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Protective effect of respiratory devices in farmers with occupational asthma

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ABSTRACT: To the authors' knowledge there have been no previous reports on the protection afforded by powered filtering respirators in farmers with occupational asthma attributed to the inhalation of organic dust.

In order to investigate this question, 26 farmers with occupational asthma were challenged with an exposure to work-related dusts for up to 60 min. This resulted in highly significant increases in airway resistance (R_{aw}), thoracic gas volume (TGV) and specific airway resistance (sR_{aw}) compared to baseline values.

After a mean period of 21 weeks the farmers were subjected to a second challenge, this time wearing a protective respiratory device (RD) with a P2 filter. Significant increases in R_{aw}, TGV and sR_{aw} were again observed, but on average these were 50–80% smaller than the increases seen when RDs were not worn. These differences were found to be statistically significant.

This shows that the use of a respiratory device in farmers suffering from occupational asthma reduces the development of bronchial obstruction but does not prevent it. The use of this kind of respiratory device cannot substitute for the proper management of asthma since the devices do not offer complete protection.

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Among farmers, the prevalence of chronic bronchitis and asthma is higher than in the general population [1–3]. This phenomenon is due to the influence of immunological and nonimmunological components of organic dusts [4, 5]. Particular importance is attached to the endotoxins [6–8]. Reduced exposure to organic dusts is an important preventive measure [9, 10]. The utilization of a personal respiratory device (RD) is a common method of cleaning contaminated air [11]. Farmers suffering from respiratory symptoms tend to wear RDs more frequently than farmers without these symptoms [12]. However, it has been shown that even the use of RDs with P2 and P3 filters did not protect patients with farmer's lung; they developed systemic and pulmonary reactions after a challenge [13, 14]. It has also been demonstrated that flour-dust asthmatics [15], pig farmers [16, 17], grain workers [18, 19], subjects suffering from laboratory animal allergy [20], and patients with a cedar allergy [21] cannot receive complete protection using RDs. This failure has been blamed on filter- and face-seal leaks. Lacey *et al.* [22] demonstrated that filters allow penetration of 0.1–3.1% of actinomycete spores, depending on design. Manninen *et al*. [23] demonstrated face-seal leakages of 2.4–3.4% in RDs.

The present study examined whether RDs have a protective effect on farmers with occupational asthma.

Methods

Twenty-six farmers from southern Bavaria with suspected occupational asthma were examined. The sample comprised eight females and 18 males with an age of 38.6± 11.8 yrs (mean±SD). Four of the females and six of the males were smokers. All 26 subjects were involved in dairy farming and/or bull breeding either using conventional straw bedding and mucking out by hand or working with manure. They all came in contact with grain dust, hay and straw daily and had been exposed to these conditions for a mean duration of 34±14.9 yrs. Health problems had been present for a mean of 9.1±6.8 yrs. The average daily duration of exposure to agricultural dust lasted up to 4 h. After the farmers had been exposed to hay, straw or grain dust, all of them suffered from coughing, dyspnoea and wheezing breath. Six of them had a history of atopy. A physical examination revealed no deviation from what is considered to be normal. The mean total serum immunoglobulin (Ig)E level was 325±403 IU·mL^{-1}. The mean serum levels of IgG, IgM, IgA and α_1-antitrypsin were within normal limits. Table 1 shows the results of the lung-function tests of the 26 farmers at the time of their admission as inpatients. The patients were taking no anti-inflammatory or bronchodilatory medicine at the time of the investigations.

In all patients, nonspecific bronchial reactivity was tested. A test was rated positive if the specific airway resistance (sR_{aw}) rose to at least twice the baseline value and the absolute value became Š2.0 kPa·s^{-1}. None of the patients showed a significant rise in sR_{aw} following the inhalation of physiological saline and lactose powder. Eleven of the farmers experienced a positive reaction after they had inhaled 1 mL of a 0.3% solution of histamine, four

Table 1. – Lung function parameters at the time of admission in the 26 farmers investigated

	Mean±SD	Minimum	Maximum
R_{aw} kPa·s^{-1}·L^{-1}	0.31±0.10	0.18	0.53
TGV L	3.77±1.05	2.01	6.15
sR_{aw} kPa·s^{-1}	1.18±0.42	0.59	2.09
TLC L	7.06±1.43	4.16	9.82
VC L	4.65±1.19	2.58	6.97
FEV_1 L·s^{-1}	3.46±0.95	1.84	5.00

R_{aw}: airway resistance: TGV: thoracic gas volume; sR_{aw}: specific airway resistance; TLC: total lung capacity; VC: vital capacity; FEV_1: forced expiratory volume in one second.

after 1 mL of a 1% solution of histamine, 10 after eucapnic hyperventilation with cold air (70 L·min^{-1}, -21.6°C) and one after having exercised on a bicycle ergometer. During the allergy examination, every patient showed at least one positive histamine-like skin reaction and/or produced specific IgE antibodies of radioallergosorbent tests (RAST) category II or higher against occupational allergens. The patients gave their informed consent to the performance of inhalation challenge tests.

