Pulmonary Adaptation Response of Chemical Veterans Following 24 Sessions of Selected Aerobic Exercises

Abstract

Background and purpose: Lung problems can be considered as the most common complication in chemical veterans, therefore strengthening the respiratory system should be emphasized. The purpose of this research was studying the effect of 24 sessions of selected aerobic exercise program on the volumes and lung capacities of chemical veterans.

Materials and methods: This quasi-experimental study was conducted in 2023 with a pre-test and post-test design. The statistical sample includes 17 chemical warfare veterans with a veteran percentage of 25-35% that were selected by purposive and convenience sampling method and were randomly assigned to two experimental (10 people) and control (7 people) groups. Chemical veterans participated in an interval aerobic exercise program with an intensity of 45-60% of heart rate reserve for eight weeks and three sessions per week. Pulmonary function of the chemical veterans were measured by the Lung Test 1000 spirometry device. Repeated measures statistics was used for comparison of the pre-test and post-test means.

Findings: Aerobic exercises significantly increase vital capacity (P=0.007), peak inspiratory flow (P=0.000), peak expiratory flow (P=0.016), forced expiratory volume in 1 second (P=0.017), maximum voluntary ventilation (P=0.000), peak expiratory flow 75% (P=0.000), peak expiratory flow 50% (P=0.001), peak expiratory flow 25% (P=0.007). Also, aerobic exercise had no significant effect on the ratio of forced vital capacity to forced expiratory volume in 1 second (P=0.960) and forced expiratory flow from 25 to 75% (P=0.690).

Conclusion: Aerobic exercises in chemical veterans improved lung volumes and capacities.

Keywords: Aerobic exercises; Chemical veterans; pulmonary function

Introduction

During the Iran-Iraq war, more than 400,000 people were injured by chemical agents, especially mustard gas. Pulmonary complications are the main complications of contact with mustard gas [2,1] which is approximately 42.5% in chemical veterans [3]. The effects of mustard gas on the respiratory system include shortness of breath, irritating cough, and frequent respiratory infections, which are associated with obstructive lung disease, chronic bronchitis, asthma, bronchiectasis, COPD, and narrowing of the large airways. Due to lung problems, these people are frequently hospitalized in hospitals and treatment centers [4]. Heavy treatment costs have affected their economic dimension and quality of life [5].

Chemical pulmonary veterans have shortness of breath and persistent cough, which interferes with their daily activities [7, 6]. A large amount of energy of pulmonary patients is used to produce respiratory muscle energy due to a decrease in lung function and weakness in respiratory muscles, and the person experiences premature fatigue and decreased performance [8] and they refrain from doing sports activities. [1, 9]. Inactivity can make them susceptible to diseases such as high blood pressure, diabetes and osteoporosis [10]. The fact is that the disease is long-term and can cause a decrease in self-confidence and life expectancy in patients [11]. Stahl stated that physical health and quality of life are low in pulmonary patients [1]. Decreasing physical activity causes a decrease in muscle mass and a further decrease in performance [12]. Regular exercise strengthens the muscles of the chest and thus strengthens inhalation and exhalation [13]. The optimal performance of the muscles leads to the performance of movement activities at a higher level along with the reduction of the level of energy consumption and the duration of the exercise becomes shorter. The strength and endurance of respiratory muscles is an effective technique for improving lung function and facilitating breathing [14,19], improving the breathing pattern and creating appropriate ventilation exchange [4] and increasing their tolerance to fatigue [15]. Aerobic exercise reduces dynamic swelling and shortness of breath, improves exercise tolerance and improves quality of life [18]. Since the respiratory system plays an important role in providing oxygen to the cells and regulating the internal environment of the body [17], any inefficiency in this system affects the overall performance of the body, as a result, by changing the equation of the ratio of ventilation to blood flow and the ratio of ventilation to oxygen absorption and oxygen removal less than the volume of ventilated air causes increasing the energy expenditure of the respiratory muscles, which is the basis for premature fatigue [17]. Considering the effectiveness of exercise training in improving their lung function, it is absolutely necessary to teach patients as a supplement to drug treatment in order to improve and progress their treatment and reduce symptoms, which reduces treatment costs and drug side effects [18]. Exercising and strengthening the inspiratory muscles causes an increase in the tidal volume, a decrease in the number of breaths during the exercise and an increase in the optimal energy consumption of the lung muscles and an improvement in sports performance. In Iran, these techniques are not paid attention to in the complementary program of clinical treatment and improvement the patient's health. Also, educating patients about the effect of exercise on health is one of the necessities of this research [6]. In studies about the effect of sports activities on veterans, decrease in breath shortness and the rate of hospitalization and the increase in quality of life has been shown [1, 15]. Ghasemi & et al (2019) by studying Effect of Eight Weeks of Modified Pilates Training on pulmonary Function of Veterans Exposed to Chemical Warfare Agents showed that The mean scores of forced vital capacity in the posttest step were significantly higher than the pretest step (p=0.001). By removing the pretest effect, the mean scores of forced vital capacity (p=0.02) in the training group were significantly higher than the control group [16]. Abolhasani (1996) by investigating the effect of a period of submaximal exercises on the amount of changes in pulmonary volumes and capacities in Isfahan chemically injured patients, found that there was no significant increase in tidal volume, inspiratory reserve volume, minute ventilation, and vital capacity, and only a significant increase was observed in forced vital capacity in the first second [17].

