



The Effect of a Single Session of Exhaustive Aerobic Activity Combined with Negative Air Ions on Certain Pulmonary Functional Indices in Active Individual

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Abstract

Background: The present study aimed to investigate the effect of a single session of exhaustive aerobic activity combined with negative air ion inhalation on certain pulmonary functional indices in active individuals.

Methods: Forty physical education students from Shahrood University of Technology, with a mean age of 22.70 ± 0.61 years and a body mass index (BMI) of 21.59 ± 0.74 kg/m², voluntarily participated in the study. This study was designed as a semi-experimental, double-blind crossover trial. Participants were randomly divided into two groups: one exposed to negative air ions and the other not exposed. Both groups performed the Bruce test, with the protocol repeated after one week while the environmental conditions were reversed. Spirometry was conducted to measure pulmonary indices in two conditions: during exercise with ion exposure (before entering the isolated room and immediately after the Bruce test) and without ion exposure (before and immediately after the test). The data were analyzed using paired t-tests and Wilcoxon tests in SPSS software version 24.

Results: The results indicated that negative air ions significantly improved (P -value <0.05) forced vital capacity (FVC) (P -value=0.015), forced expiratory volume in the first second (FEV1) (P -value=0.001), the FEV1/FVC ratio (P -value=0.001), and forced expiratory flow at 25-75% of the pulmonary volume (FEF25-75%) (P -value=0.001).

Conclusions: In conclusion, a single session of negative air ion exposure during exhaustive aerobic exercise significantly improved pulmonary function indices, suggesting potential benefits for respiratory performance.

Keywords: Spirometry, Bruce test, Ventilatory indices, Negative air ions, Ionization.

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Introduction

Air ions are electrically charged particles in the atmosphere that respond to electric fields. They are categorized into positive and negative ions. Negative air ions, often abundant in natural environments such as forests and waterfalls, are considered beneficial to health, while high concentrations of positive ions are commonly associated with polluted, high-traffic urban areas. The 'serotonin balancing by air ions'

hypothesis has attracted significant attention, and considerable experimental data support it. This hypothesis could explain why humans feel more alert, balanced, and energetic in the presence of negative ions¹.

In recent years, negative air ions have been recognized as a marker of air quality, sometimes referred to as "air vitamins" due to their documented benefits on human health^{2, 3}. With growing awareness of environmental and public health issues, negative air ions are now considered an important indicator for evaluating ambient air quality².

Their positive effects span multiple body systems, including cardiovascular, nervous, and respiratory functions. Evidence suggests that they can improve sleep, enhance oxygen utilization, regulate blood pressure, and aid in the management of certain chronic diseases^{4, 5}. Negative ions also improve respiratory efficiency by acting directly on the mucous membranes of the respiratory tract, increasing antioxidant activity, and enhancing oxygen absorption during breathing^{6, 7}.

During physical activity, particularly high-intensity exercise, the body's demand for oxygen increases significantly. Simultaneously, increased ventilation can lead to deeper penetration of airborne particles into the respiratory system⁸. The presence of negative ions in the inhaled air during exercise may enhance oxygen uptake and utilization, improve metabolism, and delay fatigue⁹. Several studies have shown improved exercise performance, reduced physiological stress, and enhanced pulmonary function when negative air ions are combined with physical activity¹⁰⁻¹¹.

However, the structural design of modern urban environments and increasing air pollution have contributed to a significant decline in ambient negative air ion concentrations¹². Artificial methods are thus being explored to simulate their natural presence for therapeutic purposes. Despite the growing global interest in this topic, there is a lack of research conducted in Iran. Given the potential physiological relevance of negative air ions during exercise and existing contradictory findings, the present study aims to investigate whether these particles can influence pulmonary function indices during high-intensity of physical activity.

Materials and Methods



Participants and Study Conditions: This study was a semi-experimental, double-blind crossover design. All participants were fully informed about the study procedures, potential risks, and benefits, and they provided written informed consent before participation.

The target population included male and female students aged 18–24 years from the Physical Education Department of Shahrood University of Technology, who were fully familiar with the Bruce Test. Purposeful sampling was used to select 40 participants (20 females and 20 males) with a mean age of 22.7 ± 0.61 years and a body mass index (BMI) of 21.59 ± 0.74 kg/m².

