

A breathing filter exchanging heat and moisture prevents asthma induced by cold air

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In order to devise a protective aid against bronchial obstruction induced by cold air, we have tested a breathing filter with heat and moisture exchanging properties. Nine asthma patients, who all had a history of cold-induced asthma, took part in exercise tests on an ergometer bicycle at a temperature of approximately -10°C , without and with a breathing filter. Without a breathing filter, the maximum reduction in FEV_1 was, on average, 36%. With the breathing filter, the maximum reduction in FEV_1 was, on average, 11%. The difference was clearly significant ($P < 0.001$). A further five cold-sensitive asthmatics performed similar exercise tests at -10°C on three occasions: 1) without and 2) with a breathing filter as above, and 3) with two breathing filters connected in parallel: one for inspiration and the other for expiration. Thus, no heat-moisture exchange could take place. The fall in FEV_1 after provocation without a breathing filter and with parallel breathing filters was similar but attenuated when rebreathing took place through the breathing filter. The results confirm the theory that in cold/exercise-induced asthma, it is indeed the heat and/or water loss from the airways that triggers airway narrowing, and that a heat and moisture exchanging filter has a considerable protective effect and can be of value in the treatment of asthma.

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Earlier research has shown that inspiration of cold and dry air may provoke bronchial obstruction in patients suffering from asthma (2, 7, 8, 16–18). It is also a common clinical experience that low outdoor temperatures, particularly in connection with physical exercise, involve a risk of bronchial obstruction in asthmatics. A questionnaire survey concerning the effect of the climate on asthma symptoms revealed that approximately one-third of the adult patients with asthma stated that they avoided being out-of-doors in winter due to respiratory complaints (13).

Against this background, we decided to test whether a breathing filter, functioning according to the principle of heat and moisture exchange, and thus heating and moisturizing the inspired air, could prevent cold-induced bronchial obstruction in sensitive asthmatics and be of use in therapy.

It is, however, possible that other mechanisms, besides heat-moisture exchange, also play a role when patients are breathing through a filter. For example, the intrathoracic pressure fluctuations are accentuated (when patients breathe through the fil-

ter), due to increased air resistance, whereby also the breathing pattern is affected. The importance of these factors in preventing the occurrence of bronchial obstruction through cold provocation cannot, *a priori*, be excluded. In order to investigate whether the prevention of bronchial obstruction is caused by heating/moisturizing of the inspired air, a series of experiments was done with inspiration and expiration taking place through separate but identical breathing filters, so that no heat-moisture exchange was possible.

Material and methods

Two groups of asthma patients (series A and B) took part in the study. They performed exercise tests on an ergometer bicycle at a temperature of approximately -10°C with and without breathing filter.

Nine patients, three men and six women aged 20–60 years, diagnosed as suffering from clinical asthma, with more than 20% increase in FEV_1 following inhalation of a beta-2 stimulant, and with a medical history of bronchial symptoms induced by

cold air, were selected for inclusion in series A. All used a beta-2 stimulant regularly. The use of other medication varied. For inclusion in series B, five asthmatics, three men and two women aged 29–64 years, were selected in the same way as for series A. None of the patients suffered from heart disease or other complaints impeding movement. There were no smokers in the group, nor had any of them ever been a regular smoker. Table 1 shows the basic anamnestic data for the patients.

The breathing filter was the one used in a respirator (Servo-Humidifier-150, Siemens-Elma, Sweden) mainly for humidifying the inspired gas. The filter container was removed from the respirator and connected to a nozzle. The breathing filter consists of a porous cellulose material, where heat and moisture from the expired air are stored and emitted to the inspired air (9, 11, 12). In the second test series, two filter containers were connected in parallel, and inspiration and expiration were separated by a unidirectional valve. Hence, inspiration and expiration took place through different but identical breathing filters, and no heat and moisture exchange could occur.

The patients were subjected to stress loads on an ergometer bicycle (RE 820, Rodby Elektronik, Sweden) in three load increments of 6 min each: 30, 70, and 100 W for women and 50, 100, and 150 W for men. The ergometer bicycle was placed in a cold storage room with a temperature of approximately -10°C .