Mohsen Tari's study (2007) showed that selected aerobic exercise with treadmill did not significantly increase the forced expiratory volume in the first second and the forced vital capacity of chemical veterans. According to the contradictions in the results of the researches, as well as the limited number of researches in the field of chemical veterans and the low interest of researchers in researching these people, Therefore, since the sedentary lifestyle reduces the functional efficiency of the lungs, and chemical veterans have less physical activity than ordinary people due to limitations such as pulmonary and physical problems, Considering the quality of aerobic fitness, which is a characteristic of the health and coordination of the respiratory system and cardiovascular system, The purpose of this research was to investigate the impact of a selected aerobic exercise program consisting of 24 sessions on the volumes and lung capacities of chemical veterans.

Materials and methods

This quasi-experimental study was conducted in 2023 with a pre-test and post-test design with two experimental and control groups, on chemical veterans of Torbat-e Heydarieh city who met the criteria for entering the research. The statistical sample includes 17 chemical warfare veterans with an age range of 50-65 years and with a veteran percentage of 25-35% and by signing the consent form in the research work. They had medical records at the Martyr and Veteran Affairs Foundation of Torbat-e Heydarieh city, they were selected by purposive and convenience sampling method and were randomly assigned to two experimental (10 people) and control (7 people) groups.

The sample size was determined by G*Power software, considering a significance level of 0.05, statistical power of 0.8, and utilizing the statistical method of repeated measures analysis of variance (ANOVA) for two experimental and control groups, each comprising 6 participants, resulting in a total of 12 participants. However, due to the necessity and the likelihood of potential participant attrition, the sample size was increased to 17 individuals (10 participants in the experimental group and 7 participants in the control group).

On the first day, the subjects were fully familiarized with the procedures of the tests. Then, using a Seka scale with an accuracy of 0.1 kg and a measuring device with an accuracy of 0.1 cm, the subjects' weight and standing height were measured in kilograms and centimeters, respectively.

On the second day, by entering the weight and height data into the spirometry machine, the body mass index was calculated in kilograms per square meter and the surface area of the body was calculated in square meters. In the following phase, static and dynamic pulmonary volumes and capacities were measured in the laboratory by a spirometry device labeled Lung test 1000 made in Poland with a reliability of 0.982;the procedure was in such a way that after the practical training of the subjects and emphasis on maintaining concentration and seriousness in exerting maximum effort during pulmonary tests, three spirometry, flow-volume and maximum voluntary ventilation tests were taken with a 5-minute rest interval, and the best pulmonary functions were recorded and stored.

After completing the preliminary tests, the training program, work method, and how to use a heart rate monitor with a polar label for determine the heart rate and controlling the intensity of the training, the duration of the training sets, and also instructions for better performance during the activity and rest phases, were explained. All the subjects participated in an eight weeks exercise program, three sessions a week (24 sessions in total), each session 45 minutes of intermittent aerobic exercise with an intensity of 45 to 60 percent of the maximum heart rate reserve (HRR) under the supervision of a trainer and sports expert in an indoor sports hall.

