Acta med. Croatica, 50 (1996) 97–101

# AIRWAY RESPONSES IN HEALTHY AND ASTHMATIC SUBJECTS FOLLOWING EXPOSURE TO LOW AMBIENT AIR TEMPERATURE

EUGENIJA ŽUŠKIN, E. NEIL SCHACHTER[1] and JADRANKA MUSTAJBEGOVIĆ

*Andrija Štampar School of Public Health, Medical Faculty, University of Zagreb, Zagreb, Croatia, and Mount Sinai School of Medicine[1], New York, NY, USA*

Ventilatory capacity following exposure to low ambient air temperature (-5 °C) was measured in 46 male and 37 female medical students. In healthy subjects there was an increase in all test parameters during a four-hour exposure as compared to preexposure values. However, six students with bronchial asthma showed a decrease in ventilatory capacity tests following exposure to low temperature. The changes in healthy subjects as well as in asthmatics were most pronounced for the maximal flow rates at 50% and the last 25% of the vital capacity (FEF50, FEF25). The mean increase in FEF25 for healthy subjects was recorded up to a +15.1% and +6.4% increase in nonsmokers and smokers, respectively. In asthmatics, the largest decrease of FEF25 was -21.5%. Authors' data indicated that environmental exposure to low ambient air temperature caused an increase of ventilatory function tests in healthy subjects and a decrease in asthmatics, particularly in flow rates at lower lung volumes.

*Key words*: low ambient temperature, ventilatory capacity, healthy subjects, asthmatics

Received for publication May 27, 1994

*Correspondence:* Professor Eugenija Žuškin, MD, PhD
Andrija Štampar School of Public Health
Rockefellerova 4
10000 Zagreb, Croatia

## INTRODUCTION

Hyper–responsiveness of the tracheobronchial tree following the inhalation of cold air with or without hyperpnea has been described by several authors.[1, 2] Weiss et al. [3] have suggested that airway responsiveness to isocapneic hyperventilation with cold air reflects nonspecific bronchial hyper–responsiveness. In the general population, cold air challenge in particular has proven to be a sensitive measure of airway reactivity.[4] Seindenberg et al.[5] reported on bronchoconstriction in asthmatic children to be induced by cold air challenge. Nicolai et al.[6] reported that reactivity to cold air challenge in otherwise healthy schoolchildren increased with the number of episodes of asthma. Zach et al.[7] observed the use of cold air challenge in children to be characterized by small airway reactivity, and the response to cold to better demonstrate the clinical severity of asthma as compared to the information from histamine challenge. Similarly, O'Cain et al.[8] have in normal subjects, that airway cooling may also cause changes in the lung function. Reisman et al.[9] described a drop in FEV1 following cold air challenge in asthmatic children. In a study of Guleria et al.[10] it is suggested that direct action of cold air on the upper respiratory tract in healthy subjects is responsible for mild local airway obstruction. The study of Berk et al. [11] suggests that cooling of the skin can also induce bronchoconstriction in both asthmatics and normal subjects. There is, however, no available information on the effects of "body cooling" on respiratory function in people who live in cold environments.

In the present study we investigated the effect of exposure to low ambient air temperature on the lung function in a group of medical students during normal daily activity.

## SUBJECTS AND METHODS

### *Subjects*

The study included 83 medical students (46 men and 37 women) aged 22 to 25 years, mean age 23 years. Forty one percent of men were regular smokers, smoking on the average 29 cigarettes daily, whereas only 24% of women were regular smokers, smoking on the average 15–20 cigarettes daily.

### *Respiratory symptoms*

Chronic respiratory symptoms were recoreded by a modification of the British Medical Research Council Committee questionnaire on the etiology of chronic bronchitis. [12] The following definitions were used:

Chronic cough/phlegm: cough and/or phlegm production on most days for at least three months in the year;

Chronic bronchitis: cough and phlegm for a minimum of three months in the year and for not less than two successive years;

Dyspnea grades: grade 2 — shortness of breath when hurrying on the level or walking up a slight hill; grade 3 — shortness of breath when walking with other people on level ground;

Asthma: chest tightness, cough, wheezing, shortness of breath accompanied by reversible obstructive lung function changes confirmed by medical records.

