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ORIGINAL RESEARCH STUDY

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Summary Exercise-induced asthma is seen following vigorous or prolonged exercise or physical exertion. It has been suggested that climatic conditions have an influence on exercise-induced asthma. Therefore, the aim of the present study was to examine the effect of two climatic conditions on exercise-induced deterioration of pulmonary function tests in 10—12 year old students.

Two hundred and fifty six students were randomly chosen from two cities namely Kerman and Gorgan (128 subjects in each who were equally from both cities) including 62 girls and 66 boys of 10—12 years old. A questionnaire was used to obtain demographic information and to identify the prevalence of asthma symptoms. Each subject performed a seven-minute free run exercise with maximum effort and sufficient motivation until they reached 70—75% heart rate. Pulmonary function tests (PFT) including, forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow (PEF), and maximum expiratory flow at 50% of vital capacity (MEF_{50}) were measured before, at the beginning, and 7 and

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20 min after physical activity.

The prevalence of both asthma (28.12%) and exercise-induced asthma (20.31%) in Kerman students was higher than those of Gorgan students (21.09% and 17%, respectively). All PFT values declined 7 and 20 min post-exercise in both groups. Although all baselines PFT in Kerman students were higher than those of Gorgan students, the decline in PFT values in Kerman students was greater than those of Gorgan students. At 20 min post exercise, the decline in FEV_1, PEF and MEF_{50} in Kerman students was significantly higher than those of Gorgan students ($p < 0.05$ to $p < 0.01$).

The results of the present study showed that prevalence of both asthma and exercise-induced asthma in a city with dry and cool climate such as Kerman was higher than in a city with humid climate such as Gorgan. In addition, the results showed that in a humid climate, post-exercise decline in PFT values was less than in a dry climate.

Introduction

Exercise-induced asthma (EIA) is known as a temporary obstruction of the airways occurring immediately after exercise, and its main symptoms are coughing and wheezing. EIA can be proven by the decrease in the forced expiratory volume in one second (FEV_1) and other spirometric parameters (Kiley et al., 2007). During normal breathing, the inspired air is warmed and humidified in the upper airways (Parlato, 1937). In EIA, airways smooth muscles are sensitive and contract in response to temperature and humidity changes, which leads to airway narrowing. EIA results in coughing, chest, tightness wheezing, unusual fatigue, and shortness of breath during exercise (Dryden et al., 2008). The symptoms of EIA generally begin within 5–20 min after the start of exercise, or 5–10 min after the end of brief exercise (Moshe et al., 2008). Inhaler bronchodilators that are used prior to exercise can prevent exercise-induced asthma symptoms.

In addition, warming up prior to exercise and cooling down after exercise can prevent exercise-induced asthma (Pelkonen et al., 2003). In allergic and asthmatic patients, exercise should be limited during high pollen period or when temperatures are extremely low and air pollution levels are high. EIA could be diagnosed by taking a history and measurement of PFT values before, during and after exercise.

Although several studies were conducted in order to clarify the mechanisms of induction of EIA, the mechanism of development of EIA has not been fully defined yet. The prevalence of EIA varies in different sports modalities, being 50% in cross-country skiing athletes, 35% in ice hockey, 43% in velocity skaters and 17% in winter and summer Olympic athletes (Laitano and Meyer, 2007). It is worth mentioning that the highest EIA prevalence occurs in athletes who compete in cold weather, which is two times higher than that of summer exercises (Helenius and Haahtela, 2000). The importance of physical activity for health is well recognized, but little is known about the influence of physical activity on pulmonary physiology (Boskabady et al., 2014). Therefore, in the present study, the effect of two different climates on the incidence of EIA in young students was examined.

