IJPM

Effects of Exercise in Polluted Air on the Aerobic Power, Serum Lactate Level and Cell Blood Count of Active Individuals

Mehdi Kargarfard[1], Parinaz Poursafa[2,3], Saber Rezanejad[4], Firouzeh Mousavinasab[5]

[1] PhD, Associate Professor, Department of Sport Physiology, School of Physical Education and Sport Sciences, University of Isfahan, Isfahan, Iran.
[2] MSc, Environment Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
[3] MSc, Department of Environment, Science and Research Branch, Islamic Azad University, Tehran, Iran
[4] MSc, School of Physical Education and Sport Sciences, University of Isfahan, Isfahan, Iran
[5] MD, PhD, Child Health Promotion Research Center, Isfahan University of Medical Sciences, Isfahan, Iran.

Correspondence to:
Parinaz Poursafa
MSc of Environmental Engineering, Environment Research Center, Isfahan University of Medical Sciences, Isfahan, Iran. & Sciences and Research Branch, Islamic Azad University, Tehran, Iran.
Email: parinaz.poursafa@gmail.com

Date of Submission: Jan 20, 2011

Date of Acceptance: Apr 25, 2011

ABSTRACT

Objectives: The purpose of this study was to assess the effects of exercise on the aerobic power, serum lactate level, and cell blood count among active individuals in the environments with similar climatic characteristics differing in their level of air pollution.

Methods: This trial comprised 20 volunteer students of Physical education in The University of Isfahan, Iran. Two places with the same climate (altitude, temperature, and humidity), but low and high level of air pollutants air were selected in Isfahan, Iran. Participants underwent a field Cooper test with a 12-minute run for fitness assessment. Then the aerobic power, serum lactate, and cell blood counts were measured and compared between the two areas.

Results: The study participants had a mean (SD) age of 21.70 (2.10) years and body mass index (BMI) of 24.44 (2.32) Kg/m2. We found a significant decrease in mean Vo2 max, red blood cell count, hemoglobin, hematocrit, and mean corpuscular hemoglobin, as well as significant increase in mean lactate level, white blood cell count and mean corpuscular volume in the higher-polluted than in the lower-polluted area. No significant difference was documented for other parameters as platelet counts or maximum heart rate.

Conclusions: Exercise in high-polluted air resulted in a significant reduction in the performance at submaximal levels of physical exertion. Therefore, the acute exposure to polluted air may cause a significant reduction in the performance of active individuals. The clinical importance of these findings should be assessed in longitudinal studies.

Keywords: Air pollution, Aerobic power, Lactate, Active individuals.

Int J Prev Med 2011; 2(3): 145-150

Original Article

INTRODUCTION

There is a growing body of evidence about the harmful effects of air pollution, which can affect human health with both short- and long-term effects. Different groups of individuals may be affected in different ways, and some individuals are more sensitive to pollutants than others. Children and elderly people and those with health problems such as asthma, heart, and lung disease often suffer more from the effects of air pollution. Numerous studies have reported short-term effects of air pollution on increasing the risk of cardiorespiratory mortality and morbidity[1,2] as well as the process of atherosclerosis from early life.[3,4]

The extent to which an individual is affected by air pollution generally depends on the total exposure to the damaging pollutants, which is usually determined by the duration of exposure and the concentration of the chemicals. In addition, to reduce the exposure to air pollutants, these vulnerable groups are advised not to exercise in the air-polluted areas. The latter might be due to an exercise-induced amplification in respiratory uptake, pulmonary deposition, and toxicity of inhaled air pollutants. Similarly, athletes are at increased risk of breathing pollutants; this vulnerability is considered to be because of a proportional increase in the amount of pollutants inhaled with increases in minute ventilation, the increased airflow velocity transferring pollutants deeper into the respiratory tract, and the larger fraction of air bypassing the normal nasal mechanisms when inhaled by mouth breathing during exercise. However, the effects of ambient air pollution on the exercising individuals remain controversial.[5,6]

The most common air pollutants are carbon dioxide, carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides, particulate matters with a diameter of less than 10 µm (PM_{10}), and ozone.[7] High level of air pollutants may lead to decrease in the maximal oxygen consumption (Vo_2 max) which is probably because of low level of oxygen transport from the pulmonary alveoli.[2,8]

The purpose of this study was to assess the effects of exercise on the aerobic power, serum lactate level, and cell blood count among active individuals in the environments with similar climatic characteristics but differing in their level of air pollution.