*Ventilatory capacity*

Ventilatory capacity was measured by recording maximal expiratory flow volume (MEFV) curves on a Pneumoscreen spirometer (Jaeger, Wurzburg, Germany). Measurements were performed according to the recommendation of the European Respiratory Society. [13] MEFV curves were recorded in the morning at 8 am and again every one hour over a 4 hour period during normal activity with the ambient temperature of –5° C. We measured the forced vital capacity (FVC), one-second forced expiratory volume (FEV1) and maximal flow rates at 50% and the last 25% of the vital capacity (FEF50, FEF25) on MEFV curves. At least three MEFV curves were recorded for each subject and the best value of the three technically satisfactory MEFV curves was taken as the result of the test. The pre–exposure measured values of ventilatory capacity tests were compared to the predicted values of Quanjer.[14]

## RESULTS

Table 1 presents ventilatory capacity data obtained in 27 male nonsmokers. There was a mean increase in all tests with the maximal increase of 2.9% for FVC, 3.6% for FEV1, 6.7% for FEF50 and 15.1% for FEF25.

Table 3 shows the ventilatory capacity data in 28 female nonsmokers. The largest increase was 5.0% for FVC, 5.5% for FEV1, 10.1% FEF50 and 8.7% for FEF25.

In 9 female smokers (Table 4), this increase was smaller: 3.4% for FVC, 2.5% for FEV1, 2.2% for FEF50 and 4.9% for FEF25. The pre–exposure measured values in female smokers and nonsmokers were more than 80% of the predicted normal values.

All changes in ventilatory capacity in healthy male and female students during the 4–hour of cooling period were not significantly different from the pre–cooling values (NS).

Table 5 presents the maximal percentage change in ventilatory capacity during 4 hour cooling in six male nonsmoking students with bronchial asthma. Asthmatic subjects were not taking any medication during the study period. In contrast to healthy subjects, all asthmatics showed a considerable decrease in all parameters, which was particularly pronounced for FEF50 (range, 9.1% to 16.2%) and in FEF25 (range, 11.3% to 21.5%). The pre–cooling measured values (as a percent of the predicted) for these six subjects varied from 90.5% to 80.6% for FVC, from 84.3% to 78.5% for FEV1, from 80.7% to 75.4% for FEF50 and from 79.4% to 71.4% to FEF25.

Table 1

*Changes of ventilatory capacity in 27 male nonsmokers during 4–hour exposure to low ambient air temperature*

| | FVC | | FEV1 | | FEF50 | | FEF25 | |
|---|---|---|---|---|---|---|---|---|
| Time | Measured | Change | Measured | Change | Measured | Change | Measured | Change |
| | L | % | L | % | L/s | % | L/s | % |
| Before | 5.52 | | 4.67 | | 6.54 | | 3.11 | |
| exposure | ±0.73 | | ±0.85 | | æ2.39 | | ±1.45 | |
| Exposure (min) | | | | | | | | |
| 60 | 5.65 | +2.3 | 4.79 | +2.6 | 6.59 | +0.7 | 3.18 | +2.3 |
| | ±0.75 | | ±0.78 | | ±2.30 | | ±1.39 | |
| 120 | 5.64 | +2.2 | 4.81 | +2.9 | 6.86 | +4.8 | 3.32 | +6.8 |
| | ±0.69 | | ±0.86 | | ±2.40 | | ±1.45 | |
| 180 | 5.67 | +2.7 | 4.84 | +3.6 | 6.96 | +6.4 | 3.50 | +12.5 |
| | ±1.14 | ±0.90 | | ±2.36 | | ±1.41 | | |
| 240 | 5.68 | +2.9 | 4.83 | +3.4 | 6.98 | +6.7 | 3.58 | +15.1 |
| | ±0.69 | | ±0.89 | | ±2.37 | | ±1.44 | |

Table 2 presents ventilatory capacity data for 19 male smokers. The maximal mean increase was 2.4%, for FVC, 3.2% for FEV1, 6.4%, 5.6% for FEF50 and 6.4% for FEF25. This increase, particularly for FEF25, was smaller than that of FEF25 in male nonsmokers. The pre–exposure (baseline) measured values in male smokers and nonsmokers were more than 80% of the predicted normal values.

