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Exercise-Induced Bronchoconstriction in Adults with Asthma

Comparison between running and cycling and between cycling at different air conditions

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ABSTRACT

The bronchial response to cycling and running was compared in six adult asthmatic persons. The effects of different air conditions during cycling regarding the induction of bronchoconstriction was studied.

The exercise consisted of 6 minutes' work at an intensity of 80-85% of maximal heart rate. Heart rate, oxygen consumption and ventilation were measured to check that the exercise level was the same in all tests. Peak expiratory flow (PEF) was used to test for bronchoconstriction.

Bicycling and treadmill running were performed under indoor conditions and bicycling while breathing cold, dry air (−18°C) and room-tempered humid air (60% RH), respectively.

No difference in bronchoconstriction was found between cycling and running under indoor conditions. However, bicycling exercise with inhalation of cold dry air provoked more bronchoconstriction than when inhalating humid air (PEF reductions of 19.4±6% and 6.1±2%, respectively). No differences were found between the exercise modes in heart rate, oxygen consumption, ventilation per minute, respiratory rate, carbon dioxide elimination or subjective ratings of perceived exertion and breathlessness.

It is concluded that it is not the type of exercise, but the ventilation demand and humidity of the inspired air that are the main determinants of the occurrence and degree of bronchoconstriction.

INTRODUCTION

Exercise can induce bronchoconstriction in many individuals with asthma, although exercise training is well known to have positive effects on asthmatics, such as increased fitness (10, 11). It is generally considered that running induces more bronchoconstriction than cycling, although there is little evidence to support this idea. Some studies on children and adolescents have shown that running more readily provokes bronchoconstriction than cycling (4, 14, 17). In others, however, no difference between cycling and running has been found in this respect (8, 12, 23). In some of the studies where such differences have been observed, the different exercise modes have not been compared under equivalent conditions (e.g. regarding exercise intensity, ventilation and air conditions). The influence of different exercise modes needs to be known in order that persons with asthma can be adviced as to how to exercise.

It is also important to determine how different environmental conditions during exercise influence the bronchial response, as many types of exercise are dependent on specific environmental conditions. It is known that when asthmatic subjects exercise, the ambient air conditions during the exercise will influence the induced bronchoconstriction. Inhalation of cold dry air during exercise is more provoking for asthmatics than that of warm humid air (2, 3, 18). The most favourable humidity for asthmatics during exercise is not known, nor is it known whether it is the same for different subjects.

The main purpose of the present study was to determine whether running and cycling under standardized conditions differ regarding induction of bronchoconstriction. As earlier studies have not been fully standardized, the present study was conducted under uniform conditions with regard to exercise intensity, oxygen consumption, minute ventilation, and the temperature and humidity of the inspired air. We also studied the effects of cycling exercise in relation to different humidities and temperatures of the inspired air. A further aim was to test a humidity that corresponds to air conditions above the water surface in swimming pools (60% relative humidity (RH), 25°C), as this is the condition under which rehabilitation programs for persons with asthma are carried out at our hospital.

MATERIAL AND METHODS

SUBJECTS

Six adult asthmatic persons (4 men, 2 women), with an age range of 29-58 years (Table 1) participated in the study after giving their informed consent. The study was part of an investigation that had been approved by the Ethics Committee of Uppsala University. All of the subjects were accustomed to physical exercise and exercise testing after having taken part in an asthma rehabilitation program some years previously. Five of them carried out physical exercise regularly at least once a week. The subjects were all inhaling corticosteroids and five of them used β_2-agonists when necessary.

Table 1. Characteristics of the subjects of the study, their inclination and speed on the treadmill, and the load on the bicycle ergometer

Subject	Age (yrs)	Sex (F/M)	Weight (kg)	Load on the bicycle ergometer (W) low intensity§	high intensity#	Settings on the treadmill# velocity (m/s)	inclination (°)
A	37	M	82	100	220	2.5	1.2
B	58	M	82	80	210	2.5	1.1
C	48	F	64	40	150	2.5	1.0
D	38	M	84	40	150	—	—
E	57	F	61	40	130	1.7	1.0
F	29	M	79	40	190	2.5	1.1

Estimated load to correspond to about 40% (§) and 80-85% (#) of each individual's maximal working capacity,
— missing value, due to technical reasons.

STUDY DESIGN

Prior to each study day, the subjects were asked not to take any short- acting β_2-agonists for 4 hours, long- acting β_2-agonists for 48 hours or theophylline for 24 hours before the exercise tests.

They were also asked to avoid any physical exercise on the day of the tests and not to have any meal or to smoke for two hours prior to the tests.

