Original Article

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TANAFFOS

Comparison of Effect of High-Intensity Interval Training and Aerobic Training on Respiratory Volumes in Female Students

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Background: Sedentary lifestyle can cause the deterioration of respiratory indices. The interventions, such as physical activity programs, might prevent such deterioration. This study aimed to compare the effect of high-intensity interval training (HIIT) and aerobic training on the respiratory volumes in female students.

Materials and Methods: In this semi-experimental study, 30 healthy inactive volunteer female students (age: 26.3±4.30 years; height: 1.63±8.36 m; body mass index: 20-28 kg/m^2) were divided randomly into two HIIT and aerobic training groups. The aerobic training consisted of three sessions of 50-60 minutes of exercise with an intensity of 70-85% of the maximum heart rate per week for 4 weeks. Additionally, the HIIT program included six repetitions of 4 minutes with an intensity of 90-95% of maximum heart rate for 4 weeks on a treadmill. Spirometry tests were performed to determine lung function before and after the training protocols. The data were analyzed by the independent and dependent t-tests at $p < 0.05$.

Results: The results showed that aerobic training significantly improved the forced expiratory volume in one second (P=0.045), forced expiratory flow (FEF) within 25-75% (P=0.002), and peak expiratory flow (P=0.003); however, HIIT did not have a significant effect on these indicators. There was no significant difference between the two types of training in any of the indicators except for FEF within 25-75%.

Conclusion: According to the study results, aerobic training might be more effective in the improvement of pulmonary parameters than intense training.

Key words: High-intensity interval training; Aerobic training; Respiratory volumes; Sedentary female students

INTRODUCTION

Pulmonary function is an important predictor of morbidity and mortality in clinical practice. Numerous studies have shown that respiratory indices, such as forced vital capacity (FVC), forced expiratory volume in one second (FEV1), forced expiratory flow (FEF) at 25% and 75% of the pulmonary volume (25-75%), peak expiratory flow (PEF), and inspiratory vital capacity (IVC), are the indicators of pulmonary function that worsen due to a sedentary lifestyle (1-3). The findings suggest that a sedentary lifestyle can worsen respiratory parameters and might increase the risk of chronic obstructive pulmonary disease (COPD) (4). However, appropriate interventions, including physical activity programs, might prevent such deterioration (5).

Prolonged aerobic training is thought to improve aerobic capacity and have a positive effect on pulmonary function. Aerobic training improves ventilation mechanics, which is evident by increasing spirometric indices (i.e., expiratory reserve volume, vital capacity, FVC, total lung capacity, and FEV1) in sedentary individuals (6). A study showed that 8 weeks of moderate-intensity aerobic training (with 70-80% of maximum heart rate) could improve pulmonary function in non-athlete women (7). The mechanism of such training is that aerobic training improves pulmonary adaptation by improving the strength and endurance of the respiratory muscles. Respiratory patterns following altered aerobic training resulting from endurance training can reduce smooth muscle tone in the airways and increase expiratory flow. Frequent stretching of the lungs due to airway smooth muscle associated with aerobic training also reduces airway resistance. Decreased tone and smooth muscle contraction can be a mechanism to reduce air resistance. As smooth muscle tone decreases, airway resistance decreases and pulmonary volume decreases; these mechanisms are likely to increase airflow (8).

There are numerous studies indicating that aerobic exercise extensively increases the endurance and strength of respiratory muscles, reduces resistance, and increases lung traction and alveolar expansion by increasing pulmonary volume and capacity; nevertheless, some studies have demonstrated that high-intensity interval training (HIIT) also has positive effects on pulmonary function in healthy and sedentary individuals (9). As the intensity of training increases, the workload on the respiratory muscles increases; as the respiratory workload increases, the ventilation increases. There is more demand for blood flow due to increased work of the respiratory muscles. It has been suggested that the respiratory muscles can demand a maximum of 10-15% of blood flow during strenuous exercise (10). This causes the premature onset of respiratory muscle fatigue due to more call-up of the respiratory muscles during high-intensity exercise (11). Under these conditions, the respiratory muscles have been shown to meet demand by “stealing” oxygen and blood flow from active muscles. These adaptations help increase pulmonary function to a new level (12).

The adaptation of pulmonary function to training has been well documented. The findings of studies show that HIIT is at least similar to moderate-intensity aerobic exercise in causing pulmonary physiological changes in individuals with COPD (13). In obese (14) and professional athletes (15), HIIT was beneficial and effective. However, there is currently limited information about the lungs’ response to various types of training, especially in sedentary individuals. Considering the important role of various physical activities in health and the prevention and treatment of diseases, especially respiratory diseases, it seems that the study of the effects of various sports activities in sedentary individuals is of great importance. The results of such studies increase interest in training programs. Furthermore, the determination of the appropriate type of training to improve pulmonary function can be a way to choose training for sedentary individuals to prevent respiratory diseases. Therefore, the present study aimed to compare the effect of HIIT and aerobic training on the respiratory volumes in female students.

