The Effect of High-Intensity Aerobic Exercise on the Pulmonary Function among Inactive Male Individuals

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A spirometer is an important instrument in the assessment of the lung functions. FVC, FEV1, MVV and ratio of FEV1/FVC are indicators of strong respiratory function that deteriorate due to a sedentary lifestyle. Prolonged aerobic exercises are thought to improve aerobic capacity and to have a favorable effect on lung function. Thus, the main aim of this study was to investigate the effect of such aerobic exercise for three weeks, specifically continuous treadmill running, on lung function (FVC, FEV1, ratio of FEV1/FVC, and MVV) in inactive yet healthy male individuals. For this study, 72 inactive male individuals were given a pulmonary function test. The test was performed three times for each session (starting with five minutes and increasing by ten minutes every three sessions, up to a maximum of 25 minutes), and its mean value was used for analysis. Exercise was performed three days a week for three weeks. The Wilcoxon test was done to determine changes pre- to post-test. Repeated-measure analyses were used to compare the changes of pulmonary values between high-intensity sessions. Spearman correlation rh_o was conducted to assess association between MVV, FVC, and FEV1, and the Friedman test was used to compare the mean ratio of FEV1/FVC before and after exercise of different intensities. FEV1, MVV and a ratio of FEV1/FVC were significantly improved after high-intensity aerobic exercise of different intensities. In addition positive relation of MVV with FEV1 improvements was found. In contrast, there were insignificant improvements in FVC before and after exercise of different intensities and with no positive relation of MVV improvements. The improvements in MVV could reflect subtle changes in lung function or airway reactivity not detected by the FVC test. In addition, higher exercise intensity or longer duration may be needed to affect other lung function parameters like MVV, FEV1 and FEV1/FVC. Thus our results demonstrate that high-intensity aerobic exercise on the treadmill has a positive effect on the pulmonary function of inactive healthy subjects.

Keywords: Pulmonary function, High-intensity aerobic exercise, FVC, FEV1, MVV.

Exercise is a reliable method of testing the physical abilities and physiological reactions that form the basis of good health and well-being and can be used, for example, to measure the ability to endure stress and carry on in circumstances where an unhealthy person cannot. At the same time, lung function is a vital predictive tool of both morbidity and mortality in medical practice. Many studies have shown that respiratory indices such as forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and maximum voluntary ventilation (MVV) are strong indicators

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of lung function, as they decline noticeably due to sedentary lifestyle[1-3].

In one study, 6790 subjects were followed for 19 months. Those with active lifestyles showed an improvement of 50 ml in FEV1 and 70 ml in FVC; however, subjects with sedentary lifestyles experienced a 30 ml reduction in FEV1 and 20 ml reduction in FVC[4]. Moreover, other studies have shown that physical activity can improve lung function dramatically in subjects with diseases like asthma and in children with intellectual disabilities[5-6]. These findings suggest that a sedentary lifestyle can cause the deterioration of respiratory indices and might put one at high risk for developing chronic obstructive pulmonary disease. Appropriate interventions such as physical activity programs, however, may prevent such deterioration.

Other recent studies have investigated the effect of exercise on pulmonary function. For example, dancing[7], playing gate ball[8], and exercising core muscles[9] were reported to have had a positive effect on pulmonary function in the elderly. The results of such studies have led to increasing interest in exercise programs that can improve pulmonary function and prevent respiratory disease.

although there have been many studies that show aerobic exercises extensively improves the endurance and strength of respiratory muscles, decrease resistance and increase lung elasticity and alveolar expansion by promoting the expansion of pulmonary volumes and capacities, others have found that it has no significant effect[10].

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MEHODS

Sample size

For this study, 72 male subjects were recruited.