The tests took place in the hospital in a room of 54 m^3 under similar conditions to those found in the patients' workplace. During the provocation, the farmers had to whirl up about 5 kg of material they had brought along, which was considered to be causative. According to the farmers the resulting dusty atmosphere corresponded to the circumstances in the barns and stables. During two hay provocations respirable dust concentrations of 7.05 and 6.38 mg·m^{-3} were measured.

Each of the patients had to undergo two inhalative challenges, one with and one without an RD. Fourteen of the farmers were tested with hay, five with straw, four with both hay and straw, two with grain dust and one with hay, straw and grain dust. On average, the second challenge, with the patients wearing respirators, was performed 21 weeks after the first positive test and the same materials were used as in the first challenges. Twenty-one of the patients used a "Dustmaster" with a P2 filter, four used an "Airstream helmet" with a P2 filter and one of them used an "Airlite" respiratory device with a P2 filter (all three respiratory devices produced by Racal, Dietzenbach, Germany).

Before each provocation a short history of the patient was taken and physical examination and body plethysmography were carried out. During the provocations which lasted for a maximum of 60 min, the farmers were questioned and auscultated and a body plethysmograph was carried out every 15 min. A test was rated positive if the sR_{aw} rose to at least twice the baseline value and if the absolute value became Š2.0 kPa·s^{-1}. The provocation was terminated and bronchodilator treatment was given if these criteria for discontinuation were attained. The patients were observed for up to 8 h after the beginning of the test.

Statistical analysis

Mean values and standard deviations were calculated from the data. Two means were compared using the Student's t-test, paired for intraindividual and unpaired for interindividual comparisons. A p-value <0.05 was regarded as significant and a p-value <0.01 as highly significant.

Results

A highly significant rise in airway resistance (R_{aw}), sR_{aw} and intrathoracic gas volume (TGV) was observed in the challenges without RDs compared to baseline values. When RDs were worn, the challenges again caused highly significant increases in R_{aw}, sR_{aw} and TGV. Table 2 shows the results of the double-challenge tests with and without the respirators being worn. The peak values of R_{aw}, sR_{aw} and TGV observed under the two conditions were compared statistically with each other and with baseline values.

Figure 1 shows the time course of sR_{aw}. When the prechallenge values of R_{aw}, sR_{aw} and TGV were compared statistically, no significant differences could be found. Using no RDs all of the farmers complained of coughing and dyspnoea and, when they were auscultated, wheezing could be heard. After these challenges all farmers received bronchodilatory treatment. In the challenge with RDs six of the 26 patients required bronchodilatory treatment because they had reached the criteria for discontinuation. Eleven of the farmers examined stated that they had no breathing difficulties when using an RD and the remaining 15 reported a reduction in their complaints.

The mean difference in increase in R_{aw} between the two tests was 0.25 kPa·s^{-1}·L^{-1}, and the mean difference in increase in sR_{aw} was 1.66 kPa·s^{-1}. These differences were statistically highly significant. The mean difference in the rise in intrathoracic gas volume was 0.72 L and was significant at the 4% level.

Table 2. – Airway resistance (R_{aw}), specific airway resistance (sR_{aw}) and thoracic gas volume (TGV) in 26 double-challenge tests with and without respiratory protection

	Without respiratory function	With respiratory function	p-value
R_{aw} kPa·s^{-1}·L^{-1}			
Prechallenge	0.30±0.08	0.30±0.1	NS
Maximum postchallenge	0.74±0.13***	0.49±0.24***	<0.001
sR_{aw} kPa·s^{-1}			
Prechallenge	1.19±0.37	1.24±0.49	NS
Maximum postchallenge	3.75±1.12***	2.13±1.26***	<0.001
TGV L			
Prechallenge	3.81±1.03	3.91±0.88	NS
Maximum postchallenge	5.06±1.08***	4.43±1.04***	<0.04

Data are mean±SD. ***: p<0.001, significant difference between prechallenge and postchallenge values.