All subjects underwent four different exercise tests. In random order they ran on a treadmill under indoor, room conditions (RR), and exercised on a bicycle ergometer both under room conditions (CR) and while breathing cold dry air (CC). Some 6-8 weeks later all subjects underwent the last test; exercising on a bicycle ergometer while breathing humid air at room temperature (CH). The tests were carried out at the same time of day in each subject.

The exercise intensity was identical during the four tests. The test started with 3 minutes of work at an intensity level of 40% of the subject's maximal work capacity, followed by 6 minutes at 80-85% of the maximal work capacity. On the basis of findings at a previous exercise test we were able to estimate what level of exercise would correspond to 40% and to 80-85% of the maximal work capacity in each subject. The speed and inclination on the treadmill and the load on the bicycle ergometer that corresponded to the intended work level are shown in Table 1. To ensure that the exercise level was identical in the different tests, the heart rate (HR), ventilation per minute (V_E), oxygen consumption (VO_2), carbon dioxide elimination (VCO_2) and the subjects' ratings of perceived exertion were measured.

MEASUREMENTS

The test days started with measurements of basic levels of peak expiratory flow (PEF) (mini-Wright Peak Flow Meter) and ventilation parameters (OxyconSigma, version 2.04, Minjhardt b. v., Holland), namely V_E, VO_2, VCO_2 and respiratory rate (Rr). To measure the temperature and relative humidity, the Hygrotest 6400 (Nordtec Instruments, Germany) was used.

As an overall physiological control, ECG was recorded continuously (Megacart V. 4.0, Siemens-Elema AB, Sweden) and also, except in the CH test, transcutaneous measurements of oxygen tension and carbon dioxide tension (Transcutanous pO_2/pCO_2 monitoring system, TINA™, Radiometer Copenhagen, Denmark).

During the exercise tests the above-mentioned ventilation parameters were measured continuously. HR was recorded every minute from the ECG registration. Every minute during the CC test the temperature of the inspired air was measured. Subjective ratings of perceived exertion (on the Borg RPE scale) and breathlessness (Borg CR-10 scale) were recorded at the end of all exercise tests. PEF was measured immediately after the termination of exercise and 5, 10 and 15 minutes after the termination. The lungs were auscultated for rhonchi before and during exercise and in the recovery period after exercise.

The running test was performed on a treadmill (Rodby RHO 1700, Sweden), and the cycling tests on a bicycle ergometer (Rodby RE 900, Sweden). A Turboair Challenger (Equilibrated Bio System Inc., USA) was used to generate dry, cold air of a temperature of approximately -20°C. As the air used was compressed medical air, the water content was practically nil. During CH the subjects breathed humid air at room temperature from Douglas bags. In advance of the study the inspiratory air was humidified to a relative humidity of 60% in the bags. Both before and after all four modes of exercise, the subjects breathed room conditioned air.

CALCULATIONS AND STATISTICAL ANALYSIS

PEF was performed to test for exercise-induced bronchoconstriction, and changes in PEF were expressed in percent of the pre-exercise value. A percentage decrease in PEF was calculated according to equation 1.

$$\% \text{ fall in PEF} = \frac{\text{pre-exercise PEF} - \text{lowest PEF after exercise}}{\text{pre-exercise PEF}} * 100 \qquad \text{(equation 1)}$$

Differences between treatments were tested with ANOVA, where the model consisted of type of exercise and the effect of individuals. Tukey's test was used for comparisons between exercise modes and between measurements. Results were considered significant when $p < 0.05$. All results are presented as mean values ± standard error of means (SEM). Correlations between variables were evaluated by simple regression analysis. For the statistical analysis, SYSTAT (version 5.2 edition, Evanston, EL, USA: SYSTAT Inc. 1992) and StatView 4.0 (Abacus Concepts, Inc. California) were used.

RESULTS

Running and cycling provoked exercise-induced bronchoconstriction to the same degree. In all tests except cycling in cold dry air, bronchodilation was noted immediately after exercise, to a greater extent with CR then with RR. The PEF value was significantly higher after CR (Fig. 1). During the 15 minutes rest after exercise the PEF value decreased equally with both exercise modes, although there was a tendency to faster recovery after CR; after RR the PEF value had decreased by 14.5 ± 6.0% and after CR by 12.9 ± 3.5%.