Study population

Subjects (aged 18–50 years) were recruited. Informed consent was taken from each after they had been given a detailed explanation of the experiment. The subjects were asked to complete questionnaires on medical history to ensure they are in a good health (no acute illnesses related to respiratory or heart disease)

Sampling method and study design

Pre-test/post-test studies measure the change in a situation. They are often used to measure the efficacy of an intervention and can be considered comparative cross-sectional. For this study, 72 male subjects were randomly selected by simple random sampling technique (SRS).

Sources and methods of data collection

Measurements of respiratory indices were taken three times in the pre- and post-exercise phases of each session, and their mean values were used for analysis. Subjects were asked not to change their habitual physical activity during the study and not to take any nutritional supplements.

Inclusion criteria

Subjects recruited for this study had to meet the criteria listed below:

1. Age 18 or older
2. In good health (no acute illnesses related to respiratory or heart disease)
3. Cooperative

Protocol

The high-intensity exercise training program consisted of continuous treadmill running (grade = 0%) three days a week for three weeks. Each session began with a warmup period of five minutes. For the session itself, running time started at five minutes, and this interval was increased by ten minutes every three sessions, up to a maximum of 25 minutes. The speed of running was adjusted according to the target heartrate zone (75–85% HR max).

Measurements

Pulmonary function tests were carried out by SPIROVIT SP-1 spirometer to determine FVC, FEV1, FEV1/FVC, and MVV. Subjects had to remain in the straight sitting or standing position throughout the test, and a nose clip was tightly attached to the nostrils, allowing no air to escape during the test. A mouthpiece was placed at least two centimeters into the subject's mouth, with lips closed around it.

FVC Maneuver: Each subject was asked to inhale completely and rapidly, pausing less than one second at total lung capacity (TLC), and then exhale as quickly and completely as possible, expelling all the air. Forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), and forced expiratory volume in the first second/forced vital capacity (FEV1/FVC) were obtained and recorded by the apparatus.

MVV maneuver: Subjects were tested in the sitting position while wearing a nose clip. They were instructed to breathe as rapidly and deeply as possible for 12 seconds after obtaining at least three resting tidal breaths with an airtight seal around the mouthpiece.

Statistical analysis

The values are reported as mean ± standard deviations. Statistical analysis was conducted using SPSS software version 16. The Wilcoxon test, a nonparametric analysis (paired t-test), was done to determine changes pre- to post-test. Repeated-measure analyses were used to compare the changes of pulmonary values between high-intensity sessions. Spearman correlation rh_o was conducted to assess association between MVV, FVC, and FEV1, and the Friedman test was used to compare the mean ratio of FEV1/FVC before and after exercise of different intensities.

RESULTS

Table 1 shows the mean of the anthropometric characteristics of the 72 subjects. The mean age was 30.94 ± 11.29 years, the mean height was 172.65 ± 5.72 cm, and the mean weight was 79.67 ± 12.56 kg.

Table 2 shows the baseline spirometry data of predicted values for the 72 subjects. The mean predicted FVC was 4.00 ± 0.51 L, mean predicted FEV_1 was 3.76 ± 0.55 L, and mean predicted MVV was 127.14 ± 22.44 L.

Table 3(A) shows the baseline spirometry data of FVC and FEV_1 pre- and post-exercise at different intensities. The mean pre-exercise FVC was 3.80 ± 0.71 L, and the mean pre-exercise FEV_1 was 3.37 ± 0.77 L. Post-exercise mean FVC after 5, 15, and 25 minutes was 3.92 ± 0.56 L, 3.92 ± 0.70 L, and 3.96 ± 0.48 L respectively. The post-exercise mean FEV_1 after 5, 15, and 25 minutes was 3.73 ± 0.62 L, 3.86 ± 0.49 L, and 3.93 ± 0.53 L respectively (the trend here is obvious).