MATERIALS AND METHODS

Subjects

The present functional and semi-experimental study was conducted with two experimental groups with a pretest and posttest design. The statistical population of the present study consisted of inactive female students of Islamic Azad University, Marvdasht Branch, Shiraz, Iran. According to Morgan’s table, 38 female students announced their readiness to participate in the study. The sampling method of this study was targeted and available sampling. In this study, according to the inclusion criteria, from inactive female students, 30 inactive students with an age range of 20-30 years were selected as subjects (using a simple random number table) and divided into two experimental groups.

The inclusion criteria were no chronic diseases according to a medical history questionnaire, inactivity (less than one physical activity per week), not following a special diet, not smoking, not taking drugs or alcohol, and not doing regular exercise during the last 6 months (according to the lifestyle survey questionnaire). The exclusion criteria were the absence of more than three sessions in the exercise program, occurrence of accidents, injuries, contracting diseases, and any interfering factor that affects the participation of the subjects in the training sessions. In a separate session after the medical examination, the purpose and the way of conducting the study were explained to the subjects. After filling in the personal information questionnaire and signing the consent form, each of the subjects came to the test site the next day to perform the tests. At the beginning of the session, anthropometric features, including height, weight, and body mass index, were measured. Spirometry was also used to measure respiratory volumes. Then, both experimental groups performed a 4-week training program. Finally, anthropometric and spirometric features were measured again.

Exercise Protocols

Moderate-intensity continuous training was performed in three sessions of 50-60 minutes with an intensity of 70-85% maximum heart rate per week for 4 weeks. At the beginning and end of each training session, the subjects warmed up and cooled down on a treadmill for 5 minutes with an intensity of 50-55% of the maximum heart rate. In the HIIT program, the subjects first warmed up for 5 minutes with an intensity of 50-55% of the maximum heart rate and then performed six 4-minute repetitions with an intensity of 90-95% of the maximum heart rate (running on a treadmill). At the end of each session, the subjects completed the program with an intensity of 50-60% of the maximum heart rate for 5 minutes. The intensity of the training program was monitored by the heart rate using a heart rate monitor (16).

Measurement of Changes in Variables

Spirometry was performed to determine pulmonary function before and after the training protocols. A Medical Econet spirometer made in Germany was used in this study. A clinical spirometer with the ability to measure 30 parameters with a printer and color screen was used. For the measurement of spirometry indices, the subject took his or her nostril after a deep breath and exhaled maximally into the spirometer. A warning device alarm was used for sufficient air. This step was performed about three times. All subjects took about 2 minutes of inactive rest after this step. The highest rate of three attempts was recorded.

Statistical Analysis

After confirming the normality of the data by the Shapiro-Wilk test, Levene's test was used to check the homogeneity of variances. The data were analyzed using the independent and paired t-tests. All statistical operations were carried out using SPSS software (version 23). A p-value less than 0.05 was considered the significance level.

RESULTS

Table 1 shows the mean and standard deviation of the anthropometric characteristics of the subjects. The results of the paired sample t-test to compare the pretest and posttest after 4 weeks of intervention showed that FVC in the aerobic exercise group was not significant, compared to that of the pretest (P=0.063). In addition, after 4 weeks of intervention, FVC in the intermittent training group was not significant, compared to that of the pretest (P=0.11; Table 2). The results of the independent t-test to compare the mean differences in FVC between the two groups of aerobic training and intermittent training showed that the FVC of female students in the aerobic training group was not significantly different from that of the intermittent training group (P=0.97; Table 3).

Table 1. Mean and standard deviation of the anthropometric characteristics of the subjects

Variable	Group	Aerobic training	HIIT
Age (year)	-	27.5±4.15	25.1±4.30
Height (cm)	-	163.4±7.55	163.3±9.44
Weight(kg)	Pretest	67.3±12.4	69.8±7.2
	Posttest	65.6±12.8	67.1±10.6
BMI (kg.m^{-2})	Pretest	25.1±4.10	26.2±4.02
	Posttest	24.4±4.28	25.3±4.23

Table 2. Dependent t-test results on pre-test and post-test changes of research variables in two groups of aerobic training and HIIT

