Airways inflammation among workers in a paper industry

R. Rylander*, J. Thorn*, R. Attefors**

ABSTRACT: Exposure to organic dusts may cause airways inflammation in a large proportion of exposed persons. Most studies have relied on questionnaires and spirometry for diagnosis. To assess the possibility of determining the presence of inflammation using clinical diagnostic procedures, a study was undertaken among workers in a paper industry.

Participants were 83 workers and 44 controls. Airborne endotoxin and (1→3)-β-D-glucan levels at the worksites were determined. The effects of this exposure were evaluated using a questionnaire, spirometry and measurements of airway responsiveness (methacholine) and levels of eosinophil cationic protein (ECP), myeloperoxidase (MPO), and C-reactive protein (CRP) in serum.

The workers had a decreased baseline forced expiratory volume in one second (FEV1) and an increased airway responsiveness compared with controls. The concentrations of ECP and MPO were elevated compared with controls. There was a relation between exposure to endotoxin and (1→3)-β-D-glucan and airway responsiveness as well as ECP levels, when controlling for age, sex, smoking habits, atopy and asthma.

The results suggest an increased prevalence of subjective respiratory symptoms, and an increased airway responsiveness among exposed workers. There was also a relationship between the serum concentration of eosinophil cationic protein and airway responsiveness. Taken together, the results suggest the presence of airways inflammation in the workers.

There is increasing evidence that diseases and symptoms caused by organic dusts are mainly those involving inflammation. A previous analysis of the symptoms present after exposure to cotton dust, byssinosis, revealed characteristics related to inflammation of the airways such as dry cough, narrowing of the airways after an acute exposure and increased airway responsiveness [1]. A study among farmers demonstrated the presence of symptoms of inflammation as well as increased airway responsiveness, most marked among those working with swine and other animals [2]. These symptoms may be present, although spirometry yields normal values [3].

Organic dusts contain several agents capable of inducing inflammation of the airways. The most widely researched of these are bacterial endotoxins and (1→3)-β-D-glucan, a cell wall component in fungi, certain bacteria and plants. A number of symptoms observed after organic dust exposure have been related to the endotoxin concentration in a dose–response fashion, and a relation between the levels of endotoxin in cotton and grain dust and airway responsiveness has been reported [4, 5]. Guidelines for environmental endotoxin exposure have been suggested [6].

The paper industry is one example of an occupational environment where organic dusts are generated. Earlier investigations have shown that changes in respiratory function occur at relatively high levels of exposure to paper dust [7]. In the initial stages of paper manufacture, however, a mixture of potentially toxic agents is also present, including micro-organisms. Assessments of exposure to chemicals, airborne dust, micro-organisms and endotoxins have been performed in six Danish paper recycling plants [8], and airborne concentrations of dust, micro-organisms and endotoxins were found to vary widely between plants. In general, endotoxin levels were low, but were high in one plant when reuse of process water was intensified. In another study, the nasal cavities of many workers, particularly those in the debarking units, contained high numbers of Klebsiella pneumoniae, coliforms, yeasts and moulds. Bacteria and yeast found in the nose were largely derived from the mill and debarker air, where they mainly originated from process water [9].

The present study was undertaken during the initial processing phase at a paper manufacturing plant. Over the years, there had been numerous complaints of respiratory symptoms and fatigue from the workers, especially among those working in the bark cleaning unit (BCU). Earlier measurements of chemical agents (α-pinene, β-pinene, β-carene and hydrogen sulphide) had not shown increased levels, but the concentrations of endotoxins were high. The purpose of this study was to assess airways inflammation among the workers, and to assess the relationships between clinical symptoms, markers of inflammation, airway responsiveness and exposure to airborne endotoxin and (1→3)-β-D-glucan.
Materials and methods

Area of paper mill investigated

The part of the paper mill investigated processes timber and recycled paper. The timber is brought into enormous tumblers, where the bark is removed in a mechanical process under a spray of water. The timber is shredded into small pieces and used for paper production in another part of the plant. Recycled paper is kept in dry storage for 2–4 weeks, whereafter it is ground in water. Chemicals are added and the slurry is washed to remove the printing ink. During all of these processes, an aerosol of waste water and recycled process water is generated.