The intensity of exercise was controlled by heart rate using the pulsometer display that was installed on the subjects' wrists, based on Karvonen's formula or a ratio of HRR calculated from equation (1):

Equation

Maximum heart rate (MHR) - age-220

Reserve heart rate (HRR) - resting heart rate

HR - maximum heart rate (MHR)

Target heart rate (THR) - HR + (percentage of exercise intensity *HRR

In this equation, the maximum heart rate is obtained from the age-to-year difference from the number 220, and HR is the person's heart rate at rest, and the relevant equation was used to obtain the target heart rate zone (THR) in exercise.

At the end of eight weeks of training, three pulmonary tests (spirometry, flow-volume and maximum voluntary ventilation) were taken from the subjects again in the same conditions as the initial test.

After recording the data in the SPSS statistical software environment to calculate the indicators of central tendency, dispersion and drawing graphs from descriptive statistics and to ensure the normality of the data from the Shapiro-Wilk test; Leven's test was used for the homogeneity of variances. Also, to compare the pre-test and post-test averages and to examine intra-group and inter-group changes, repeated measures parametric statistics method was used. A significance level ($P<0.05$) was considered to test the hypotheses.

Finding

Table 1. The results of the repeated measures statistics Test (Within and between groups) related to changes in volumes and lung capacities of chemical veterans

Pulmonary Function	**Group**	**Stages**		**Tests of Within-Subjects, factor1**		**Tests of Within-Subjects(factor1 * group)**	
		Pre-test	Post-test	F	P	F	P
VC (Liter)	Experimental (10)	2.04±0.35	2.37±0.31	13.290	0.002	9.561	.007

	Control (7)	1.93±0.46	1.96±0.52				
PIF (Liter)	Experimental (10)	2.09±0.53	3.05±0.74	46.99	0.000	54.86	0.000
	Control (7)	1.91±0.54	1.87±0.54				
PEF (Liter)	Experimental (10)	2.35±0.57	3.12±0.77	6.33	0.024	7.32	0.016
	Control (7)	2.28±0.59	2.25±.55				
FEV1 (Liter)	Experimental (10)	1.04±47	1.38±0.32	6.77	0.020	7.24	0.017
	Control (7)	1.14±0.63	1.14±0.58				
MVV (Liter)	Experimental (10)	56.74±14.75	79.48±17.22	32.47	0.000	31.63	0.000
	Control (7)	56.90±18.41	57.5±17.40				
FEV1/FVC	Experimental (10)	1.32±0.41	1.60±0.37	2.62	0.126	3.15	0.960
	Control (7)	1.33±0.47	1.31±0.50				
MEF 75% (Liter/Sec)	Experimental (10)	2.54±0.66	3.01±0.77	22.78	0.000	28.35	0.000
	Control (7)	2.48±0.51	2.45±0.51				
MEF 50% (Liter/Sec)	Experimental (10)	1.87±0.25	2.48±.48	10.26	0.006	17.97	0.001
	Control (7)	1.82±0.37	1.74±0.34				
MEF 25% (Liter/Sec)	Experimental (10)	1.09±0.42	1.09±0.49	11.16	0.004	9.69	0.007
	Control (7)	1.74±0.40	1.21±0.45				
MEF 25% -75% (Liter/Sec)	Experimental (10)	2.02±0.67	1.91±0.57	0.001	0.970	0.166	0.690
	Control (7)	1.99±0.49	1.94±0.60				

The results of the Shapiro-Wilk test showed that the raw data related to each of the variables have a normal distribution. Based on the results of Leven's test, the assumption of equality of variances for all variables in both control and experimental groups has been observed to compare the average between the groups. The test of repeated measurements showed that aerobic exercises significantly increase vital capacity (P=0.007), peak inspiratory flow (P=0.000), peak expiratory flow (P=0.016), forced expiratory volume in 1 second (P=0.017), maximum voluntary ventilation (P=0.000), peak expiratory flow 75% (P=0.000), peak expiratory flow 50%

(P=0.001), peak expiratory flow 25% (P=0.007). Also, aerobic exercise had no significant effect on the ratio of forced vital capacity to forced expiratory volume in 1 second (P=0.960) and forced expiratory flow from 25 to 75% (P=0.690), (Table 1).

Discussion

Studying pulmonary responses to exercise through the use of non-invasive methods for evaluating the effectiveness of exercise programs aimed at health, therapy and regeneration was one of the main goals of this research.