Methods

Population

Two hundred and fifty six students, 10–12 years old were included in this study from two cities of Iran namely Kerman and Gorgan. This study performs in two cities of Iran namely Kerman and Gorgan. Distance from gorgan to kerman 1123 km. Kerman (dry city) is the capital city of Kerman Province in the central south of Iran. The city of Kerman has a moderate climate with average annual temperature of 16.8 °C, and average annual rainfall of 135 mm. Because it is located close to the Kavir-e lut, Kerman has hot summers, and in the spring it often has violent sand storms. At the 2011, its population was 821,374, making it the 10th most populous city of Iran. This city is 1755 m above sea level, making it third in elevation among provincial capitals in Iran. Gorgan (humid city) is the capital of Golestan Province in the north east of Iran, approximately 30 km away from the Caspian Sea. In the 2006, its population was 269,226. The average annual temperature is 18.2 °C (64.8 °F) and the annual rainfall is 600 mm. One hundred and twenty eight students from each city (including 62 girl and 66 boys) were randomly recruited. Eight schools from different regions of each city and 16 students in each school were selected by electoral roll. Therefore, the studied subjects were of different socioeconomic classes.

No subject had history or symptoms of cardiovascular diseases that require treatment. The protocol was approved by the ethics committee of Shahid Bahonar University of Kerman. Demographic information was shown in Table 1.

Protocol

All participants completed specific and standard questionnaire in Farsi language which was provided according to the

Table 1 Demographic information of the subjects from Kerman and Gorgan cities.

City	Gender	No.	Height (cm)	Weight (kg)	Age (year)	BMI
Kerman	Girl	66	146.65 ± 6.81	41.75 ± 4.45	10.61 ± 0.76	19.60 ± 3.51
	Boy	62	147.90 ± 6.78	40.22 ± 5.02	10.83 ± 0.78	18.62 ± 3.22
	Total	128	147.27 ± 6.80	40.98 ± 4.73	10.72 ± 0.77	18.97 ± 3.38
Gorgan	Girl	66	147.20 ± 6.92	42.09 ± 3.90	10.90 ± 0.81	19.48 ± 3.45
	Boy	62	148.06 ± 6.23	41.29 ± 4.61	10.58 ± 0.79	18.85 ± 3.17
	Total	128	147.63 ± 6.58	41.69 ± 4.25	10.73 ± 0.80	19.30 ± 3.27

Data are presented as mean ± SD.

previous studies (Marefati et al., 2011; Turcotte et al., 2003). The asthma symptoms in the questionnaire were recurrent wheezing, recurrent cough or tightness at rest, night cough, wheezing or coughing during exercise. Subjects with two or more symptoms or those who were previously diagnosed as asthmatic were considered as individuals having asthma symptoms (Table 2).

An Exercise test was also performed for the student's undergoing PFT measurements. Each subject performed a seven-minute free run exercise test with maximum effort and sufficient motivation of subject till reaching 70—75% HR (heart rate) in the morning.

All exercise tests took place in February and March 2013 with at ambient temperatures of 18 and 12 °C and humidity of 57 and 27% in Gorgan and Kerman, respectively. Pulmonary function testing was performed using the standards outlined by the American Thoracic Society, and pulmonary function tests were performed three times for each subject in a standing position while wearing nose clips (Marefati et al., 2012).

The highest level for forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow (PEF), and maximum expiratory flow at 50% of the FVC (MEF_{50}) were taken independently from the three measurements. Subjects were asked to avoid taking caffeinated beverages, theophylline or long acting β-agonist inhalers 12 h before testing. Prior to pulmonary function test, required manoeuvres were instructed for PFT measurements and subjects were encouraged during the course measurements by operator. PFT values were measured before, immediately, and 7 and 20 min after exercise test for each subject (Mahler, 1993).

Table 2 The criteria for respiratory symptom severity score, according to National Institutes of Health, 2002.

Symptom	Frequency	Score
Wheezing	None	0
	During heavy exercise	1
	During mild exercise (walking)	2
	At rest	3
Cough	None	0
	During heavy exercise	1
	During mild exercise (walking)	2
	At rest	3
Tightness	None	0
	During heavy exercise	1
	During mild exercise (walking)	2
	At rest	3
Sputum	None	0
	Small volumes of non purulent sputum	1
	Large volumes of non purulent sputum	2
	Purulent sputum	3
Total score		12

Statistical analysis

PFT results were expressed as mean ± SD. To compare the PFT values of pre and post-exercise, paired t test and for comparison of the PFT results between the two cities, unpaired t test were used. Statistical analyses were performed using SPSS software (version 11.5, SPSS Inc. USA). A $p < 0.05$ was considered statistically significant.