The forced expiratory volume in 1 s (FEV_1) was determined by a spirometer (Vitalograph, UK) at normal room temperature. For each determination, three satisfactory forced expirations were performed, and the highest value was used in further analyses.

The patients received no medication for at least 4 h prior to the tests (long-lasting beta-2 stimulants were not available at the time of these experiments). Each test was performed at about the same time of day with intervals of at least 1 week. A nasal clip was used in all tests.

The patients in series A performed the first test without a filter. Approximately 1 week later, the test was repeated with identical load increments, but, on this occasion, the patients breathed through the

breathing filter. FEV_1 was determined immediately before each exercise as well as 0, 3, 6, and 9 min after completed exercises.

The patients in series B performed the exercise test on three occasions on different days, following the same procedure as in the first group. During the first exercise test, the patients breathed through the parallel breathing filters. This was a single-blind test; i.e., the patients were not informed about the aim of the test and could not distinguish whether there was any heat and moisture exchanging. In the second test (with a model of exactly the same appearance), re-breathing through the heat and moisture exchanging filter took place. The third test was carried out without any breathing filter. FEV_1 was determined as above.

The protective effect of a heat-moisture exchanging filter was calculated according to the following formula: $(\Delta\text{FEV}_1 \text{ without filter} - \Delta\text{FEV}_1 \text{ with filter}) * 100 / \Delta\text{FEV}_1 \text{ without filter}$. ΔFEV_1 corresponds to the maximum reduction in percentage of the initial value.

Results

Without a breathing filter, the maximum reduction in FEV_1 was, on average, 36%. With the breathing filter, the maximum reduction in FEV_1 was, on average, 11%. In all patients, FEV_1 fell less when the breathing filter was used. The difference was clearly significant ($P < 0.001$). The average protective effect of the breathing filter was 70% (range 19–100%). In the exercise tests without breathing filter, two women (MZ, UH) had to interrupt the test due to obstructive complaints after only 3 min of exercise at 70 W. In their second test with a breathing filter, both women completed all three exercise increments; nevertheless, FEV_1 fell less. Fig. 1 illustrates the average results from series A.

When subjects breathed through the parallel filters, the results were similar to those without any filter whereas the reduction in FEV_1 was substantially less when re-breathing through the filter took place. The average protective effect of re-breathing through the filter was 74% (range 51–88%) and of breathing through the parallel filters 13% (range 29–32%). Fig. 2 illustrates the results from series B.

Table 1. Characteristics of asthmatic patients studied

Patients	RJ*	GP*	MF	GPe	MT*	GH	MZ	UH	LK	PS**	JB**
Age (yr)	59	49	20	43	25	23	17	33	39	27	41
Sex	M	F	M	F	F	F	F	F	M	M	M
FEV_1 (% pred.)	116	86	82	67	108	108	95	65	72	98	105

* Participated in all exercise tests (series A and B).

** Participated only in group which tested filter with no exchange of heat and moisture (series B). Normal FEV_1 was predicted according to Berglund et al. (4).