Inclusion criteria:

- Performing at least 150 minutes of weekly physical activity (assessed via the Beck Questionnaire).
- Normal blood pressure.
- No physical injuries, use of performance-enhancing substances, or smoking within the specified timeframe.
- Absence of chronic diseases or respiratory infections.
- Avoidance of physical activity for 24 hours prior to the test.

At the beginning of the study, we collected data on participants' medical history, training experience, and daily activity levels. Anthropometric measurements were then performed, and participants were randomly assigned to two groups (exercise with and without ion intervention). After 48 hours, the Bruce Test was conducted using a professional treadmill (H/P/COSMOS model), and the test was repeated a week later under reversed conditions to eliminate ion effects.

Ionization Conditions: To create an ionized environment, a 2×2 meter room with a height of 3 meters was prepared. The room was sealed to prevent air exchange, and the temperature (20–23°C) and humidity (27–29%) were controlled. An ion generator device (Masa I320 model, Iran) producing 100,000

ions/cm³ was used to ionize the air, and ion levels were calibrated using an AIC ion tester (USA).

Participants sat one meter away from the device for one hour before the test. To maintain consistent conditions, thick curtains blocked sunlight, ensuring uniform light levels across all testing days.

Spirometry Index Assessment: Respiratory indices were measured using a portable spirometer manufactured by Cosmed (Italy). Two tests were conducted:

- **Forced Vital Capacity (FVC):** measuring vital capacity under forced conditions.
- **Forced Expiratory Volume in 1 Second (FEV1):** measuring expiratory volume during the first second of forced expiration.

Prior to each test, the spirometer was calibrated. Since body posture significantly influences lung capacities, all participants were seated during measurements. Spirometry was performed both before and after the Bruce Test in both conditions (with and without ion exposure).

Statistical Methods: After data collection, both descriptive and inferential statistical methods were used for data analysis. The normality of the data was first assessed. For normally distributed data, paired t-tests were used, while the Wilcoxon test was applied for non-normally distributed data to examine significant changes in each of the respiratory indices.

All statistical operations and analyses were performed at a significance level of 0.05 and a 95% confidence interval using SPSS software, version 24.

Results

The mean and standard deviation of anthropometric characteristics of the subjects are presented in Table 1, and the mean and standard deviation of various pulmonary indices in different conditions are presented in Tables 2 and 3.

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

Characteristics	Total Group	Male	Female
Number	40	20	20
Age (years)	21.80 ± 0.37	22.70 ± 0.61	20.90 ± 0.34
Height (cm)	170.98 ± 1.62	178.35 ± 1.64	163.61 ± 1.55
Weight (kg)	63.09 ± 1.98	68.16 ± 2.77	58.01 ± 2.43
BMI (kg/m ²)	21.48 ± 0.51	21.36 ± 0.74	21.59 ± 0.74

Table 2. Mean and standard deviation of various pulmonary indices in two rest conditions with and without ion intervention

Environmental Condition	FVC (L)	FEV1 (L)	FEF25-75 (L)	FEV1/FVC (%)
No ion intervention - Total	3.51 ± 0.84	2.98 ± 0.92	3.35 ± 1.26	100.97 ± 13.45
No ion intervention - Girls	3.61 ± 0.00	2.79 ± 0.51	2.77 ± 0.90	98.75 ± 13.80
No ion intervention - Boys	4.02 ± 0.73	3.82 ± 0.45	3.94 ± 1.31	103.20 ± 13.06
Ion intervention - Total	3.74 ± 0.82	3.33 ± 0.82	4.10 ± 1.17	109.07 ± 7.34
Ion intervention - Girls	3.63 ± 0.28	2.66 ± 0.78	3.35 ± 0.94	107.45 ± 7.80
Ion intervention - Boys	4.75 ± 0.20	3.54 ± 0.88	4.69 ± 1.09	110.70 ± 6.64

Table 3. Mean and standard deviation of various pulmonary indices in two activity conditions with and without ion exposure