According to the findings of this research, eight weeks of selected aerobic exercises had a significant effect on vital capacity. It is consistent with the research of Saeed Shamlou et al. [21] and Attarzadeh et al. [15]. The research showed that increasing the strength of the chest muscles, which increases the volume of the chest, significantly increases the pulmonary function and spirometry indicators. Basically, the increase in the volume of the chest is due to the change in the total volume of the pulmonary bubbles [24].

According to the results of the present study, the selected aerobic exercises caused a significant increase in the average peak inspiratory flow (PFI) and peak expiratory flow (PEF). The peak of inspiratory and expiratory flow, like other volumes, is a reflection of the static properties of the respiratory system [27] and strengthening the elasticity of the main and auxiliary intercostal muscle fibers increases the effective inspiratory force [27]. In line with the current research, Sharifian et al. (2007) showed that eight weeks of aerobic exercise significantly increased the respiratory indices of PEF and PFI. Inspiratory muscles cause the expansion of the chest; the increase in the volume of the chest decreases the pressure difference between the bubbles and the pleural cavity, and as a result, the force of expansion prevails over the elasticity and causes the intra-pulmonary volume to fill with air quickly [28]. Filling the lungs with air to the maximum amount is the most important factor in stimulating the secretion of surfactant. As a result, the amount of prostaglandins increases in the alveolar space, which reduces the tone of the bronchial smooth muscles and increases lung efficiency. Surfactant, as one of the factors involved in improving lung function, plays a role by increasing the size of lung cells, facilitating cell-to-cell communication, and reducing the surface tension of air sacs. On the other hand, surfactant can appear in the form of a bronchodilator and by increasing the diameter of airways and reducing air resistance, it can increase lung volumes and capacities, and this issue can be considered as one of the reasons for increasing PIF [29].

In the research of Rupam Bassi (2019), during a period of 10 weeks, a significant decrease in BMI and a significant increase in PEF and PFI was observed. They stated that the improvement of PEF values can be due to aerobic exercises, which increases breathing efficiency and decreases pulmonary resistance, as well as reducing fat percentage [24].

In the results of the present study, the FEV1 index showed a significant increase which is similar to the research of Qanbarzadeh et al. (2002), Modi et al. (2018), Azad et al. (2011) In the research of Azad et al., which aimed to investigate the effect of aerobic exercise on lung function in overweight and obese students, they concluded that aerobic exercise improves FEV1. In all the mentioned researches, it was shown that by doing aerobic exercises, the endurance and tolerance of the respiratory muscles increases, which can cause an increase in the expansion of the chest and an increase in lung volumes. Cardiovascular fitness is improved through sports such as walking in order to strengthen aerobic capacity. Probably, the increase in FEV1 following exercise intervention has occurred because the degree of bronchial compression or the occurrence of the pathological phenomenon of airway bronchospasm has decreased, which is in line with the results of the present study.

In the research results of Attarzadeh et al. (2011) Mohsen Tari & et al. (2018) showed that the implementation of the aerobic exercise program had an effect on the subjects' FEV1 and FVC, and it was slightly increased in the post-test, but it was not meaningful. Among the contradictory factors of the above studies and the current research, we can point to the type of subjects, the intensity of training, the duration of training, the type of training, the age of the subjects, and the physical fitness of the subjects, so that in Mohsen Tari's research, the training period is 4 weeks and on the workbench, Shamhammadi, female students of the field of education. Bedni and Atarzadeh girls have been inactive.

The ratio of forced expiratory volume in 1 second to forced vital capacity (FEV1/FVC) is an indicator of airway obstruction. And the development of respiratory and trunk muscles helps to improve chest mobility and has positive effects on FEV1/FVC [38]. In the present study, aerobic exercises did not cause significant changes in FEV1/FVC. Since in the present study, FEV1 increased due to aerobic exercise, but FVC/FEV1 did not differ much, it means that FEV1 and FVC increased equally. In this index, it is consistent with the results of towfighi et al. (2013).

Physical inactivity and obesity can impair FEV1 and FVC, while appropriate aerobic exercise training can partially improve FVC and FEV1 due to increased respiratory muscle function. However, participation in long-term physical activity and achieving a normal BMI are two important factors that cause sufficient improvement in FVC and FEV 1 in overweight and sedentary patients [32].