Population sample

The study group comprised all persons working in the bark cleaning unit (BCU), the recycled paper storage (RPS), and the recycled paper processing (RPP) unit. Control persons were recruited from the local municipal administration, mainly office workers, and from a wholesale dealer in the same municipality, mainly storemen but also office workers. They were largely similar to the workers in terms of sex and social and educational background.

Three controls and two subjects working in the paper mill were excluded because they had worked <1 yr in the present workplace and had previously worked in a dusty environment. Two control subjects were excluded because they were exposed to organic dusts. One worker was excluded because of a serious pulmonary disease. Subjects with colds were not examined at that time, but after recovery.

Data on the number of persons invited, participants in the study and their background characteristics are presented in Table 1.

The proportion of atopic subjects (see below) was lower among workers, but the difference was not significant. There was a significantly higher proportion of asthmatics among subjects with a positive Phadiatop test (Pharmacia Diagnostics, Uppsala, Sweden) (atopic) as compared with those with a negative Phadiatop test (nonatopic) (13 versus 1%, p<0.01).

To assess turnover, employment data were collected between 11 June, 1987 and 31 October, 1995. In the BCU, 19 workers left their jobs during this period, one retired and ten transferred to other sites in the industry. One worker left the RPS unit and six left the RPP unit. These subjects were not included in the study.

Exposure measurements and investigations of subjects were made between 31 October, 1995 and 2 April, 1996. All investigations of any one subject were made on the same day, first a blood sample was taken, then the subject was interviewed using a questionnaire, and finally tests of lung function and airway responsiveness were carried out. The tests were performed during an ordinary working week. The examinations of workers were mainly carried out in the afternoon. The examinations of controls were carried out in the afternoon, just after their shift. The area of the mill investigated industry operates 24 h, 7 days week−1 and most of the workers were on a shift system. When performing the examinations of the subjects, they had to have worked ≥2 days in a row.

Table 1. – Population characteristics of controls and workers in the bark cleaning unit (BCU), recycled paper processing (RPP) unit and recycled paper storage (RPS) unit

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>BCU</th>
<th>RPP unit</th>
<th>RPS unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persons invited n</td>
<td>68</td>
<td>52</td>
<td>34</td>
<td>10</td>
</tr>
<tr>
<td>Participants n (%)</td>
<td>44 (65)</td>
<td>48 (92)</td>
<td>28 (82)</td>
<td>7 (70)</td>
</tr>
<tr>
<td>Age, mean (range) yrs</td>
<td>40 (22–59)</td>
<td>39 (20–60)</td>
<td>39 (19–61)</td>
<td>47 (28–57)</td>
</tr>
<tr>
<td>Males n (%)</td>
<td>34 (77)</td>
<td>43 (90)</td>
<td>26 (93)</td>
<td>6 (86)</td>
</tr>
<tr>
<td>Smokers n (%)</td>
<td>4 (9)</td>
<td>16 (33)</td>
<td>9 (32)</td>
<td>2 (29)</td>
</tr>
<tr>
<td>Working time, mean (range) yrs</td>
<td>8 (0.2–30)</td>
<td>11 (2.22)</td>
<td>13 (0.2–46)</td>
<td>12 (4.22)</td>
</tr>
<tr>
<td>Physician-diagnosed asthma n (%)</td>
<td>4 (9)</td>
<td>1 (2)</td>
<td>1 (4)</td>
<td>1 (14)</td>
</tr>
<tr>
<td>Positive Phadiatop test n (%)</td>
<td>19 (43)</td>
<td>15 (31)</td>
<td>8 (29)</td>
<td>3 (43)</td>
</tr>
</tbody>
</table>
rate of air through the filter, this value was transformed to ng·m⁻³. The detection limit for this technique is 10 pg·mL⁻¹ for endotoxin and 20 pg·mL⁻¹ for (1→3)-β-D-glucan.