Table 3(B) shows the baseline spirometry data of MVV before and after exercise at different intensities. The pre-exercise mean MVV was 125.47 ± 32.97 L, the post-exercise mean MVV after 5, 15, and 25 minutes was 134.26 ± 30.21 L, 135.54 ± 53.18 L, and 143.95 ± 31.34 L respectively, and the post-exercise means of FVC, FEV_1, and MVV for all intensities were 3.94 ± 0.30 L, 3.84 ± 0.34 L, and 137.92 ± 21.53 L respectively. The improvement here is obvious when compared to pre-mean values for all lung functions (FVC, FEV_1, and MVV).

The FEV1/FVC ratios before and after exercise at different intensities were measured by the Friedman test, which showed that the pre-exercise FEV1/FVC ratio is significantly lower than the post-exercise mean of the FEV1/FVC ratio with p-value < 0.001.

Table 4 shows the paired t-test. The means of pre-exercise FEV_1 and MVV were significantly lower than the post-exercise means, with $p < 0.001$ and $p = 0.003$, respectively. However, the mean of FVC showed no significant difference before or after exercise, with $p = 0.241$.

Post-exercise means at different intensities of FEV_1 and MVV were significantly higher than pre-mean values, with $p < 0.001$ and 0.039 respectively. However, FVC showed no significant difference between pre- and post-exercise means at different intensities ($p = 0.444$) (Table 5).

Table 6 shows that the post-exercise FEV1 improvements were positively and significantly associated with MVV improvement. However, pre-exercise improvements in FVC are not associated with MVV improvement.

DISCUSSION

Many studies have recommended treadmill aerobic exercise as a way to maintain or improve pulmonary function[11-12].

A spirometer is an important instrument in the assessment of the lung functions. FVC, FEV1, MVV and ratio of FEV1/FVC are indicators of strong respiratory function that deteriorate due to a sedentary lifestyle.

Prolonged aerobic exercises are thought to improve aerobic capacity and to have a favorable effect on lung function. Thus, the main aim of this study was to investigate the effect of such aerobic exercise for three weeks, specifically continuous treadmill running, on lung function (FVC, FEV1, ratio of FEV1/FVC, and MVV) in inactive yet healthy male individuals.

Therefore, in this study, we investigated the effect of three weeks of continuous treadmill running on FVC, FEV1, FEV1/FVC, and MVV values for 72 inactive yet healthy male individuals.

FEV1 and MVV significantly improved after high-intensity aerobic exercise. In contrast, there were insignificant improvements in FVC. The improvement in FEV1 means that high-intensity aerobic exercise improves air flow in the respiratory tract. This finding is consistent with other studies, which postulated that FEV1 improvement is mainly caused because the lungs expand during high-intensity aerobic exercise, resulting in a larger volume of air introduced into the airways and a widening of the respiratory tract[13].

MVV is the measure of respiratory muscle performance. Positive relation of MVV improvement with FEV1 improvements showed that the respiratory muscle performance enhancement due to aerobic exercise can improve lung function. This is consistent with a previous study by Miyahara et al., in which MVV improved significantly in 18 COPD patients following a three-week cycle ergo-meter exercise training program. Similarly, MVV improved significantly in 40 COPD patients after a nine-week program of aerobic and upper-body exercise[14], and in asthmatic subjects after a 36-session aerobic exercise program[15].

Table 1. Anthropometric characteristics (m ± SD) of total subjects

	Age (yr)	Height (cm)	Weight (kg)
Mean	30.94	172.65	79.67
Std. Deviation (SD)	11.29	5.72	12.56

Table 2. Baseline spirometric data (m ± SD) of predicted values

	pred FVC (L)	pred FEV_1 (L)	pred MVV (L)
Mean	4.00	3.76	127.14
Std. Deviation	0.51	0.55	22.44

Table 3(A). Baseline spirometric data (m ± SD) of FVC and FEV_1 before and after exercise at different intensities

	Pre exercise FVC	5 min post exercise FVC	15min post exercise FVC	25 min post exercise FVC	Pre exercise FEV_1	5 min post exercise FEV_1	15 min post exercise FEV_1	25 min post exercise FEV_1
Mean	3.80	3.92	3.92	3.96	3.37	3.73	3.86	3.93
SD	0.71	0.56	0.70	0.48	0.77	0.62	0.49	0.53