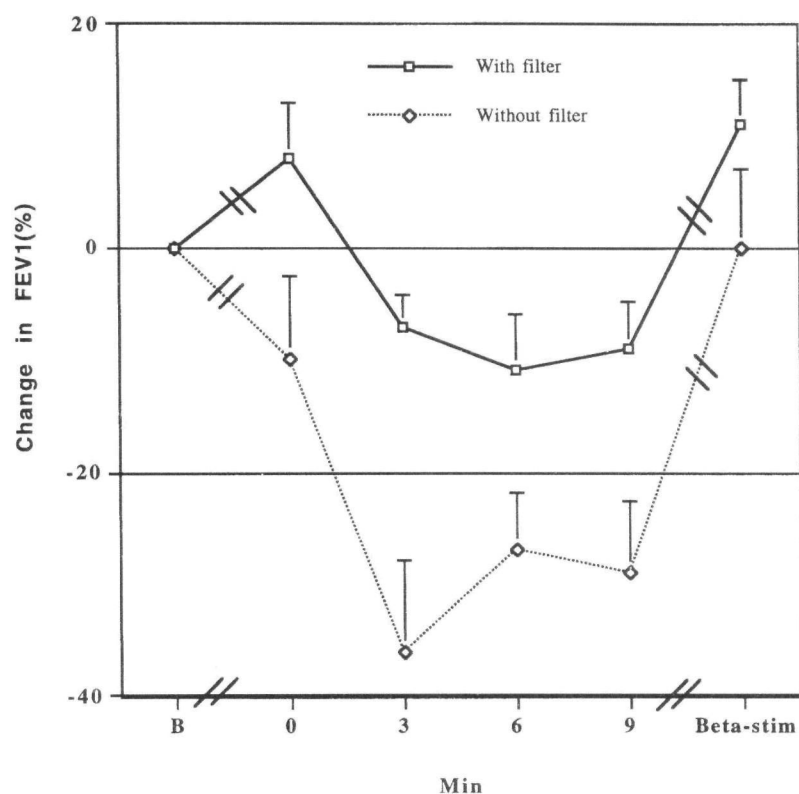


Fig. 1. Change in FEV_1 in nine asthmatics after exercise at temperature of about -10°C . Results were obtained after breathing either with or without heat and moisture exchanging filter, and are mean values expressed in percentage of pre-exercise value. "B" denotes before exercise, and "beta-stim" denotes after inhalation of beta-2 stimulant. Bars represent SE.

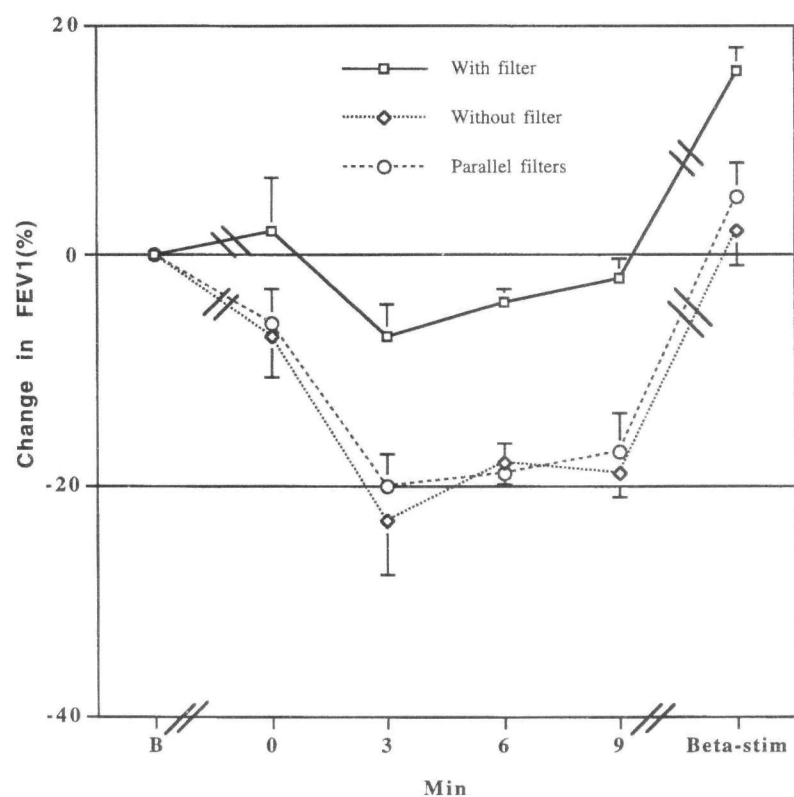


Fig. 2. Change in FEV_1 after exercise at temperature of about -10°C in five asthmatics breathing either with or without heat and moisture exchanging breathing filter, or breathing with parallel filters not exchanging heat and moisture. Mean values and SE are illustrated. Abbreviations as in Fig. 1.

Discussion

The results show that the heating and moisturizing of inspired air by a heat and moisture exchanging breathing filter effectively reduces bronchial obstruction induced by exercise in cold air.

The results of this study are remarkably consistent. On all 14 occasions, in 11 patients, where the effectiveness of the breathing filter could be evaluated, the reduction in FEV_1 was less pronounced after breathing through the filter. Furthermore, in two cases (patients MZ and UH), the exercise intensity was substantially stronger with the breathing filter. The average protective effectiveness was 72%.