Variable	Group		Mean ±SD	Df	t	P
FVC	Aerobic training	Pretest	3.94±1.84	14	0.06	0.063
		Posttest	2.79±0.79			
	HIIT	Pretest	4.09±2.36	14	1.71	0.11
		Posttest	2.91±0.74			
FEV1	Aerobic training	Pretest	59.2±26.2	14	2.27	0.045
		Posttest	39.1±21.4			
	HIIT	Pretest	72.5±29.5	14	1.64	0.13
		Posttest	54.0±32.2			
FEF25-75	Aerobic training	Pretest	2.63±1.38	14	4.05	0.002
		Posttest	0.84±0.99			
	HIIT	Pretest	2.01±1.34	14	1.36	0.20
		Posttest	1.51±1.18			
PEF	Aerobic training	Pretest	5.09±1.37	14	3.72	0.0003
		Posttest	3.66±0.47			
	HIIT	Pretest	5.10±1.47	14	1.32	0.21
		Posttest	4.24±1.75			
VC-in	Aerobic training	Pretest	5.71±3.34	14	1.75	0.11
		Posttest	7.94±3.56			
	HIIT	Pretest	5.51±5.63	14	0.23	0.83
		Posttest	5.94±3.21			

Table 3. Independent t-test results of changes in respiratory volumes of subjects between the two groups

Variable	Group	Df	t	P
FVC	Aerobic training HIIT	14	0.03	0.97
FEV1	Aerobic training HIIT	14	0.11	0.91
FEF25-75	Aerobic training HIIT	14	2.26	0.03*
PEF	Aerobic training HIIT	14	0.74	0.47
VC-in	Aerobic training HIIT	14	0.79	0.44

The results showed that the volume of active exhalation of the first second in the aerobic training group was significant, compared to that of the pretest (P=0.045); nevertheless, after 4 weeks of the intervention period, the volume of the active exhalation of the first second in the intermittent training group was not significant, compared to that of the pretest (P=0.13; Table 2). The results showed that the volume of active exhalation of the first second of female students in the aerobic training group was not significantly different from that of the intermittent training group (P=0.91; Table 3). The results showed that the maximum expiratory flow within 25-75% in the aerobic training group was significant, compared to that of the pretest (P=0.002); however, after 4 weeks of the intervention period, the maximum expiratory flow within 25-75% in the intermittent training group was not significant, compared to that of the pretest (P=0.20; Table 2). The results showed that the maximum expiratory flow within 25-75% of the female students in the aerobic training group was significantly different from that of the intermittent training group (P=0.03; Table 3).

The results showed that the maximum expiratory flow in the aerobic training group was significant, compared to that of the pretest (P=0.003); nonetheless, after 4 weeks of the intervention period, the maximum expiratory flow in the intermittent training group was not significant, compared to that of the pretest (P=0.21; Table 2). The results showed that the maximum expiratory flow of the female students in the aerobic training group was not significantly different from that of the intermittent training group (P=0.47; Table 3). The results showed that IVC in the aerobic training group was not significant, compared to that of the pretest (P=0.11). Furthermore, after 4 weeks of the intervention period, IVC in the intermittent training group was not significant, compared to that of the pretest (P=0.83; Table 2). The results showed that the IVC of female students in the aerobic training group was not significantly different from that of the intermittent training group (P=0.44; Table 3).

DISCUSSION

The results of the present study showed that aerobic training significantly improved the active exhalation volume of the first second, maximum expiratory flow within 25-75% of vital capacity, and maximum expiratory flow. Consistent with the findings of previous studies (7), the current study's findings showed that aerobic training significantly improves the spirometric parameters of nonathletes. For explaining the reasons for the effect of aerobic training on increasing FVC and FEV1 after aerobic training, it should be said that respiratory muscle weakness, including the diaphragm, intercostal muscles, and abdominal muscle group, changes FVC and FEV1 levels. Additionally, the increase in residual volume due to weakness of the expiratory muscles and neuromuscular disorders, reduced lung elasticity, are among the factors that reduce the amount of FVC. On the other hand, it has been shown that neuromuscular coordination and greater diaphragm muscle activity improve these components (17). Therefore, aerobic training has probably led to the improvement of these indicators through the aforementioned mechanisms.

The increased breathing rate leads to an increased ventilation rate per minute. During physical activity, the number of pulmonary volume receptors and other receptors in the respiratory control center increases, leading to increased ventilation. The high volume of exhalation with pressure in the first second in adults indicates the optimal ventilation performance of individuals. It can be concluded that aerobic training puts more workload on the inspiratory muscles and has better strengthened the dilator forces of the chest and increased their endurance.