Among the respiratory maneuvers, maximum voluntary ventilation (MVV) is more important as a dynamic test of ventilatory capacity, so that the reduction of MVV can be seen in patients with airway obstruction or stenosis. Therefore, from this point of view, the values of MVV are dependent on the individual's exercise capacity and ability, as well as the limitation of shortness of breath [17]. In the present research, the value of MVV increased significantly by 42.36%. In line with the present research, the researches of Azad et al. (2011), Zahra Hojjati et al. (2013), Plankil et al. (2005) By examining the effect of aerobic exercise on 30 obese women with mild asthma (who participated in the exercise protocol for eight weeks), Babaei Bonab concluded that aerobic exercise has a significant effect on MVV, FEF, FEV and PEF indices. . Nazem et al. (2011) investigated the effect of three months of aerobic exercise and no exercise on pulmonary function indicators of middle-aged men; they reported a significant increase in MVV at the end of exercise. This research has shown the positive effect of exercise programs on the exercise tolerance and shortness of breath of the subjects. In the field of possible physiological mechanisms that reduce shortness of breath due to aerobic exercise in chronic obstructive pulmonary diseases, O'Donnell et al. (1994) mentioned four main mechanisms; Reducing ventilatory requirements or increasing ventilatory reserve, reducing ventilatory apparent resistance, improving ventilatory muscle performance and psychological factors. The results of the research of Kazaburi et al. (2004) regarding the effect of aerobic exercise on MVV are not consistent with the results of the current research. The contradiction in the result the present research can be attributed to the difference in the number of subjects, their gender and age, the type of exercise and the duration of the exercise [37].

In the present study, the maximum expiratory flow of 75% (MEF75%), maximum expiratory flow of 50% (MEF50%) and maximum expiratory flow of 25% (MEF25%) increased significantly. which indicates that exercise has increased the speed of muscle shortening and as a result has increased muscle strength and strength. In line with the results of the present study, Zahra Hojjati et al. (2013) investigated the effect of intermittent aerobic exercises on the lung volumes of 100 inactive female students (who participated with the protocol of aerobic intermittent running with 65-80% of the reserve heart rate) to this They concluded that intermittent aerobic training had a significant effect on MEF75%, MEF50%. But it had no significant effect on MEF25%. Park Junsang et al. (2017) investigated the effect of high-intensity aerobic exercise on pulmonary function of elderly women after eight weeks of exercise. According to their findings, aerobic exercise with high intensity had a significant increase in MEF75%, MEF50% was unchanged and MEF25% decreased, which was not significant.

In the present study, the amount of forced expiratory flow of 25-75% (FEF 25-75%) was not statistically significant. Wu et al. (2020) investigated the effects of continuous aerobic exercise on lung function in a meta-analysis study and concluded that aerobic exercise forced expiratory volume in one second of peak expiratory flow, forced vital capacity, (FEF 25-75%) Improved.

Also, other research on the effect of combined exercises on lung function in smokers showed that 16 weeks of physical exercises in 50 sedentary male smokers who were divided into four groups of aerobic, resistance, combined and control, caused significant changes in FEF-75, FEF- 50, (FEF 75-25%) was not found [45] and also in the research of Alireza Brari et al. (2015) by examining the effect of resistance training and ivy extract consumption on a selection of spirometric indicators on 48 men with respiratory diseases, the FEF value was -25 75% was not significant after training. Womack CJ et al. (2000) conducted a study aimed at the effect of aerobic training (eight weeks of training with an intensity of 50-75% HRmax) on the lung function of obese men. The results of their research did not show significant changes in respiratory indices after eight weeks of aerobic exercise. Which is consistent with the present research.

Overall, several lines of evidence support the improvement of pulmonary function as a result of exercise training, including the compensatory effect of exercise training on the restriction caused by muscle imbalances in the chest, the strengthening of the accessory respiratory muscles by regular exercise, the increase in residual airflow, and the reduction ventilation in asthmatic patients (by strengthening bronchial dilation during exercise), reducing airway resistance, increasing airway diameter, strengthening respiratory muscles and increasing chest elasticity as a result of exercise, reducing pulmonary reversibility and increasing pulmonary vascular dilation (in The result of increased activation of the adrenaline system during exercise), decreased airway resistance and increased FEV1 and FVC through increased airflow (following pulmonary vasodilation) and the correlation of serum cortisol with bronchial dilation and pulmonary surfactant production [43]. Since the training program had a significant effect on most of the pulmonary indicators, it can be concluded that the training program has increased the ability and coordination of the respiratory muscles.