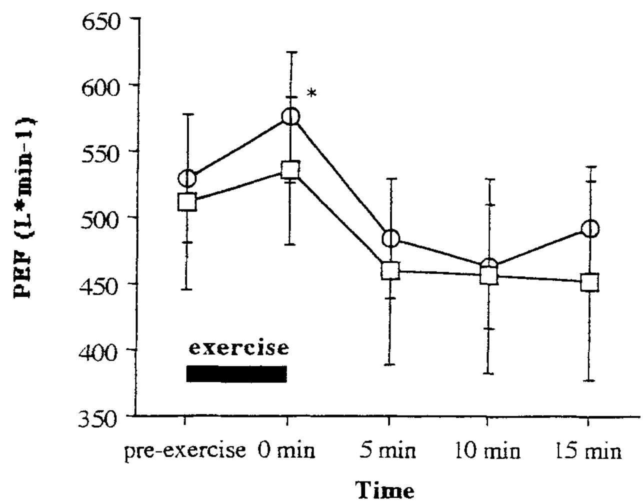

FIGURE 1.
PEF values in subjects with asthma before and after treadmill (RR, ❑) and bicycle ergometer (CR, O) exercise. The symbols represent mean values ± SEM. * significant ($p<0.05$) difference between running and cycling.

There were no differences in performed work between the four exercise tests. Nor were any differences found between the tests in either resting values or exercise values (Table 2) for HR, V_E, VO_2, VCO_2 or Rr. The subjects' estimation of perceived exertion and breathlessness did not show any significant differences between any of the four exercise tests. However, on an individual level there was a tendency for the subjects to experience exercise while breathing dry cold air to be more strenuous than that in the other tests (Table 3). The transcutaneous measurements of oxygen tension and carbon dioxide tension did not show any differences between the tests either at rest or during and after exercise.

Table 2. Heart rate (HR), oxygen consumption (VO_2), carbon dioxide elimination (VCO_2), minute ventilation (V_E) and the V_E/VO_2 ratio in the last part of the exercise tests for subjects with asthma. RR, running on a treadmill; CR, CC and CH, cycling under room conditions, cycling in cold dry air, and cycling in humid air, respectively.

	RR (n=5)	CR (n=6)	CC (n=6)	CH (n=6)
HR (beats/min)	162 ± 7	159 ± 6	156 ± 7	159 ± 5
VO_2 (l/min)	2.60 ± 0.29	2.44 ± 0.21	2.33 ± 0.18 ¤	2.56 ± 0.20
VCO_2 (l/min)	2.67 ± 0.28	2.56 ± 0.25	2.50 ± 0.23 ¤	2.71 ± 0.26
V_E (l/min)	76.7 ± 6.3	77.8 ± 9.3	74.7 ± 8.6 ¤	79.6 ± 7.4
V_E/VO_2	29.9 ± 1.3	31.7 ± 1.7	32.2 ± 3.6 ¤	31.2 ± 2.0

Values are means ± SEM. ¤ n=3 for technical reasons. V_E values are expressed as liter BTPS (body temperature pressure saturated), and all other ventilation parameters as litre STPD (standard temperature and pressure, dry).

Table 3. Perceived exertion and breathlessness during the exercise tests. RR, running on a treadmill; CR, cycling under room conditions; CC, cycling in cold dry air; CC, cycling in humid air. No significant differences were found

Subject	Perceived exertion (Borg 6-20)				Breathlessness (Borg 0-10)			
	RR	CR	CC	CH	RR	CR	CC	CH
A	16	18	20	19	7	8	10	—
B	14	17	19	16	4	—	9	6
C	16	18	19	18	—	6	8	5
D	—	17	17	14	—	—	7	4
E	17	15	17	17	6	6	7	7
F	17	17	15	15	9	7	5	7
Mean ± SEM	16±1	17±0	18±1	16±1	6±1	7±0	8±1	6±1

— missing values

The air conditions during exercise influenced the occurrence of bronchoconstriction. CC induced a higher degree of bronchoconstriction than CH (Fig. 2), with PEF reductions of 19.4 ± 3.8% and 6.1 ± 1.6% respectively ($p<0.05$). The subjects suffered to a lesser extent from asthma symptoms (PEF, $ß_2$-inhalation and/or rhonchi) after CH than after the other three tests. In the room temperature tests the PEF value 10 and 15 minutes after RR was lower than after CH ($p<0.05$) and tended to be lower after CR than after CH. After CH the need for $ß_2$-agonists was low and rhonchi seemed to be less pronounced than after the other tests. There were no correlations between induced bronchoconstriction (measured as percent decrease in PEF) and V_E or V_E/VO_2 in any of the exercise tests.

The room temperature ranged from 22.7 to 24.6°C and the relative humidity was 24%. The inspired air during cold air provocation had a temperature of -17.6 ± 0.8°C and contained practically no water.