Results

Asthma prevalence comparison in the young boys and girls and in two climates showed that the prevalence of asthma in dry city (28.12%) was higher than that in humid city (21.09%). The incidence of EIA in dry city (20.31) was also higher than Gorgan (17.08) (Table 3). All PFT values declined 7 and 20 min post-exercise in subjects from both cities. Although all baselines PFT of dry city students were higher than those of humid city students, the decline in PFT values in dry city students was greater than those of humid city students. The results showed a time-dependent post-exercise decline in all PFT values in subjects from both

Table 3 The incidence of asthma and exercise-induced asthma (EIA) among studied subjects in Kerman and Gorgan cities.

City	Gender	Asthma		EIA	
		N	Percent	N	Percent
Kerman	Girl	15	24.19	12	19.35
	boy	21	31.81	14	21.21
	Total	36	28.12	26	20.31
Gorgan	Girl	9	14.51	10	16.12
	Boy	18	27.27	12	18.18
	Total	27	21.09	22	17.18

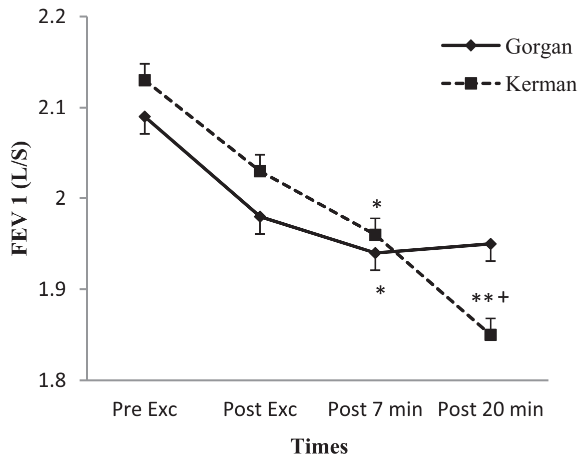

Fig. 1 Results of Forced expiratory volume in 1 s (FEV1), before, on start, 7 and 20 min after physical activity. +: $p < 0.05$, compared to Gorgan city. *: $p < 0.05$, **: $p < 0.01$ compared to baseline value.

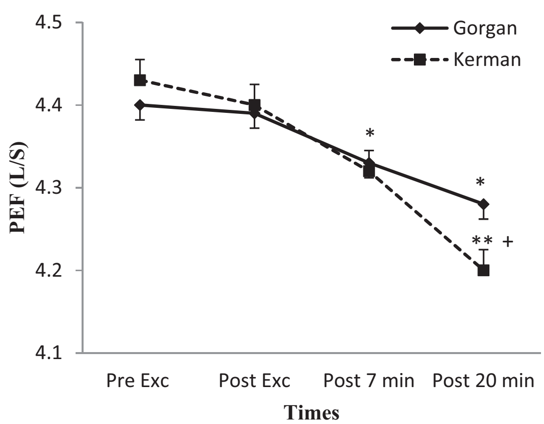

Fig. 2 The values of peak expiratory flow (PEF) before, on start, 7 and 20 min after physical activity. +: $p < 0.05$, compared to Gorgan city. *: $p < 0.05$, **: $p < 0.01$ compared to baseline value.

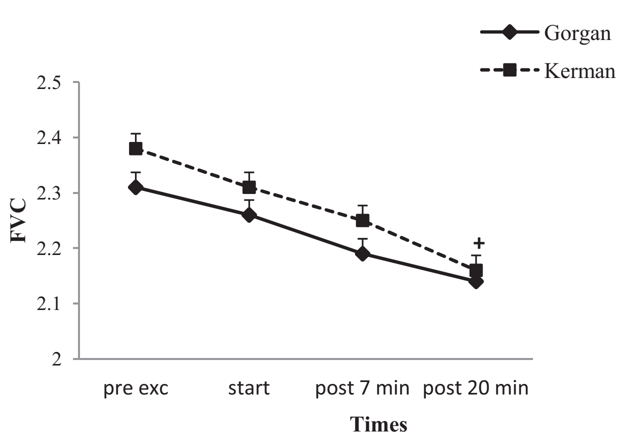

Fig. 3 The values of forced vital capacity (FVC) before, on start, 7 and 20 min after physical activity. +: $p < 0.05$, compared to Baseline.