Group	Environmental Condition	FVC (L) (Mean±SD)	FEV1 (L) (Mean±SD)	FEF25–75 (L) (Mean±SD)	FEV1/FVC (%) (Mean±SD)
Total	Without ion intervention	3.35±0.77	2.84±0.81	3.33±1.29	100.67±13.45
Girls	Without ion intervention	2.63±0.91	2.51±0.47	1.01±2.97	112.01±100.10
Boys	Without ion intervention	3.65±0.79	2.90±0.22	1.46±3.69	115.04±101.25
Total	With ion intervention	3.61±0.86	3.17±0.81	4.03±1.33	106.45±11.50
Girls	With ion intervention	3.53±1.11	2.58±0.66	0.99±3.39	110.62±105.15
Boys	With ion intervention	4.85±1.11	3.69±0.68	1.32±4.68	112.46±107.75

In Tables 4 to 7, the summary of the ANOVA analysis presents the mean changes and standard deviations of Forced Vital Capacity (FVC), Forced Expiratory Volume in the first second (FEV1), the ratio of FEV1 to FVC (FEV1/FVC), and

Forced Expiratory Flow at 25–75% (FEF25-75) under two activity conditions, with and without negative ion exposure. All analyses demonstrate the significant effect of ionization on respiratory indices.

Table 4. Results of ANOVA test for evaluating the effect of two conditions (with and without negative ion intervention) on Forced Vital Capacity (FVC)

Source of Variation	SS	df	MS	F	p
Interaction of Condition × Time	0.797	1.72	0.463	7.23	0.002 *
Error	72.73	16	4.407		

Table 4.1. Comparison of means between conditions with and without ion intervention

Condition 1	Condition 2	Mean Difference	Std. Deviation	p-value
Ion	No Ion	0.162	0.34	0.000 *

* Indicates a statistically significant difference in respiratory indices at P-value<0.05

Table 5. Results of ANOVA test for evaluating the effect of two conditions (with and without negative ion intervention) on Forced Expiratory Volume in One Second (FEV1)

Source of Variation	SS	df	MS	F	p-value
Interaction of Condition × Time	1.533	1.63	0.939	9.08	0.000 *
Error	6.500	63	0.103		

Table 5.1. Comparison of means between conditions with and without ion intervention

Condition 1	Condition 2	Mean Difference	Std. Deviation	p-value
Ion	No Ion	0.226	0.041	0.000 *

Table 6. Results of ANOVA test for evaluating the effect of two conditions (with and without negative ion intervention) on FEF25–75 (Forced Expiratory Flow 25–75%)

Source of Variation	SS	df	MS	F	p-value
Interaction of Condition × Time	695.7	1.26	550.4	4.87	0.010 *
Error	556.2	49	112.91		

Table 6.1. Comparison of means between conditions with and without ion intervention

Condition 1	Condition 2	Mean Difference	Std. Deviation	p-value
Ion	No Ion	4.625	0.762	0.000 *

Table 7. Results of ANOVA test for evaluating the effect of two conditions (with and without negative ion intervention) on FEV1/FVC Ratio

Source of Variation	SS	df	MS	F	p-value
Interaction of Condition × Time	7.027	1.93	3.640	15.80	0.000 *
Error	17.34	75	0.230		

Table 7.1. Comparison of means between conditions with and without ion intervention

Condition 1	Condition 2	Mean Difference	Std. Deviation	p-value
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Ion	No Ion	0.483	0.078	0.000 *
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The changes in the respiratory indices showed (Table 8) that the forced vital capacity (FVC) increased by 7.7%, forced expiratory volume in one second (FEV1) increased by 11.6%, the FEV1/FVC ratio increased by 5.7%, and the maximum mid-expiratory flow (FEF25-75) increased by 21%. Among

these indices, the most significant increase was seen in FEF25-75.

Summary of results: The ANOVA results indicate that the effect of negative ion intervention on respiratory indices is statistically significant (P -value<0.05).

