject's maximum heart rate. Using a Polar heart rate device (Polar Electro TM, Kempele, Finland) heart rate and the exercise intensity was monitored.

Statistical procedure

The SPSS software version 16 was used to perform the statistical analysis. All values were reported as mean ± sd. To determine the within group changes from pre- to post-test, dependent paired t-test was used. Independent t-test was applied to determine changes in post-test values between both groups. Association between VO_{2peak} and MVV was determined using Pearson correlation coefficient. Data were considered statistically significant if $p<0.05$.

RESULTS

Seven subjects were not able to complete the trial and thirteen subjects were excluded from the data analysis because of less than 80% training adherence. Only 48 of 68 participants completed the trial (75%). Table 1 shows the baseline characteristics of both groups. No significant difference between both groups in any measurement was found.

Table I: The baseline characteristics of both groups.

	Group A (*n*= 23)	Group B (*n*=25)
Age (years)	19.5±1.8	20.1±2.4
BMI (kg/m^2)	18.7±0.41	18.88±0.67
WC (cm)	78.68±1.94	79.03±1.53
Duration of smoking (years)	4±2	-
FVC (% of predicted)	94.24±2.29	94.3±2.22
FEV_1(% of predicted)	91.59±2.9	92.08±3.1
FEV_1/FVC% (% of predicted)	98.1±0.9	98.4±0.89
FEF_{25-75} (% of predicted)	94.3±2	95.1±2.3
MVV (% of predicted)	88.3±3	89.1±3.6
VO_{2peak} ($mL.min^{-1}.kg^{-1}$)	37.2±3.8	36.7±3.2

BMI: body mass index; WC: waist circumference; FVC: forced vital capacity; FEV_1: forced expiratory volume in the 1st second; FEV_1/FVC: forced expiratory volume in the 1st second/forced vital capacity; FEF_{25-75}: forced expiratory flow at 25% and 75% of forced vital capacity; MVV: maximum voluntary ventilation; VO_{2peak}: peak oxygen consumption.

Post-test anthropometric measures and peak oxygen consumption

Table 2 shows the anthropometric measures and VO_{2peak} after 8 weeks of aerobic training. There were no statistically significant changes in anthropometric variables within or between groups. VO_{2peak} values showed a significant increase in both groups (P<0.05).

Table 2: VO_{2peak} and anthropometric measures after 8 weeks of aerobic exercise.

	Group A (n= 23)		Group B (n=25)	
	Before	**After**	**Before**	**After**
BMI (kg/m^2)	18.7±0.41	18.5±0.66	18.88±0.67	1896±0.66
WC (cm)	78.68±1.94	78.59±1.95	79.03±1.53	79.09±1.46
VO_{2peak} ($mL.min^{-1}.kg^{-1}$)	37.4±3.8	40.76±3.1*	36.74±3.2	46.18±2.33**

BMI: body mass index; WC: waist circumference; VO_{2peak}: peak oxygen consumption. *: significantly different from baseline (P< 0.05). **: significant difference between groups (P< 0.05).

Post-training pulmonary functions

Table 3 shows the spirometric values in both groups before and after intervention period. In group A, only MVV showed statistically significant increase. A significant positive correlation between MVV and VO_{2peak} was found in both groups (group A: r=0.659, P<0.05, group B: r=0.591, P<0.05).

Table 3: Pulmonary functions changes in both groups.

	Group A (n= 23)		Group B (n=25)	
	Before	**After**	**Before**	**After**
FVC (L)	4.75±0.2	4.73±0.27	4.77±0.26	5.14±0.27*
FEV_1(L)	3.95±0.23	3.95±0.23	3.99±0.24	4.49±0.22*
FEV_1/FVC%	83.16±2.4	83±2.67	83.14±3.22	87.53±4.44*
FEF_{25-75} (L/s)	4.81±0.3	4.82±0.3	4.85±0.29	5.08±0.29*
MVV (L/min)	136.3±7.4	147.3±7.4*	136.1±8.2	151.8±5.8**

*Significantly different from baseline (P < 0.05). **Significant difference between groups (P < 0.05).

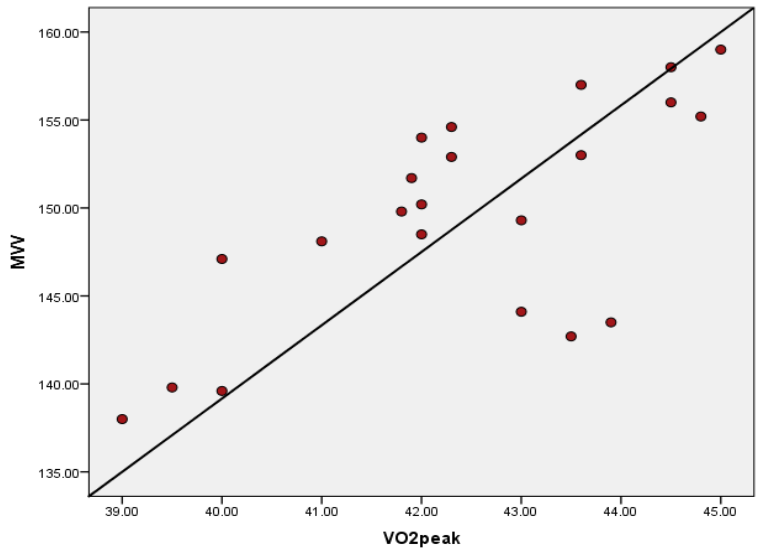

Figure 1: Correlation of MVV (L/min) with VO_{2peak} ($mL.min^{-1}.kg^{-1}$) in Group A. Change in VO_{2peak} was positively correlated with the change in MVV (r=0.659, P<0.05).