METHODS

Study participants

This trial comprised 20 volunteer students of Physical education in The University of Isfahan, Isfahan, Iran. The eligibility criteria were being apparently healthy, non-smoker and participating in physical training sessions for at least 3 times a week round year, and without any chronic medication use and acute or chronic diseases.

The study was approved in the Research and Ethics Committee of the Physical education faculty, The University of Isfahan, Isfahan, Iran. Written informed consent was obtained from participants.

The age of participants was calculated from the birth date. Weight and height were measured under standard protocols to the nearest 200 grams and 0.1 cm, respectively by using calibrated weighing scale and stadiometer (Seca, Germany). Body mass index (BMI) was calculated as weight (kg) divided by squared meter (m^2).

Study area

Isfahan is an industrial city with a population of near 2 million, located in the center of Iran plateau, with an average altitude of 1500 m from the sea level bounded by NW-SE mountain range of 3000 m. The average monthly temperature is 16°C with maximum 29°C in July and minimum 3°C in December with mild winds from West and South. The air of this city is predominantly affected by industrial emissions and motor traffic which can lead to a build-up of elevated concentrations during stagnant conditions.[9,10]

Procedures and measurements

Two places with the same climate (altitude, temperature and humidity), but with low and high level of air pollutants, were selected in Isfahan city (Bakhtiyardasht as low-, and Azadi square as high-polluted area) on the basis of information collected by the stations of the Environmental Protection Agency.

For fitness assessment, Cooper test was used; the point of the test is to run as far as possible within 12 minutes, in addition to age and gender, the outcome is based on the distance the person ran, and the results can be correlated with VO_2 max.[11]

Participants were asked not to participate in any physical activity session in the 24 hours before the test, which was conducted at 9-11 a.m. in the area with low pollution level, and after a 7-day interval, it was repeated in the other area. Maximum oxygen consumption of each participant was determined by putting distance run within 12 minutes in the following equation: (Distance in 12 min per mile) × 35.9712 + 11.2872 = Vo_2 max (ml/kgm).[12]

Immediately after the test and recording the distance, participant's maximum heart rate (HR) was calculated and recorded using a Polar HR meter, installed on the chest. Then by taking a drop of fingertip blood sample, serum lactate level was measured by using Scott Lactometer device.[13] Moreover, 2 ml. venous blood was obtained from each individual to test for complete blood count, including red blood cell (RBC) count, hemoglobin (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), white blood cells (WBC), and platelets count. The blood specimens were measured by American hematology system H3 (Homolog 3) method (pass blood cells in front of light and measure the Peroxidase content of blood cells).

Statistical Analysis

We used the Kolmogorov–Smirnov test to determine the normality of the variables' distribution, and Paired t-test to compare the mean value of variables in the two areas under study. Statistical analysis was performed using the Statistical Package for Social Sciences software version 13.0 (SPSS Inc, Chicago, IL). The statistical significance was set at $P < 0.05$.

RESULTS

The mean (SD) of age, weight, height and BMI of the study participants was 21.70 (2.10) years, 65.85 (4.23) Kg, 175.80 (6.78) cm, and 24.44 (2.32) Kg/m^2, respectively.

The environmental characteristics of the two study areas are presented in Table 1, and confirm the difference in the air quality of the two areas under study.

Comparison of variables before and after running test showed significant decrease in mean Vo_2 max, RBC count, Hb, HCT, and MCH, as well as significant increase in mean lactate level, WBC count, and MCV in the higher-polluted than in the lower-polluted area. No significant difference was documented for other parameters as platelet counts or maximum heart rate.