Table 8. Spirometry Indices in Two Environments With and Without Ion Exposure

Spirometry Index	Without Ion (Mean±SD)	With Ion (Mean±SD)
FVC (L)	3.35±0.77	3.61±0.86
FEV1 (L)	2.84±0.81	3.17±0.81
FEF25-75 (L)	1.29±3.33	1.33±4.03
FEV1/FVC (%)	100.67±13.45	106.45±11.50

Discussion

In the present study, the effect of a single session of aerobic exercise combined with negative air ions on certain respiratory performance indices was examined. Researchers have long been interested in the respiratory performance of individuals under different conditions¹³. Studies show that respiratory performance is influenced by various factors, including the nervous system, the strength of respiratory muscles, and lung dimensions¹⁴. Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1) are parameters used to measure lung performance and are strong indicators of respiratory function¹⁵. Additionally, FEV1, as one of the main metrics of lung function, reflects expiratory capacity and airway diameter, both large and small. Furthermore, FEV1 also assesses bronchial contraction and expansion responses¹⁶.

Studies indicate that the elastic properties of the lungs, airway resistance between the alveolar region, and airway compliance mechanisms significantly impact airflow in this phase. Processes that increase lung elasticity or reduce resistance, as well as enhance the rigidity of airway walls, can increase airflow in any given lung volume¹⁷.

The results of this study indicated a significant effect of inhaling negative air ions on FVC and FEV1 levels. Specifically, exposure to ionized air for just one hour led to a 7.7% increase in FVC and an 11.6% increase in FEV1. It is likely that the direct effect of negative ions on the mucosal membrane of the airways and increased oxidative capacity of airway muscles contributed to these improvements and this may refer to increased oxygen consumption by airway muscles. These factors are critical during exercise for maintaining airway patency and expanding lung volumes.

The FEV1/FVC ratio, which represents breathing power and airway resistance, was also found to improve significantly. In this study, alongside the improvement in FVC and FEV1, this ratio also showed significant growth, suggesting that negative ions may facilitate bronchial dilation, reduce airway resistance, and enhance ventilation efficiency.

Another key finding of this research was the significant increase in the maximum mid-expiratory flow (FEF25-75). In

more than 95% of cases, airflow in the mid-expiratory phase was above optimal levels, indicating improved performance of the small airways.

Unfortunately, the existing literature does not include studies on healthy athletes that match the variables measured in this study, as research on negative ions and exercise is limited. Thus, the references to prior research are not directly comparable with the present study's sample. However, several studies investigating respiratory systems and negative ions are worth mentioning. For instance, in 2016, Zhang et al. examined the therapeutic effect of low-intensity aerobic exercise combined with inhaling negative oxygen ions in workers with pneumoconiosis, showing a significant increase in FVC and FEV1. Similarly, in a 2008 study by Sirota, even a brief exposure to negative air ions improved respiratory and oxygen-dependent phagocytosis.

However, studies by Petter Walner et al. (2015) and Wiesznowski & Sachanowski (2008) did not show any significant effects. Walner et al.'s study, conducted on 20 healthy young adults, reported no effect on respiratory function after exposure to ion concentrations of 1038 and 2194 ions per cubic centimeter¹⁸. This may have been due to the ion concentration and the method of ion generation used. Similarly, Wiesznowski & Sachanowski's study on 10 male physical education students showed no improvement in respiratory function, possibly because of insufficient ion concentration, which may have prevented the ions from reaching the lungs¹⁹.

Overall, improvements in respiratory performance indices after exposure to negative ions may confirm the beneficial role of negative air ions in improving respiratory system efficiency by providing a favorable air environment for better lung function. Although the precise mechanisms of negative ions are still unclear, limited research indicates that they have biological effects on the human body, particularly on the respiratory system. Likely mechanisms include serotonin modulation, improving red blood cell deformability, and stimulating the nervous system.

Conclusion



In conclusion, exposure to negative air ions leads to numerous physiological changes in the human body, particularly in the respiratory system. The spirometry results after just one hour of exposure to negative air ions demonstrated significant increases in key ventilatory performance indices such as FVC, FEV1, FEV1/FVC, and FEF25-75 following intense exercise. While further research with larger sample sizes and different exercise intensities is necessary to confirm these findings.

Ethical Considerations

This study received ethical approval from the Ethics Committee of Shahrood University of Medical Sciences (Code: 1397-182.IR.SHMU.REC).

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Conflict of Interest

The authors declare no conflicts of interest regarding this study or its publication.

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