The PEF is also affected by lung dilatation and the strength and endurance of the respiratory muscles. Probably, the reason for the improvement of this index is the increase in the rate of chest dilation after aerobic training (18). The effects of aerobic training on respiratory volumes depend on age group, race, gender, and training intensity and type (19). It can be said that the effectiveness of aerobic training in some studies has been attributed to the improvement of strength and endurance of respiratory muscles, reduction of inflammation, and consequently reduction of airway resistance. This factor reduces the apparent resistance of the ventilation and will allow efficient ventilation to be increased with less effort.

In general, respiratory function depends on numerous factors, including the nervous system, neuromuscular coordination, respiratory muscle strength, and pulmonary dimensions. Increasing the strength of the respiratory muscles and reducing the resistance of the airways by physical activity is effective in improving pulmonary function. Bronchial dilatation due to physical activity reduces airway resistance and improves ventilation. Training also increases the range and depth of respiration which improves FVC, oxygen consumption, and diffusion rate by engaging the muscles (20).

Similar to many skeletal muscles, the respiratory muscles respond to stimuli through physical training. An increase in pulmonary volume and capacity and an increase in pulmonary dilatation indicate better oxygen delivery and proper distribution of oxygen to all parts of the body (21). Contrary to the current study's findings, Attarzadeh Hosseini et al. reported an insignificant increase in pulmonary volumes of high vital capacity, high-pressure expiratory volume in the first second, and PEF following an intermittent aerobic program in inactive female subjects (18), which are inconsistent with the results of this study. Hulke and Phatak examined the effect of 12 weeks of training on the pulmonary function of male and female students and demonstrated that no significant changes were observed in the pulmonary function test except peak expiratory flow rate. The peak of expiratory flow was also significant only in male subjects (22). In general, these differences can be attributed to differences in the number and type of subjects, their gender and age, and the severity and duration of the program.

The results of the present study also showed that intense intermittent training had no effect on FVC, volume of the first secondary active exhalation, maximum expiratory flow, vital expiratory capacity, and maximum expiratory flow. Although aerobic training was more successful in the improvement of respiratory parameters than intense intermittent training, this difference was not significant except for the maximum expiratory flow within 25-75% of vital capacity at the 5% level. Training is widely recognized as an effective way to improve human fitness, health, and function (23). However, the benefits of training might be limited by several factors. Depending on the type of training, the pulmonary function can be limited by training capacity, strength, and muscle fatigue (24, 25).

Consistent with the findings of the current study, Dunham and Harms did not observe a significant difference in respiratory volumes after 4 weeks of intense intermittent and endurance training (26). As the intensity or duration of training increases due to the increased need for oxygen, the demand for circulation by active muscles also increases. Increased respiration also requires the further activity of the respiratory muscles and blood flow (27). The evidence suggests that during high-intensity or heavy exercise, competition for the demand for increased blood flow by the respiratory and training muscles is moderated by sympathetic nerve-induced vasoconstriction (28). Due to the accumulation of metabolites on account of this vascular contraction, muscle metabolites are activated to restore blood flow.

Diaphragmatic surgery is thought to be a potential cause of vascular contraction for active muscles (29). During high-intensity training (>90% VO_2 max), adequate ventilation has been shown to help prevent or delay diaphragmatic fatigue and increase pulmonary function (30, 31). However, the results of this study indicated that the rate of change in the studied indices did not differ significantly between the groups. Although increased pulmonary function might be greater with HIIT (32), the main cause of adaptation might be the type of training. Contrary to the findings of the present study, the results of a study performed by Rawashdeh and Alnawaiseh showed that intense intermittent training, 3 days a week for 3 weeks, significantly improved pulmonary function in healthy inactive male subjects. However, intense intermittent training had no effect on FVC in healthy inactive male subjects. The researchers suggested that longer training might be needed to affect FVC (9). Such contradictory results in different studies can be due to reasons, such as age, gender, genetics of subjects, and, more importantly, type of subjects.

There are some limitations in the present study. One of the limitations is the lack of pulmonary function measurement following over ventilation. For the determination of whether the observed adjustments are the results of training or increased ventilation, future studies should examine the effects of over ventilation on changes in respiratory muscle strength and respiratory volume. In addition, the small sample size might affect the results, which can be further investigated in future studies with larger sample sizes.

CONCLUSION

Overall, the results of the present study showed that aerobic training significantly improved the active expiratory volume of the first second, maximum expiratory flow within 25-75% of vital capacity, and maximum expiratory flow; nevertheless, intense intermittent training had no significant effect on these indicators. There was no significant difference between the two types of training in any of the indicators except for the maximum expiratory flow within 25-75% of vital capacity. Therefore, according to the results of the present study, aerobic training might be more effective in the improvement of pulmonary parameters than intense training; however, it is required to perform further studies in this area, especially considering the intervals of training and the amount of rest time between intervals and comparison of them with the effects of aerobic exercise.

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