Conclusion

Exercise, particularly aerobic activities like running and jogging, enhances respiratory muscle resistance, improving ventilation and increasing expiratory flow in patients with respiratory diseases. Integrating exercise into the treatment of these patients is crucial for symptom improvement, lung function enhancement, and reducing reliance on inhalation sprays and oral corticosteroids. This approach not only progresses treatment but also lowers costs and minimizes drug side effects. Overall, the research underscores the effectiveness of aerobic exercise as an accessible and suitable option for improving pulmonary function in individuals with normal physical fitness levels, including chemical veterans.

Acknowledgments

We hereby express our thanks and appreciation for the sincere cooperation of the Martyr Foundation and the affairs of Torbet Heydarieh city and the chemical veterans.

Ethical Permission: Extracted from master thesis of sport physiology in Islamic Azad University of Torbat-e Heydarieh Branch.

Funding/Support: The present research has not received financial support from any institution or organization.

Conflict of interest: The authors declare no conflict of interest.

Reference

1. Jafari FA, Guitynavard FA, Soroush MR, Mousavi B. Quality of life in chemical war victims with sever pulmonary damage. Iranian Journal of War and Public Health. 2012 Jan 10;4(1):46-52. http://dx.doi.org/10.18869/acadpub/ijwph
2. Amini H, Solaymani-Dodaran M, Mousavi B, Alam Beladi SN, Soroush MR, Abolghasemi J, et al. Long-term Health Outcomes Among Survivors Exposed to Sulfur Mustard in Iran. JAMA Network Open [Internet]. 2020 Dec 10;3(12):e2028894. Available from: http://dx.doi.org/10.1001/jamanetworkopen.2020.28894
3. Mousavi ZB, Ebrahimi A, Mirian M, "Investigation of the long-term effects of contact with mustard gas on the skin of combatants 10 to 19 years after the end of the imposed war, Imam Khomeini Hospital," Skin Clinic. 2010, 5
4. Kaheri Sarabi A, Heydarizadeh K, Brahimi N, Alavi Majed H, Yaghmai F, "Investigation of the effect of breathing exercises on the lung function of chemical veterans," Shahid Beheshti School of Nursing and Midwifery,216; 16, 58,
5. Qolipour S, Parhizgar Kalat SZ, Qolipour M, "Injury type and quality of life among veterans of Kerman province," 2015.
6. Amini M, Gholami M, Aabed Natanzi H, Shakeri N, Haddad H. The Effect of Diaphragmatic Respiratory Training on Some Lung Factors in Chronic Obstructive Pulmonary Disease. Salmand [Internet]. 2017 Jul 30; Available from: http://dx.doi.org/10.32598/sija.13.10.330
7. Salehi M, Shahrabi J, Aliannejad R, Khayabani J,. "Estimation of VO2php in chemical veterans based on the values of spirometry test parameters using decision tree and SVR," 4th Iran Data Mining Conference, 2009.
8. Ghanbari A, - Niknam-Ahmed Azad-Reza Karakhanlou. 2011; 10 (3): 24-31
9. Boskabady M, Boskabady MH, Zabihi NA, Boskabady M. The effect of chemical warfare on respiratory symptoms, pulmonary function tests and their reversibility 23–25 years after exposure. Toxicology and Industrial Health [Internet]. 2012 Dec 20;31(1):79–84. Available from: http://dx.doi.org/10.1177/0748233712468025
10. Ahmadi Z, Moradi M, Abedi B. Effect of breathing exercises on lung volumes and fatigue in chemical victims. Iranian Journal of War and Public Health. 2016 Oct 10;8(3):127-33.
11. Sedighi Moghadam MR, Ghanei M, Kenn K, Hopkinson NS. Pulmonary rehabilitation in patients with mustard gas lung disease: a study protocol for a randomized controlled trial. Trials [Internet]. 2019 Feb 14;20(1). Available from: http://dx.doi.org/10.1186/s13063-019-3180-3