Table 3(B). Baseline spirometric data (m ± SD) of MVV before and after exercise at different intensities

	Pre exercise MVV	5 min post exercise MVV	15 min post exercise MVV	25min post exercise MVV	FVC-Post exercise	FEV_1-post exercise	MVV-post exercise
Mean	125.47	134.26	135.54	143.95	3.94	3.84	137.92
SD	32.97	30.21	53.18	31.34	0.30	0.34	21.53

Improvement in MVV after exercise training could be due to increased development of respiratory musculature incidental to physical training[16] or to decreased release of inflammatory mediators in patients with bronchial asthma[17]. However, if the mechanism is an increase in respiratory muscle force production, this may explain why MVV improved significantly in the present study while FVC showed no significant increase. The increase in MVV with no improvement in FVC suggests a training effect on the respiratory muscles without an improvement in large or small airways, as MVV is less affected by the state of airways than other parameters.

Moreover, the improvement in MVV could reflect subtle changes in lung function or airway reactivity not detected by the FVC test. In addition, higher exercise intensity or longer duration may be needed to affect other lung function parameters like MVV[18].

What supports this idea in our study that we recruited healthy inactive subjects who values of pre FVC, FEV1 and MVV values were lower compared to predicted values results of respiratory muscle weakness due to sedentary lifestyle. This finding is consistent with Simões et al.[19] who found that respiratory muscle strength was significantly lower in individuals with sedentary lifestyles. Thus, such subjects have needed greater training intensity or longer exercise duration to affect their pulmonary systems and get more significant results. Also, improvement in MVV could be due to improvement in the compliance of the lung-thorax system after exercise training that mainly affects MVV[20].

Table 4. Lung function indices before and after exercise (paired t-test)

Variable	Pre exercise	Post exercise	P-Value
FVC(L)	3.80±0.71	3.94±0.30	0.241
FEV_1 (L)	3.37±0.77	3.84±0.34	<0.001*
MVV(L)	125.47±32.97	137.92±21.53	0.003*

*Significantly different before and after exercise ($p < 0.05$). FVC: forced expiratory volume. FEV_1: forced expiratory volume in one second. MVV: maximum voluntary ventilation.

Table 5. ANOVA of lung function before and after exercise at different intensities

Variable	Pre exercise	Post exercise 5min	Post exercise 15min	Post exercise 25min	F-test	P-Value
FVC(L)	3.80	3.92	3.93	3.96	0.895	0.444
FEV_1 (L)	3.37	3.73	3.86	3.93	12.044	<0.001*
MVV(L)	125.47	134.26	135.54	143.95	2.834	0.039*

*Significantly different before and after exercise at different intensities ($p < 0.05$). FVC: forced expiratory volume. FEV1: forced expiratory volume in one second. MVV: maximum voluntary ventilation.

Table 6. Associations of MVV changes with FVC and FEV1 improvements before and after exercise

		Pre	
		FVC	FEV1
MVV	R	0.140	0.038
	P-Value	0.239	0.751
		Post	
		FVC	FEV1
MVV	R	0.104	-0.307
	P-Value	0.384	0.009**

**Significant at $p < 0.01$.

Many studies have shown that FVC is significantly improved after high-intensity aerobic exercise[21-22]. This means that the vital capacity also increased. It has been suggested that high-intensity aerobic exercise would increase VO2 max and activated inactive alveoli. Moreover, repeated stimulation of inspiration and expiration would increase alveolar compliance. As a result, FVC would increase. In addition, many studies have investigated the effect of exercise on FEV1/FVC and suggested that the enhancement of respiratory muscles and trunk muscles and the improvement of rib cage movement had a positive effect[23-24-25].