Table 1. Characteristics of the low- and high-polluted areas

	Low-polluted area	High-polluted area
Humidity (%)	48.5	49.5
Temperature (°C)	9.8	9.6
Altitude (m)	1626	1600
CO (ppm)	2.4	35.4
O_3 (ppb)	1.6	10.1
PM_{10} (µg/m^3)	20	248
NO_2 (ppb)	18.3	45.4
SO_2 (ppb)	18.2	46.9
PSI	< 50	> 200

SD: Standard deviation; PM_{10}: Particular matter 10 (acceptable level: 50 µg/m^3); CO: Carbon monoxide (acceptable level: 9 ppm); SO_2: Sulfur dioxide (acceptable level: 0.03 ppb); NO_2: Nitrogen dioxide (acceptable level: 0.05 ppb); O_3: Ozone (acceptable level: 0.08 ppb); PSI: Pollution Standards Index (Good: 0-50; Moderate: 51-100; Unhealthful: 101-199; Very unhealthful: 200-299; Hazardous: > 300)

Table 2. Comparison of changes in variables after exercise in areas with low- and high-polluted air

Variables	Low-polluted air	High-polluted air	P-value
Distance traveled (m)	2880 ± 150.78	2810 ± 174.41	0.003
Maximal oxygen consumption (Vo_2 max)* (ml/kg/hour)	51.45 ± 2.69	50.20 ± 3.09	0.003
Maximum heart rate (/min)	192.70 ± 5.68	192.90 ± 5.82	0.66
Blood lactate (milimol/lit)	10.16 ± 3.36	1080 ± 3.61	0.001
Red blood cell count* (million/uL)	5.41 ± 0.30	5.23 ± 0.27	0.001
Blood White Blood Cell* (X10^3/ µl)	9.24 ± 1.78	10.39 ± 1.95	0.033
Hemoglobin (gr/dl)	15.63 ± 0.72	15.35 ± 0.63	0.028
MCV	90.20 ± 4.34	90.78 ± 4.39	0.001
MCH(picogram)	29.38 ± 1.56	28.91 ± 1.45	0.001
Hematocrit (%)	48.75 ± 2.05	47.42 ± 1.71	0.001
Platelet count (X10^3/µl)	263.00 ± 51.95	263.70 ± 51.52	0.88

Data are mean± standard deviation

MCV: mean corpuscular volume MCH:mean corpuscular hemoglobin

DISCUSSION

This study, which assessed the effects of exercise in areas with low and high levels of air pollution on the aerobic power, serum lactate level and cell blood count among active individuals, revealed that exercise in high-polluted air resulted in a significant reduction in the performance at submaximal levels of physical exertion.

Most previous studies on the acute health effects of air pollution have been conducted on elderly or known cases of respiratory or cardiovascular diseases. The current study showed the acute effects of air pollutants in young individuals. This might be because exercise increases the amount of inhaled pollutants[14] in a harmful level for healthy young individuals.

We found a significant increase in lactate range along with significant decrease in the maximum oxygen consumption without significant change in the maximum heart rate. These changes might be due to the oxygen used by tissues, particularly by the active muscles, and resulting in reduced blood oxygen content. Given that the energy production during the prolonged aerobic activities requires oxygen consumption, any disturbance in the blood oxygen transport would lead to severe physiological responses affecting the individual's performance during the physical activity.[4,5,7]

Carbon monoxide (CO) is one of the most important pollutants with extreme effect on the oxygen transport in the circulation.[7] As the bonding of Hb with CO is about 240 fold higher than oxygen, so carboxyhemoglobin (COHb) will not release the carbon monoxide, and therefore hemoglobin will not be available to transport oxygen from the lungs to other body organs.[5,7]

In our study, exercise in the high-polluted area led to significant decrease in the mean Vo_2 max and significant increase in the mean serum lactate level. The reduced aerobic physical activity can be attributed to the increase in COHb, so the individual would enter earlier to the anaerobic system. This may result in decreased anaerobic threshold and in turn in accumulative lactate production, as well as in reducing maximum oxygen consumption.