12. Modi H, Ghiathi F, Afshar M, Akbari A, Herat Hi, Modi M, Sheikhzadeh AS,. "Effect of a type of plyometric and aerobic exercise on chest expansion and lung volumes in high school students," Journal of University of Medical Sciences Kurdish city. 2018; 11, 2. https://doi.org/10.4103/atmph.atmph_203_17
13. Haji Rasouli M, Mehzeb A, Soroush MR, Amini R Ghanei M., "Investigating the amount of changes in the physical parameters of chemical veterans after participating in a regular exercise program," Scientific-Research Journal. 2011; 4(9).
14. Burr JF, Davidson W, Shephard RJ, Eves N. Physical activity in chronic respiratory conditions: assessing risks for physical activity clearance and prescription. Canadian Family Physician. 2012 Jul 1;58(7):761-4. https://doi.org/10.1201/b11718-10
15. Attarzadeh Hosseini SR, Hojati Oshtovani Z, Soltani H, Hossein Kakhk SA. Changes in pulmonary function and peak oxygen consumption in response to interval aerobic training in sedentary girls. Journal of Sabzevar University of Medical Sciences. 1970 Jan 1;19(1):42-51.
16. Ghasemi Gh, Barati Rokati P, Salehi OR. Effect of Eight Weeks of Modified Pilates Training on Pulmonary Function and Quality of Life of Veterans Exposed to Chemical Warfare. Iranian Journal of War and Public Health [Internet]. 2019 Dec 1;11(4):183–8. Available from: http://dx.doi.org/10.29252/ijwph.11.4.183
17. Abolhosni, Hossein (1996) Investigating the effect of a period of submaximal exercises on the amount of changes in lung volumes and capacities in Isfahan chemically injured patients, Master's thesis, University of Tehran, Faculty of Physical Education and Sports Sciences.
18. Moghaddasi B, Moghaddasi Z, Taheri Nasab P. The effect of physical exercise on lung function and clinical manifestations of asthmatic patients. Arak Medical University Journal. 2010 Jun 1;13(2).
19. Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. Muscles: testing and function with posture and pain. Baltimore, MD: Lippincott Williams & Wilkins; 2005 Feb 24. http://dx.doi.org/10.2106/00004623-195032010-00033
20. Fisher LR, Cawley MI, Holgate ST. Relation between chest expansion, pulmonary function, and exercise tolerance in patients with ankylosing spondylitis. Annals of the Rheumatic Diseases [Internet]. 1990 Nov 1;49(11):921–5. Available from: http://dx.doi.org/10.1136/ard.49.11.921
21. Saeed Shamlou-Morteza Taheri-Nafise Nowrozi-Saeed Sohrabi, investigating the effect of eight weeks of aerobic exercise in water on respiratory indices of middle-aged men, 2015
22. Astrand PO, Rodahl K. Text book of work physiology, physiology basis of exercise. New York: McGraw-Hill; 1988. https://doi.org/10.2310/6640.2004.00030
23. Bradley J, Moran F. Pulmonary rehabilitation improves exercise tolerance in patients with bronchiectasis. Australian Journal of Physiotherapy [Internet]. 2006;52(1):65. Available from: http://dx.doi.org/10.1016/s0004-9514(06)70068-x
24. Bassi R, Sharma S, Sharma A, Kaur D, Kaur H. The effect of aerobic exercises on peak expiratory flow rate and physical fitness index in female subjects. National Journal of Physiology, Pharmacy and Pharmacology. 1970 Jan 1;5(5):376-. https://doi.org/10.5455/njppp.2015.5.2107201560
25. Hulke SM. Effect of endurance training on lung function: a longitudinal study. Int J Biol Med Res. 2011 Jan 31;2(1):443-6.
26. Farid R, Ghasemi R, JABARI AF, BARADARAN RM, TALAEI KM, GHAFARI J, EBRAHIMI AA, KHALEDAN A. Effect of aerobic exercise training on pulmonary function and tolerance of activity in asthmatic patients.
27. Cancelliero-Gaiad KM, Ike D, Pantoni CBF, Borghi-Silva A, Costa D. Respiratory pattern of diaphragmatic breathing and pilates breathing in COPD subjects. Brazilian Journal of Physical Therapy [Internet]. 2014 Aug;18(4):291–9. Available from: http://dx.doi.org/10.1590/bjpt-rbf.2014.0042
28. Sharifian, "Investigation of normal indicators of pulmonary function test," Scientific Journal of the University of Sciences, 1311.
29. Tari Mohsen, Fallah Mohammadi Zia, Dobidi Roshan Valiullah, Aliali Masoud. The effect of a selected aerobic training session with a treadmill on FEV1 and FVC, exercise tolerance, and dyspnea in pulmonary chemical veterans. Olympic Quarterly. Spring 2018. Volume 17, Number 1
30. Azad A, Gharakhanlou R, Niknam A, Ghanbari A. Effects of aerobic exercise on lung function in overweight and obese students. Tanaffos. 2011;10(3):24.
31. Qanbarzadeh, Mohsen. Comparison of the effect of two types of special exercise programs on spirometry indicators and activity tolerance in the injured Pulmonary effects of chemical warfare gases in Khuzestan province", thesis of the doctoral course of physical training and sports sciences. 2002;Tarbiat Modares University.
32. Tawfiqi, A., The effect of 12 weeks of endurance, resistance and parallel training on the volume and lung capacities of inactive male students, Olympic Games.2013; 20(2).
33. Eftekhari E. Pilates Training on Pulmonary and Endurance Function in Female Patients with Multiple Sclerosis.
34. Bonab SB. Changes in spirometric parameters of obese women with mild asthma following selected aerobic exercises.
35. Nazem F, Izadi M Keshavarz B, Jalili M., The effect of aerobic exercise and non-exercise on pulmonary function indicators of obese middle-aged patients with chronic asthma, Scientific Research Journal of Arak University of Medical Sciences. 2011;15(9) 85-93