## DISCUSSION

Our data showed that exposure of healthy subjects to low ambient air temperature did not cause a decrease of ventilatory capacity. On the contrary, there was an increase (not statistically significant) in the lung function following the 4–hour cold exposure. This increase was similar to that recorded in workers not exposed to pollution, whose lung func-

Table 2

*Changes of ventilatory capacity in 19 male smokers during 4–hour exposure to low ambient air temperature*

| | FVC | | FEV1 | | FEF50 | | FEF25 | |
|---|---|---|---|---|---|---|---|---|
| Time | Measured | Change | Measured | Change | Measured | Change | Measured | Change |
| | L | % | L | % | L/s | % | L/s | % |
| Before | 5.51 | | 4,63 | | 6.24 | | 3.14 | |
| exposure | ±0.63 | | ±0.80 | | ±2.10 | | ±1.50 | |
| Exposure (min) | | | | | | | | |
| 60 | 5.52 | +0.2 | 4.65 | +0.4 | 6.25 | +0.2 | 3.17 | +0.9 |
| | ±0.71 | | ±0.86 | | ±1.99 | | ±1.54 | |
| 120 | 5. 58 | +1.2 | 4.67 | +0.9 | 6.51 | +4.3 | 3.30 | +5.1 |
| | ±0.70 | | ±0.86 | | ±2.05 | | ±1.58 | |
| 180 | 5.64 | +2.4 | 4.73 | +2.2 | 6.57 | +5.3 | 3.31 | +5.4 |
| | ±0.61 | | ±0.78 | | ±2.14 | | ±1.47 | |
| 240 | 5.64 | +2.4 | 4.78 | +3.2 | 6.59 | +5.6 | 3.34 | +6.4 |
| | ±0.65 | | ±0.81 | | ±2.12 | | ±1.52 | |

Table 3

*Changes of ventilatory capacity in 28 male nonsmokers during 4–hour exposure to low ambient air temperature*

| | FVC | | FEV1 | | FEF50 | | FEF25 | |
|---|---|---|---|---|---|---|---|---|
| Time | Measured | Change | Measured | Change | Measured | Change | Measured | Change |
| | L | % | L | % | L/s | % | L/s | % |
| Before | 3.37 | | 3.47 | | 5.67 | | 3.46 | |
| exposure | ±0.45 | | ±0.55 | | ±0.76 | | ±0.95 | |
| Exposure (min) | | | | | | | | |
| 60 | 3.91 | +3.7 | 3.59 | +3.5 | 5.86 | +4.7 | 3.50 | +1.2 |
| | ±0.50 | | ±0.56 | | ±0.68 | | ±0.92 | |
| 120 | 3.96 | +5.0 | 3.62 | +4.3 | 6.20 | +9.3 | 3.71 | +7.2 |
| | ±0.47 | | ±0.51 | | ±0.92 | | ±1.07 | |
| 180 | 3.95 | +4.8 | 3.65 | +5.2 | 6.24 | +10.1 | 3.74 | +8.1 |
| | ±0.44 | | ±0.52 | | ±0.94 | | ±1.09 | |
| 240 | 3.95 | +4.8 | 3.66 | +5.5 | 6.24 | +10.1 | 3.76 | +8.7 |
| | ±0.46 | | ±0.52 | | ±0.91 | | ±1.07 | |

tion was measured before and after the morning shift (6 a. m. and 2 p. m.). [15] Our data are also similar to those reported by other authors. [9, 16–18]

In our six asthmatic subjects there was a decrease in ventilatory capacity tests which was particularly pronounced in FEF50 and FEF25 (range 9.1%–21.5%). Such a decrease in ventilatory capacity tests in our asthmatics caused by body cooling could be compared to the bronchospasm seen following inhalation of cold air. Wiebicke et al. [19] pointed to the role of histamine as a mediator in exercise–induced asthma, but not in isocapneic hyperventilation of cold air. Exercise tests while inspiring cold dry air caused exercise–induced asthma in asthmatic subjects. [20] Strauss et al. [21] have reported that in asymptomatic atopic subjects, a small acute bronchoconstrictive effect of cold–air breathing occurred at rest, but the magnitude of the response was markedly enhanced during exercise. Heat loss and/or water loss from the airways during exercise have been described as a cause of exercise–induced asthma in asthmatic subjects by Chen and Horton.

Table 4

*Changes of ventilatory capacity in 9 female smokers during 4–hour exposure to low ambient air temperature*