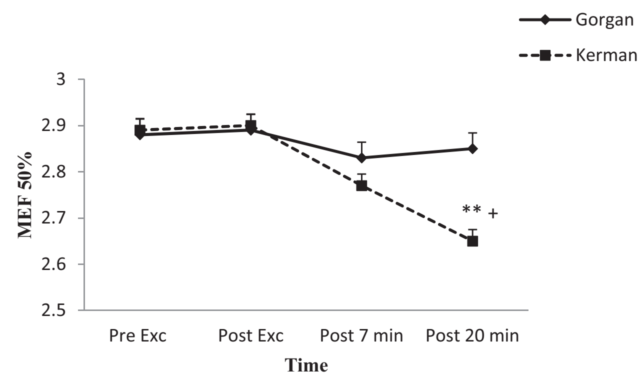

Fig. 4 The values of maximum expiratory flow in 50% of vital capacity(MEF_{50}) before, on start, 7 and 20 min after physical activity in each city. +: $p < 0.05$, compared to Gorgan city. **: $p < 0.01$ compared to baseline value.

cities and the maximum decline were seen for all PFT values at 20 min post-exercise in subjects from both cities.

At 20 min post-exercise, the values of all measured PFTs, as well as the values of FVC, and MEF_{50} at 7 min post-exercise were significantly decreased in dry city students ($p < 0.05$ to $p < 0.01$). In addition, the values of PEF and FEV1 also decreased in humid city students at 7 min post-exercise ($p < 0.05$ for both cases) (Figs. 1—4). At 20 min post-exercise, the decline in FEV_1, PEF and MEF_{50} in dry city students was significantly higher than those of humid city ($p < 0.05$ to $p < 0.01$) (Figs. 1—4).

Discussion

Most studies on the effects of temperature and humidity on exercise-induced asthma (EIA) were performed indoors. However, exercise-induced asthmatic subjects may be exposed to varying climatic conditions. It is possible that the effects of seasonal variation on EIA are not easily observed when exercise challenges are performed indoors with a treadmill or a bicycle. In this study, the prevalence of EIA among young male students with asthma-like symptoms in dry city (a city with cold and dry climate) was more than that of humid city (which has a humid and warmer climate). These findings suggest a significant role for climates variation in the prevalence of EIA. In addition, post-exercise reduction of PFT values in dry city students was significantly greater than that of humid city students. In this study, exercise practice was performed using free running method outdoors. Therefore, results were affected by temperature and humidity, and represent the real clinical setting (Boskabady and Kolahdoz, 2002). The prevalence of EIA reaches 12% in school-aged children and varies among different sports. The highest EIA prevalence occurs in athletes who compete in cold weather (Boskabady et al., 2003) which support the findings of the present study. Similar to the present study, the effects of physical exercise on EIA have been previously studied in order to measure the response to different types of physical training by measurement of PFT values for subjects with EIA (Boskabady et al., 2008). The response of 16 boys with EIA to aerobic and anaerobic training indicated that both types of training may increase the physical capacity of subjects (Boskabady et al., 2012).

It was also shown that inhalation of cold air along with exposure to outdoor pollutants during intensive training is a possible cause of EIA which is in agreement of the results of the present study (Bellia et al., 2003). Trained athletes are highly exposed to cold air and allergens during winter training. Asthma occurs most commonly in athletes engaging in endurance events such as skiing, swimming, or long-distance running (Turcotte et al., 2003). In this study, cold and dryness of weather in a dry city led to bronchospasm and obstruction of airways after physical exercise more than in a humid city with a humid and warm climate.

In fact, the inspired air is warmed and humidified in the upper airways during normal breathing (Parlato, 1937). During exercise, the process of warming and humidifying the inspired air in the upper airways may decrease due to high rate of air flow. This may cause smooth muscles contracting in response to temperature and humidity changes, which leads to airway narrowing. Therefore, the possible reason for higher prevalence of EIA and the decline in PFT values during exercise in a dry city with cold and dry climate might be due to a reduction of warming and humidifying of the inspired air in the upper airways. However, further studies are required to clarify the exact mechanism of higher EIA and decline in PFT values in cold and dry climate.

In conclusion, the results of the present study showed that responses of lung functions to exercises that leads to EIA is more marked in regions with a dry and cool climate than in a humid climate.

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