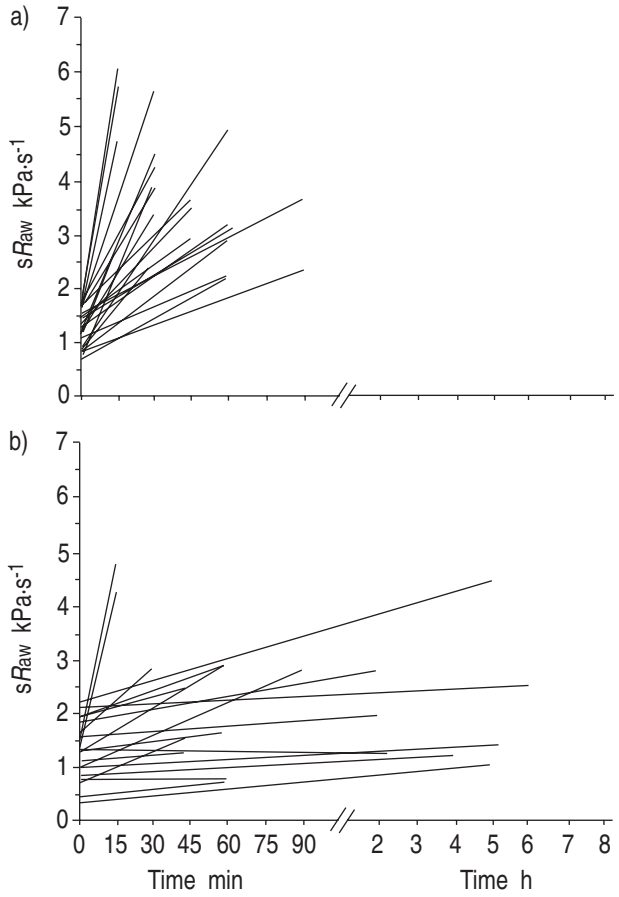

Fig. 1. – Time course of specific airway resistance (sR_{aw}) in 26 double-challenge tests a) without and b) with respiratory protection. The end of the lines indicate the point at which the criteria for discontinuation or the maximum response after provocation were reached.

As a group, the six farmers who reached the criteria for discontinuation when using an RD were not different from the others in terms of bronchial reactivity, the kind of RD worn, age, sex, or duration of exposure.

Discussion

The main result of this study was that the use of respiratory devices in farmers with occupational asthma significantly reduced the degree of bronchial obstruction, but did not provide complete protection. This was shown in 26 farmers by work-related inhalation challenge tests with natural materials. In the tests without RDs all patients experienced symptoms and their R_{aw}, sR_{aw} and TGV rose in a statistically highly significant way. A highly significant increase in these three parameters, compared with the baseline values, was also observed in tests using an RD, but these increases were, on average 57% (R_{aw}), 60% (TGV) and 77% (sR_{aw}) less than those observed when RDs were not worn. Fifteen of the 26 farmers complained of problems even when they had worn an RD and six of these required bronchodilatory treatment.

These patients were male and female farmers working on small farms where the farmer and their spouse accomplished all of the work together. It was hardly possible for them to delegate the dusty work to someone else. From the allergological point of view changing their profession would be necessary, but for economic reasons almost none of the affected asthmatics could do so.

In order to reduce morbidity, organizational and hygiene measures at the workplace should be considered at an early stage, because some of the affected persons suffering from occupational asthma will face a worsening of their complaints if their exposure continues. Another reason for taking early measures is the fact that asthma improves in only half of the patients after exposure has been reduced [20, 24].

In Germany, agricultural compensation boards provide powered RDs (using a P2 Filter) to the affected persons as a measure of secondary prevention. These RDs eliminate 90% of all particles >0.5 μm.

Measurements showed that the dust concentration used in the provocations represented the occupational conditions in a realistic way. Vogelmeier *et al.* [25] measured total dust concentrations of 100±54.3 mg·m^{-3} and respi-rable dust concentrations of 34.8±19.2 mg·m^{-3} during a work-related hay challenge. During hay work in barns they measured total dust concentrations of 36.1±24.5 mg·m^{-3} and respirable dust concentrations of 14.6±12.7 mg·m^{-3}. In the present study respirable dust concentrations of 6.38 and 7.05 mg·m^{-3} were measured. do Pico [26] reported that, in grain elevators, total airborne dust concentrations ranged from <10–780 mg·m^{-3} [26]. Louhelainen *et al.* [27] measured total dust concentrations of up to 60.2 mg·m^{-3} during farm work. Schwartz *et al.* [5] showed that work-related respiratory symptoms were more closely associated with the concentration of endotoxin in the bioaerosol of the work setting than with the total dust concentration. In the farm environment endotoxin levels vary from 0.01–100 μg·m^{-3} [26, 28].

Using natural materials did not allow differentiation between specific and nonspecific airway obstruction, but provided the opportunity to investigate the efficacy of RDs. The tests were evaluated according to the recommendations of the Deutsche Gesellschaft für Allergie- und Immunitätsforschung [29].

The present study shows that the use of an RD with a P2 filter fails to prevent the development of symptomatic bronchial obstruction in most sensitized farmers exposed to work-related dust. Having performed investigations among persons with laboratory animal allergy, Slovak *et al.* [20] doubted that using an Airstream helmet could prevent the worsening of asthma. In persons exposed to grain dust, the utilization of RDs did not cause a decrease in symptoms or changes in lung function [16, 19]. It has been demonstrated among patients suffering from farmer's lung that the use of an RD cannot avoid the allergic reaction completely when the farmers are exposed to appropriate allergens [13] and acute febrile reactions may even occur [14]. It has also been shown that, among persons suffering from flour-dust asthma, RDs could not protect all patients who were exposed [15].

This failure to protect all exposed subjects has to be attributed to filter- and face-seal leaks [10, 22, 23]. The present investigation allows the conclusion to be drawn that the use of respiratory devices with P2 filters in farmers suffering from occupational asthma can reduce the development of bronchial obstruction during an acute exposition but cannot prevent it. The influence of the use

of respiratory devices on the long-term outcome of patients with occupational asthma could not be answered by this study. Longitudinal studies should be conducted to answer this question.

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