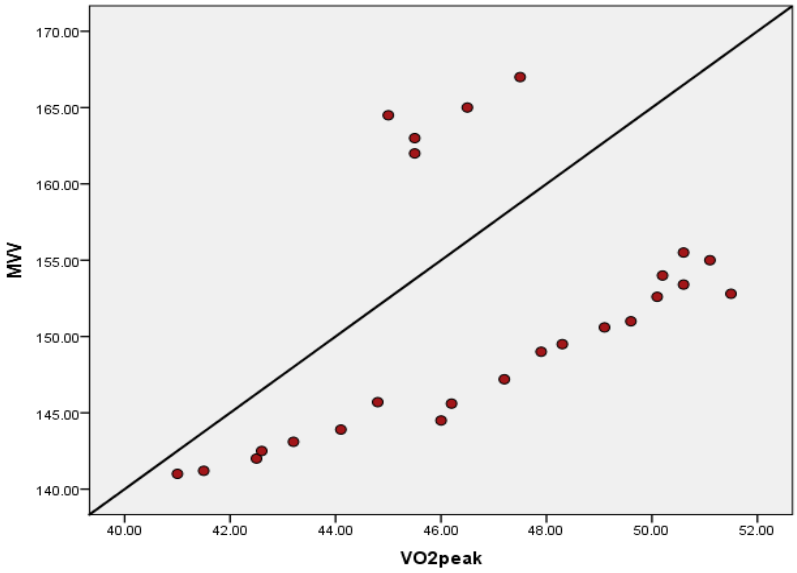

Figure 2: Correlation of MVV (L/min) with VO_{2peak} ($mL.min^{-1}.kg^{-1}$) in Group B. Change in VO_{2peak} was positively correlated with the change in MVV (r=0.591, P<0.05).

DISCUSSION

Lung structure and function in cigarette smokers is adversely affected by both active and passive cigarette smoking. Therefore, the aim of this study was to determine the impact of cigarette smoking on pulmonary functions in response to aerobic exercise training in apparently healthy university students.

The data presented in the current study showed that pulmonary functions and VO_{2peak} significantly improved after aerobic training in non-smokers while no significant changes were detected in the smokers' group in any of the parameters except for MVV. This suggests that cigarette smoking has an adverse effect on pulmonary response to aerobic training. Both pulmonary and aerobic functions in both groups were within normal as smoking subjects were asymptomatic and healthy.

However, these findings are consistent with a previous cross sectional study that reported a dose-response relationship between exercise training and pulmonary functions in nonsmokers but not smokers.[8] Also, patients with cystic fibrosis revealed no significant change in spirometric functions following a four week intensive aerobic program significant improvement in MVV[18] Similarly, a three weeks of cycle ergometer exercise significantly improved MVV in COPD patients.[19] In agreement with the present study, several studies did not report significant improvement in pulmonary functions after aerobic training.[20,21,22]

Mechanisms such as anti-inflammatory and anti-oxidant effect of exercise, effects on obesity and fat distribution or on respiratory muscle strength were proposed to counteracting the harmful effects of smoking.[8,9,23]

However, training cannot change the size or the elasticity of airways[23] which may explain the negative findings in the smokers' group. Moreover, when pulmonary functions are affected by cigarette smoking, lost values will not be regained even after smoking cessation but the rate of loss, at best, may return to the rate in nonsmokers.[24] Cigarette smoking is known to decrease oxygen carrying capacity[25] and aerobic exercise increases the oxygen extraction by tissues through large muscle groups contraction during exercise.[26] Overall, it seems that the negative effects of smoking could not be counteracted by the positive training effects on pulmonary functions.

Improvement in MVV, which is the only parameter improved in the smoking group after training, could be due to improved respiratory musculature strength and endurance[27] or due to the anti-inflammatory effect of exercise training.[28] If so, then it is of interest to explain why MVV improved significantly in the smoking group while other parameters did not improve. MVV is less affected by airway state than the other spirometric parameters and it is possible that training improved respiratory musculature without affecting airways.[29]

Also, MVV improvement may be due to slight improvement in pulmonary function could not be detected by the FVC maneuver.[30] It should be noted that smoking group subjects are healthy young smokers and might have needed more training intensity or longer exercise duration to improve their lung function.[31]

Data in the present study revealed a significant improvement in VO_{2peak} after an 8-week aerobic exercise program in both groups. Similar improvement was reported after 2 weeks of aerobic exercise[32] and after 8 weeks of high-intensity aerobic training in healthy, nonsmoking, moderately trained male subjects.[33]

Improvement in VO_{2peak} in both groups could be due to increased oxygen delivery and utilization secondary to increased mitochondrial density and capillarization in the exercising muscles.[34] Moreover, there was a significant positive correlation between MVV and VO_{2peak} in both groups which is supported by other studies.[35] This association may be due to improved ventilatory capacity causing less ventilatory limitation to VO_{2peak} at maximum exercise irrespective to the unchanged other spirometric parameters.[36]

Limitations

First, the study recruited only male participants. Second, respiratory muscle strength and endurance were not evaluated to confirm the mechanism underlying pulmonary function changes. Third, there could have been transference of learning in the post-test that might have improved the test values.

CONCLUSION

Cigarette smoking counteracts the beneficial effect of aerobic exercise training on pulmonary functions in sedentary healthy smokers. Our data suggest that cigarette smokers are advised to promptly quit smoking in order to avoid further pulmonary damage and to benefit from participation in exercise programs.

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