36. Hojati Z, Kumar R. The effect of interval aerobic exercises on some dynamic pulmonary volumes of non-athlete female students. Advances in Environmental Biology. 2013 Jul 1:1249-55.
37. Casaburi R, Bhasin S, Cosentino L, Porszasz J, Somfay A, Lewis MI, et al. Effects of Testosterone and Resistance Training in Men with Chronic Obstructive Pulmonary Disease. American Journal of Respiratory and Critical Care Medicine [Internet]. 2004 Oct 15;170(8):870–8. Available from: http://dx.doi.org/10.1164/rccm.200305-617o
38. Park J, Han D. Effects of high intensity aerobic exercise on treadmill on maximum-expiratory lung capacity of elderly women. Journal of Physical Therapy Science [Internet]. 2017;29(8):1454–7. Available from: http://dx.doi.org/10.1589/jpts.29.1454
39. Shaw I, Shaw BS, Brown GA. Concurrent Training and Pulmonary Function in Smokers. International Journal of Sports Medicine [Internet]. 2011 May 26;32(10):776–80. Available from: http://dx.doi.org/10.1055/s-0031-1277214
40. Barari A, Kazemi M, Abdi A., Investigation of the effect of resistance training and ivy extract consumption on a selection of spirometric indices in men with respiratory diseases, Razi Journal of Medical Sciences. 2015; 23, 146,
41. Shadmehri S, Kazemi N, Heydari FZ. Comparison of Effect of High-Intensity Interval Training and Aerobic Training on Respiratory Volumes in Female Students. Tanaffos. 2021 Apr;20(4):337.
42. Womack CJ, Harris DL, Katzel LI, Hagberg JM, Bleecker ER, Goldberg AP. Weight loss, not aerobic exercise, improves pulmonary function in older obese men. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2000 Aug 1;55(8):M453-7. https://doi.org/10.1093/gerona/55.8.m453
43. O'Donnell DE. Breathlessness in Patients with Chronic Airflow Limitation. Chest [Internet]. 1994 Sep;106(3):904–12. Available from: http://dx.doi.org/10.1378/chest.106.3.904
44. Wu X, Gao S, Lian Y. Effects of continuous aerobic exercise on lung function and quality of life with asthma: a systematic review and meta-analysis. Journal of Thoracic Disease [Internet]. 2020 Sep;12(9):4781–95. Available from: http://dx.doi.org/10.21037/jtd-19-2813
45. Plankeel JF, McMullen B, MacIntyre NR. Exercise Outcomes After Pulmonary Rehabilitation Depend on the Initial Mechanism of Exercise Limitation Among Non-Oxygen-Dependent COPD Patients. Chest [Internet]. 2005 Jan;127(1):110–6. Available from: http://dx.doi.org/10.1378/chest.127.1.110
46. Trueblood N, Means I, Martin L, Young J, Wheeler M, Thomas E, Rankin M, Philips L, Pamla P, O'Connell M, Muhrer S. respiratory resistance training increases ventilatory capacity in the elderly. Retrieved January. 2004 Mar 24;20:2006.