| | FVC | | FEV1 | | FEF50 | | FEF25 | |
|---|---|---|---|---|---|---|---|---|
| Time | Measured L | Change % | Measured L | Change % | Measured L/s | Change % | Measured L/s | Change % |
| Before | 3.78 | | 3.50 | | 5.86 | | 3.44 | |
| Exposure | ±0.48 | | ±0.43 | | ±0.90 | | ±0.85 | |
| Exposure (min) | | | | | | | | |
| 60 | 3.84 | +1.6 | 3.51 | +0.3 | 5.86 | 0 | 3.47 | +0.9 |
| | ±0.51 | | ±0.45 | | ±0.81 | | ±0.92 | |
| 120 | 3.88 | +2.6 | 3.58 | +2.3 | 5.90 | +0.7 | 3.50 | +1.7 |
| | ±0.47 | | ±0.48 | | ±0.91 | | ±0.85 | |
| 180 | 3.89 | +2.9 | 3.58 | +2.3 | 5.94 | +1.4 | 3.53 | +2.6 |
| | ±0.47 | | ±0.50 | | ±1.00 | | ±0.79 | |
| 240 | 3.91 | +3.4 | 3.59 | +2.5 | 5.99 | +2.2 | 3.61 | +4.9 |
| | ±0.45 | | ±0.49 | | ±0.98 | | ±0.84 | |

Table 5

*Changes of ventilatory capacity in 6 male nonsmoking students with bronchial asthma during 4–hour exposure to low ambient air temperature*

| Subject | FVC % | FEV1 % | FEF50 % | FEF25 % |
|---|---|---|---|---|
| 1 | −5.3 | −5.6 | −9.1 | −11.3 |
| 2 | −3.2 | −6.5 | −10.2 | −12.3 |
| 3 | −4.1 | −6.7 | −11.3 | −11.8 |
| 4 | −5.1 | −7.2 | −12.4 | −15.2 |
| 5 | −6.2 | −9.5 | −14.1 | −18.2 |
| 6 | −7.3 | −10.1 | −16.2 | −21.5 |

Data are presented as percentage of precooling values

[22] Hahn et al. [23] stress the importance of cooling and osmotic effects in inducing exercise–induced asthma in asthmatics. Weiss et al. [3] suggest that airway response caused by isocapneic hyperventilation with cold air reflects nonspecific bronchial hyper–responsiveness. In spite of the fact that body cooling can induce bronchoconstriction, there was a significant improvement of FVC in patients with an obstructive pulmonary disease during the sauna program. [24]

Lung function measured in Eskimos is mostly compared to the predicted values for "white" subjects with large FEV1, FVC and diffusing capacity and with the metabolic activity directly related to body temperature. [25–26] A study of Shepard and Rode[27] in Canadian Inuit Eskimos demonstrated high normal values for both lung function and maximal oxygen intake. Another study of the Canadian Inuit demonstrated an accelerated loss of lung function in the elderly subjects. [28–29]

Our data indicated asthmatic subjects to be susceptible to the development of bronchoconstriction following exposure to cold air at low levels of activity. Therefore, they shoud take appropriate precautions when exposed to low ambient air temperature.

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## ACKNOWLEDGEMENT

This study was in part supported by grant no. RO1-OH 2593-01A1 from the National Institute of Occupational Safety and Health, Centers for Disease Control, Atlanta, Ga, USA.

## SAŽETAK

## REAKTIVNOST DIŠNIH PUTOVA U ZDRAVIH OSOBA I OSOBA S ASTMOM IZLOŽENIH NISKOJ TEMPERATURI OKOLINE

E. ŽUŠKIN, E. N. SCHACTER[1] i J. MUSTAJBEGOVIĆ

*Škola narodnog zdravlja »Andrija Štampar« Medicinskog fakulteta Sveučilišta u Zagrebu i Medicinski fakultet Mount Sinai[1], New York, NY, SAD*

Ispitivan je ventilacijski kapacitet pluća nakon izloženosti niskoj temperaturi okoline (–5 °C) u 46 studenata i 37 studentica medicine. U zdravih osoba utvrđeno je povećanje svih testova ventilacije tijekom 4 sata izloženosti u odnosu na vrijednosti prije izloženosti. Međutim, u šestoro studenata sa simptomima bronhalne astme utvrđeno je smanjenje testova ventilacijskog kapaciteta tijekom izloženosti niskoj temperaturi. Promjene u zdravih osoba kao i u astmatičara bile su naročito izražene u maksimalnim protocima pri 50% i zadnjih 25% vitalnoga kapaciteta (FEF50, FEF25). Srednje povećanje FEF25 u zdravih osoba iznosilo je do +15,1% u nepušača i do +6,4% u pušača. U astmatičara najveće smanjenje FEF25 iznosilo je –21,5%. Rezultati upućuju da izloženost niskoj temperaturi okoline uzrokuje povećanje testova ventilacijske funkcije pluća u zdravih osoba, a smanjenje u osoba s astmom, poglavito u protocima pri manjim plućnim volumenima.