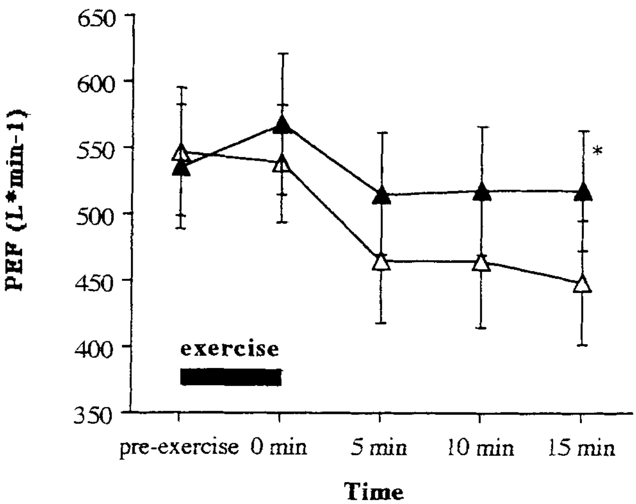

FIGURE 2.
PEF values in subjects with asthma before and after bicycle exercise with breathing of cold dry air (Δ) and humid air (▲). The symbols represent mean values ± SEM. * significant ($p<0.05$) difference between running and cycling.

DISCUSSION

Running on a treadmill (RR) and cycling (CR) on a bicycle ergometer provoked bronchoconstriction in asthmatic subjects to the same degree. Six minutes' work at an intensity of 80-85% of the maximal work capacity induced the same level of bronchoconstriction, measured as decrease in PEF up to 15 minutes after exercise. This is in agreement with other studies (8, 12). In contradiction, some studies on adolescents and children have shown that running is more provoking (14, 17), but in those studies the ventilation or exercise intensity, or both, were not constant. With our study design, with constant ventilation and exercise intensity, we have been able to show that there are no differences in induced bronchoconstriction between running and bicycling, although there were some tendencies to different reactions after the two exercise modes. Immediately after cessation of exercise the PEF value was higher after cycling than after running, but subsequently deteriorated to below baseline. In the rest period after exercise the PEF value tended to return to normal more quickly after cycling.

It appeared that an equal amount of work was performed during running and the three different cycling tests as concluded from the fact that there were no differences in HR, V_E, VO_2, VCO_2, Rr or perceived exertion and breathlessness between the tests.

Inhalation of dry cold air during cycling resulted in a significantly higher degree of bronchoconstriction than inhalation of warmer, humid air. CR induced a decrease in PEF intermediate between those caused by CC and CH, though not significantly so. That inspiration of cold dry air during exercise is more provoking than that of humid air is well known (3, 7, 16). However, few investigators have tested air humidity conditions other than a) air with no humidity, b) air fully saturated with water or c) room conditioned air. A reason for that could be technical problems to create other air humidities. We found a difference between 60% RH and cold dry air, but not between 60 and 24% RH. In a climate chamber, however, relative humidities of 15, 50 and 85% (22.5°C) during exercise have been shown to result in significantly different degrees of bronchoconstriction (16).

The degree of dryness of the airways seems to be the main determinant of the induced bronchoconstriction. Accordingly, the ventilatory demand of the exercise type together with the humidity and, indirectly, the temperature of the inspiratory air will determine whether and to what degree a specific type of exercise will induce bronchoconstriction. Athletes, especially those performing endurance exercise, show a higher incidence of exercise-induced asthma than the normal population (9). This is even more pronounced in sports that take place under cold winter conditions, such as cross-country skiing (15, 19, 20) and figure skating (21). A high incidence of exercise-induced bronchoconstriction in these types of exercise could probably be explained by the long duration of high intensity work; that is both the minute ventilation and the total ventilation are very high and the effect will be even more accentuated by the dry cold air. Mannix *et al.* (22) have done an extended study, where they compared exercise in cold air with eucapnic voluntary hyperventilation to provoke bronchospasm and it was concluded that those tests were comple-mentary to each other for identifying exercise-induced bronchospasm. All these results together are in accordance with the main hypothesis of the stimulus for exercise-induced bronchoconstriction: evaporative losses from the airways cause an increase in osmolarity of the submucosa that will stimulate the release of mediators and cause the narrowing of the airways (5). However there may be other factors than drying of the airway mucosa that influence the bronchoreaction in response to exercise in asthmatic subjects. For instance, the posture of the body during exercise (6), air pollution (1), and chlorine and its derivatives from swimming pools (13) could alter the response.

In conclusion, there seems to be no difference in the effects of running and cycling regarding exercise-induced bronchoconstriction when the exercise intensity level, ventilation and ambient air humidity are kept constant. Cold dry air induces a higher degree of bronchoconstriction than warmer humid air during exercise.

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