The study was not randomized, and this was a disadvantage. On the other hand, we did want to make sure that the provocation was at least as strong with the breathing filter as without it, in order not to complicate the interpretation of the results.

Some preliminary results of the present study have been reported earlier (3). Prior to that study, the effectiveness of a face mask on exercise-induced asthma had been demonstrated (5, 15). Brenner et al. (5) provoked 10 children through exercise at room temperature with and without a face mask. A significantly reduced bronchial obstruction was noted with the face mask. Schachter et al. (15) reported similar results in a group of adult patients, who were examined after exercise with and without a face mask. The tests were carried out at a temperature of approximately 4°C , and a nasal clip was used. The authors discussed the possibility that heating of the face mask's "dead space" could be the cause of the protective effect.

Since the publication of our preliminary results (3), at least two studies have been published, in which the effects of inspiration through heat and moisture exchanging respiratory appliances were reported (10, 14). In one of the studies (10), asthma patients were provoked by hyperventilation of dry air at room temperature. Bronchial obstruction was prevented to a great extent when the provocation was performed by inspiration through a heat and moisture exchanging material of the same type and model as that described in our tests. In the second study (14), asthma patients were provoked by exercise at room temperature as well as in cold air, and the tests were carried out both with and without an aluminum heat and moisture exchanger. The degree of bronchial obstruction was significantly reduced by the use of the heat and moisture exchanger. The average percentage of protective efficiency, calculated on the basis of the median values given in the article, was 55% in cold air and 54% at room temperature. The corresponding protective efficiency in the present study, calculated on the basis of the median values in our tests, was 64% in series A and 78% in series B.

Several earlier studies have been published, in which the protective effect of a beta-2 stimulant and cromoglycate was investigated, and FEV_1 was measured in at least two studies (1, 6). The percentage of protective effect varied in these studies between

60% and 70%; i.e., about the same level as in our findings.

In order to investigate the mechanisms behind the protective effect of the breathing filter, tests were carried out with parallel filters. In these experiments, the subjects were unaware of the aim of the experiment and of the fact that no heat and moisture exchange took place, despite inspiration and expiration through a breathing filter. The results show that the protective effect is linked to the heat and moisture exchange rather than to any other factors, such as added respiratory resistance, dead space, or impaired respiratory pattern. Consequently, our results fully support earlier findings that it is the heat and/or moisture losses from the mucosa of the airways that precipitate bronchial obstruction (8).

Ventilation was not measured in the present experiments. One could argue that consistently different levels of ventilation when rebreathing through a filter compared to without filter or breathing through parallel filters could, theoretically, explain the results. The similarity in results in series B between parallel filters and no filter does not support this idea. The small protective effect of the parallel filters in series B (13%) may, however, be explained by differences in ventilation.

Will heat/moisture exchanging breathing filters prove to be of value for therapeutic purposes? Among asthmatics resident in Göteborg exposed to a moderately cold climate in winter with temperatures of around 0°C, 50–60% suffer from cold-induced complaints, according to a previous survey (13). Thus, accentuated bronchial obstruction at exposure to cold air can be regarded as a common symptom of asthma. The results of the present study show that asthmatics who experience cold-induced problems do indeed develop airway obstruction when exposed to cold inspired air and that cold-induced obstruction is common among asthmatics.

Of course, pharmacologic prevention is a possible treatment method. However, it should be noted that the patients in the previous study (13) avoided being out-of-doors in cold weather despite pharmacologic treatment. We therefore assume that there is a need for a complementary treatment. From the viewpoint of efficiency, the above attempts at a quantitative comparison between pharmacologic treatment and the breathing filter indicate that the filter is a competitive alternative. There are virtually no adverse effects of the breathing filter. However, breathing filters of different types present a cosmetic problem. Patient compliance can therefore be assumed to depend on the design of the breathing filter. So far, practitioners who have advised their cold-sensitive asthmatic patients to wear a filter during the winter seem to have had positive experiences.

To summarize, the present results confirm that heat and moisture losses from the airways at exercise in cold air lead to bronchial obstruction in asthmatics sensitive to cold, and that breathing through a heat and moisture exchanging filter offers considerable protection. In our accompanying report, results are presented that were obtained in tests with a breathing filter designed as a breathing mask.

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