In one study, very young competitive female swimmers were found to have an increase in their vital capacity and total lung capacity during one year of training, suggesting that larger lung volumes in swimmers may be due to training. Although the mechanism by which physical inactivity might influence FVC and FEV1 is unclear, the relationship between muscular force and FVC and FEV1 is established[26].

In this study, FEV1/FVC seemed to increase significantly after exercise. This result suggests that the exercise used in our study was not a muscle-strengthening or rib-cage-expanding exercise, but one directly stimulating alveoli with high-intensity aerobic exercise. This may explain the significant improvements in MVV and FEV1 but not FVC.

However, the results of pulmonary functions in our study cannot be compared directly with previous research mainly due to the different method and sample size used, as well as differences in the investigated subjects' age and sex. Thus, more research is needed to investigate and confirm this study's findings.

CONCLUSION

This study examines whether high-intensity aerobic exercise on a treadmill is effective in improving pulmonary function among 72 healthy inactive male individuals. A significant improvement after exercise was observed in FVC, FEV1, MVV, and FEV1/FVC. The results demonstrate that high-intensity aerobic exercise on the treadmill has a positive effect on the pulmonary function of inactive healthy subjects.

In conclusion, Aerobic exercise training should be included in plans to decrease sedentary behavior, improve aerobic capacity, and improve or at least maintain lung function in sedentary subjects. Our data suggest that a much longer exercise intervention or more exercise intensity may be needed to significantly improve lung function in inactive subjects.

REFERENCES

1. Courteix, D., Obert, P., Lecoq, A.M., Guenon, P., Koch, G. Effect of intensive swimming training on lung volumes, airway resistance and on the maximal expiratory flow-volume relationship in prepubertal girls. *Eur J Appl Physiol Occup Physiol*., **76**(3):264-9 (1997).
2. Chanavirut, R., Khaidjapho, K., Jaree, P., Pongnaratorn, P. Yoga exercise increases chest wall expansion and lung volumes in young healthy Thais. *Thai Journal of Physiological Sciences*. **19**(1):1-7 (2006).
3. Radovanovic, D., Aleksandrovic, M., Stojiljkovic, N.D.J., Ignjatovic, A., Popovic, T., Marinkovic, M. Influence of physical training on cardiorespiratory endurance in preadolescent age. *Acta Medica Medianae*. **48**:37-40 (2009).
4. Garcia-Aymerich, J., Lange, P., Benet, M., Schnohr, P., Antó, J.M. Regular physical activity modifies smoking-related lung function decline and reduces risk of chronic obstructive pulmonary disease: a population-based cohort study. *Am J Respir Crit Care Med*. **175**(5):458-63 (2007).
5. Chang, Y.F., Yang, Y.H., Chen, C.C., Chiang, B.L. Tai Chi Chuan training improves the pulmonary function of asthmatic children. *J Microbiol Immunol Infect*. **41**(1):88-95 (2008).
6. Khalili, M.A., Elkins, M.R. Aerobic exercise improves lung function in children with intellectual disability: a randomised trial. *Aust J Physiother*; **55**(3):171-5 (2009).
7. Lee, Y.R., Yu, S.J. The effect of dance therapy on pulmonary and cognitive function in the elderly. *J Korean Acad Nurs*. **29**:1273–83 (1999).
8. Kim, M.J., Lee, J.K., Jung, D.G. The change of body composition, physical fitness, and capacity of the lungs according to gateball experience in old persons. *Korea J Sports Sci*. **16**: 417–26 (2007).
9. Kang, S.W., Lee, S.N., Seo, C.J. The effects of 12 weeks core exercise on pulmonary function in elderly women. *Korea J Sports Sci*. **24**:1423-31 (2015).
10. Cicek, G., Gullu, A., Gullu, E., Yamaner, F. The effect of aerobic and core exercises on forced vital capacity. *Physical culture and sport*. Turkey. (2018).
11. Azad, A., Gharakhanlou, R., Niknam, A., Ghanbari, A. Effects of aerobic exercise on lung function in overweight and obese students. *National Research Institute of Tuberculosis and Lung Disease*. Iran. **10**(3):24-31 (2011).
12. Chan, L., Chin, L.M., Kennedy, M., Woolstenhulme, J.G., Nathan, S.D., Weinstein, A.A., Connors, G., Weir, N.A., Drinkard, B., Lamberti, J., Keyser, R.E. Benefits of intensive treadmill exercise training on cardiorespiratory function and quality of life in patients with pulmonary hypertension. *Chest*. **143**:333-43