The current study showed a significant decrease in the distance traveled in the high- than in low-polluted air, and in line with some other studies;[2,15] it showed that endurance performance decreased in the polluted air. This phenomenon is reported to be related to an impaired oxygen distribution system and pulmonary dysfunction in polluted air during activity.[2,5,6,16]

An experimental study, which simulated urban CO air pollution, aggravated the rat heart ischemia-reperfusion injury. This study proposed that exercise in air-polluted environments might increase the risk of diseases due to an exercise-induced amplification in respiratory uptake, lung deposition and toxicity of inhaled pollutants.[17]

The relationship of air pollution and hematological factors remains controversial. Our findings are in line with an experimental study that revealed a significant decrease in hematocrit and a significant increase in leucocyte number in mice exposed to polluted air.[18]

The current study showed significant decreases in RBC count, Hb, HCT, and MCH after exercise in polluted air. This decrease might be due to small increase in the blood volume because of air pollution, as documented in experimental studies.[19] Furthermore, our findings about the effects of acute exposure to air pollutants on WBC count of healthy young individuals are in line with an experimental study[20] and a population-based study conducted among people aged 20-89 years.[21]

Increase in WBC count after chronic exposure to air pollutants might be the result of the tissue damaging and increase of the antibody production in response to exposure to pollutions. However, limited experience exists on the short-term effects of air pollutants on WBC count. Our finding on increase in WBC count is consistent with a study conducted on military firemen.[22]

A recent study investigated the effects of a 20-minute bicycle ride along a crowded road on inducing changes in biomarkers of pulmonary and systematic inflammation in 38 healthy individuals (mean age: 43 ± 8.6 years). It found that exposure to pollutants caused a slight increase in the distribution of inflammatory blood cells, the percentage of blood neutrophils increased significantly more after exercise in the road test than after exercise in the clean room, whereas total WBC count did not differ significantly between the two situations.[23] It might be suggested that these changes occur to strengthen the immune system in order to deal with pollutants. However, the findings of the present study are not consistent with a study that compared hematological parameters before and after a period of exposure to heavy pollution in Turkey, and found increased Hb and Hct levels.[24]

However, given the harmful effects of air pollution on the early stages of atherosclerosis from early life,[25] the health benefits and risks of exercising in urban polluted air should be compared. A systematic review assessed whether the health benefits of increasing physical activity of a modal shift for urban travels outweigh the health risks. It estimated that societal benefits of this change are superior because of a modest reduction in air pollution and greenhouse gas emissions as well as traffic accidents.[26]

Study limitations

Given that our study was performed under "real world" conditions, we could not identify the association of a single agent with the effects observed. Furthermore, we could not determine the mechanisms underlying the health effects observed after exposure to air pollution.

CONCLUSION

Our findings suggest that air pollution adversely affected cardiorespiratory fitness and some hematologic factors in young individuals during exercise. The clinical importance of these findings should be assessed in longitudinal studies. We suggest that recommendations for reducing exercising in exposure to air pollutants should not be limited to children and elderly.

Conflict of interest statement: All authors declare that they have no conflict of interest.

Source of funding: This study was funded by the University of Isfahan.

REFERENCES

1. Dockery DW, Pope CA, III, Xu X, Spengler JD, Ware JH, Fay ME, et al. An association between air pollution and mortality in six U.S. cities. N Engl J Med 1993; 329(24): 1753-9.
2. Oliveira RS, Barros Neto TL, Braga AL, Raso V, Pereira LA, Morette SR, et al. Impact of acute exposure to air pollution on the cardiorespiratory performance of military firemen. Braz J Med Biol Res 2006; 39(12): 1643-9
3. Kelishadi R, Poursafa P. Air Pollution and Non-respiratory Health Hazards for Children. Arch Med Sci 2010; 6 (4): 483-95.
4. Poursafa P, Kelishadi R. Air pollution, platelet activation and atherosclerosis. Inflamm Allergy Drug Targets 2010; 9(5): 387-92.
5. Williams C. Environmental factors affecting elite young athletes. Med Sport Sci 2011; 56: 150-70.
6. Poussel M, Chenuel B. [Exercise-induced bronchoconstriction in non-asthmatic athletes]. Rev Mal Respir 2010; 27(8): 898-906.
7. Brook RD, Rajagopalan S, Pope CA, Brook JR, Bhatnagar A, Diez-Roux AV, et al. Particulate Matter Air Pollution and Cardiovascular Disease An Update to the Scientific Statement From the American Heart Association. Circulation 2010; 121: 2331-78.
8. Liu X, Song X, Meng Z. [Effects of airborne pollution on cardiopulmonary function of healthy person]. Wei Sheng Yan Jiu 2008; 37(4): 429-32.
9. Talebi SM, Tavakoli T, Ghinani A. Levels of PM10 and its chemical composition in the atmosphere of the city of Isfahan. Iran J Chem Engin 2008; 3: 62-7.
10. Modarres R, Khosravi Dehkordi A. Daily air pollution time series analysis of Isfahan City. Int J Environ Sci Technol 2005; 2(3): 259-67.
11. [cited 2011 Feb]. Available from: URL:http://www.cooperaerobics.com/About-Cooper/Dr--Kenneth-Cooper.
12. Maud PJ, Foster C. Physiological Assessment of Human Fitness. United States of America: Human Kinetics Publishers; 1995.
13. Conconi F, Ferrari M, Ziglio PG, Droghetti P, Codeca L. Determination of the anaerobic threshold by a noninvasive field test in runners. J Appl Physiol 1982; 52(4): 869-73.
14. Folinsbee LJ. Effects of air pollutants on exercise. In: Garret WE, Kirkendall DT, editors. Exercise and sport science. Philadelphia: Lippincott Willians & Wilkins; 2000. p. 285-97.
15. Adir Y, Merdler A, Ben Haim S, Front A, Harduf R, Bitterman H. Effects of exposure to low concentrations of carbon monoxide on exercise performance and myocardial perfusion in young healthy men. Occup Environ Med 1999; 56(8): 535-8.
16. Rodriguez C, Tonkin R, Heyworth J, Kusel M, De Klerk N, Sly PD, et al. The relationship between outdoor air quality and respiratory symptoms in young children. Int J Environ Health Res 2007; 17(5): 351-60.
17. Meyer G, Andre L, Tanguy S, Boissiere J, Farah C, Lopez-Lauri F, et al. Simulated urban carbon monoxide air pollution exacerbates rat heart ischemia-reperfusion injury. Am J Physiol Heart Circ Physiol 2010; 298(5): H1445-H1453.
18. Goto Y, Hogg JC, Shih CH, Ishii H, Vincent R, van Eeden SF. Exposure to ambient particles accelerates monocyte release from bone marrow in atherosclerotic rabbits. Am J Physiol Lung Cell Mol Physiol 2004; 287(1): L79-L85.
19. Davidson SB, Penney DG. Time course of blood volume change with carbon monoxide inhalation and its contribution to the overall cardiovascular response. Arch Toxicol 1988; 61(4): 306-13.
20. Gorriz A, Llacuna S, Riera M, Nadal J. Effects of air pollution on hematological and plasma parameters in

Apodemus sylvaticus and Mus musculus. Arch Environ Contam Toxicol 1996; 31(1): 153-8.
21. Chen JC, Schwartz J. Metabolic syndrome and inflammatory responses to long-term particulate air pollutants. Environ Health Perspect 2008; 116(5): 612-7.
22. Oliveira RS, Barros Neto TL, Braga AL, Raso V, Pereira LA, Morette SR, et al. Impact of acute exposure to air pollution on the cardiorespiratory performance of military firemen. Braz J Med Biol Res 2006; 39(12): 1643-9.
23. Jacobs L, Nawrot TS, de Geus B, Meeusen R, Degraeuwe B, Bernard A, et al. Subclinical responses in healthy cyclists briefly exposed to traffic-related air pollution: an intervention study. Environ Health 2010; 9: 64.
24. Baskurt OK, Levi E, Caglayan S, Dikmenoglu N, Kutman MN. Hematological and hemorheological effects of air pollution. Arch Environ Health 1990; 45(4): 224-8.
25. Kelishadi R, Mirghaffari N, Poursafa P, Gidding SS. Lifestyle and environmental factors associated with inflammation, oxidative stress and insulin resistance in children. Atherosclerosis 2009; 203(1): 311-9.
26. Johan dH, Boogaard H, Nijland H, Hoek G. Do the health benefits of cycling outweigh the risks? Environ Health Perspect 2010; 118(8): 1109-16.