(2013).
13. Kang, D.H: Physiology. 5th ed. Shinkwang Publication Company. (1988).
14. Miyahara, N., Eda, R., Takeyama, H., Kunichika, N., Moriyama, M., Aoe, K., Kohara, H., Chikamori, K., Maeda, T., Harada, M. Effects of short-term pulmonary rehabilitation on exercise capacity and quality of life in patients with COPD. *Acta Med Okayama*. **54**(4):179-84 (2000).
15. Haas, F., Pasierski, S., Levine, N. Effect of aerobic training on forced expiratory airflow in exercising asthmatic humans. *J Appl Physiol*. **63**: 1230-5 (1987).
16. Neder, J., Andreoni, S., Lerario, M., Nery, L. Reference values for lung function tests: II. Maximal respiratory pressures and voluntary ventilation. *Braz J Med Biol Res*.**32**(6)719-27 (1999).
17. Dassios, T., Katelari, A., Doudounakis, S., Dimitriou, G. Aerobic exercise and respiratory muscle strength in patients with cystic fibrosis. *Respiratory Medicine*. **107**:684-90 (2013).
18. Gimenez, M., Servera, E., Vergara, P., Bach, J., Polu, J. Endurance training in patients with chronic obstructive pulmonary disease: A comparison of high versus moderate intensity. *Arch Phys Med Rehabil*. **81**: 102-9 (2000).
19. Simões, R.P., Deus, A.P., Auad, M.A., Dionísio, J., Mazzonetto, M., Borghi-Silva, A. Maximal respiratory pressure in healthy 20 to 89 year-old sedentary individuals of central São Paulo State. *Rev Bras Fisioter*. **14**(1):60- 7 (2010).
20. Neder, J., Andreoni, S., Lerario, M., Nery, L. Reference values for lung function tests: II. Maximal respiratory pressures and voluntary ventilation. *Braz J Med Biol Res*.; **32**(6):719-27 (1999).
21. Farrell, P.A. Maximal expiratory flow-volume relationships before and after eight weeks of endurance training. *J Sports Med Phys Fitness*. **21**(2):145-9 (1981).
22. Lee, J.Y., Jung, J.H., Chung, E.J. The effect of feedback breathing exercise and treadmill exercise on chest length and pulmonary function of the middle-aged. *J Spec Educ Rehabil Sci*. **52**:319-33 (2013).
23. Park, J., Han, D. Effects of high intensity aerobic exercise on treadmill on maximum-expiratory lung capacity of elderly women. *J Phys Ther Sci*; **29**(8):1454-1457 (2017).
24. Lee, B., Park, S., Han, D. Analysis of the influential factors of maximal-effort expiratory capacity of elderly women. *J Phys Ther Sci.* **28**: 2924-2928 (2016).
25. Song, JW., Kim, GD. Effects of core stability training on the pulmonary function and trunk muscle activity in chronic stroke patients. *Asia-pacific Journal of Multimedia Services convergent with Art.*; **6**: 101-108 (2016).
26. Courteix, D., Obert, P., Lecoq, A.M., Guenon, P., Koch, G. Effect of intensive swimming training on lung volumes, airway resistance and on the maximal expiratory flow-volume relationship in prepubertal girls. *Eur J Appl Physiol Occup Physiol*. **76**(3):264-9 (1997).