**Spirometry and airway responsiveness**

Spirometry was performed using standard techniques. A Vitalograph model S (Vitalograph Ltd., Buckingham, UK) with a pulmonary function test printer was used and calibrated every morning using a 1-L syringe. The subjects performed at least three technically acceptable trials, and the largest value of forced expiratory volume in one second (FEV₁) was recorded and compared with predicted values [11].

Airway responsiveness was assessed using the methacholine challenge test according to Yan et al. [12] with some modifications. Spirometry was performed to exclude subjects with FEV₁ and/or FEV₁/forced vital capacity (FVC) values of <70% predicted. A Pari Boy nebulizer (Pari Inhalierboy, Sverup, Gothenburg, Sweden) with automatic dosing was calibrated to an output of 3 µL·dose⁻¹. The subjects exhaled to slightly less than functional residual capacity, placed the nebulizer in their mouth and started to inhale. At maximum inhalation, the breath was held for 3 s before exhaling. One min after inhalation, the maximum FVC and FEV₁ were recorded.

The subjects initially inhaled one dose of saline. The spirometric values obtained 1 min after this inhalation were used as baseline values for the methacholine test. Methacholine was administered in increasing doses at 3-min intervals to a total of 1.2 mg. FVC and FEV₁ were recorded 1 min after each dose of methacholine. In subjects in which FEV₁ decreased by >10% of the baseline value after one dose, a slower increase in dose levels was administered. If FEV₁ decreased by >20% of the baseline value after any dose of methacholine, the test was discontinued. The results were expressed as the group mean decrease in FEV₁ after the highest dose of methacholine administered. A decrease in FEV₁ was identified as an increase in airway responsiveness.

**Inflammatory markers and atopy in serum**

Eosinophil cationic protein (ECP), myeloperoxidase (MPO) and C-reactive protein (CRP) were determined in serum (Clinical Allergy Laboratory at Sahlgrenska Hospital, Gothenburg, Sweden). ECP was assayed by means of a fluorescence enzyme immunoassay (FEIA) technique (CAP ECP FEIA; Pharmacia Diagnostics), MPO by a radioimmunoassay (RIA) technique (CAP MPO RIA; Pharmacia Diagnostics) and expressed in µg·L⁻¹. CRP was assayed by the Mancini technique (Behringer Mannheim, Mannheim, Germany), and expressed in µg·mL⁻¹.

Atopy was assayed via an FEIA technique (CAP Phadiatop FEIA, Pharmacia Diagnostics). The results were expressed as being positive (atopic) or negative (nonatopic). The Phadiatop test is an in vitro test system based on ImmunoCAP technology for the determination of immunoglobulin (Ig)E specific to inhaled allergens in human serum. A mixture of 10 relevant inhaled allergens, covalently coupled to ImmunoCAP™ (Pharmacia Diagnostics), reacts with the specific IgE in the patient’s serum specimen.
differences (Δ) with 95% CIs. ECP and MPO level data were not normally distributed, and the data were therefore logarithmically transformed before performing the analyses. The results were then back-transformed and expressed as percentage differences on the original scale (Δ%) with 95% CIs.

The airway responsiveness data were not normally distributed and contained negative values. The values were therefore treated as positive values for the logarithmic transformation. To achieve a satisfactory normal distribution after the logarithmic transformation, 10 was the smallest positive value that could be used (10-FEV1 values). The percentage differences for the airway responsiveness data (Δ%) with 95% CIs were reported on the transformed scale. As a consequence of this transformation, these values are approximate. There is also an underestimation of the percentage differences between the groups on the original scale.

The number of asthmatics in the investigated population was small (four among controls and three among workers) and the regression analyses were only performed on nonasthmatics. Differences were considered statistically significant at p<0.05. In view of the relatively small number of workers, no subanalysis of different working sites could be made.

The study was approved by the Ethics Committee of the Faculty of Medicine in Gothenburg.

Results

Exposure conditions

The results of the determinations of airborne endotoxins and (1→3)-β-D-glucan at the different worksites are found in table 2. The BCU contained the highest levels. Between the others, endotoxin levels were highest in the RPP unit and (1→3)-β-D-glucan levels highest in the RPS unit. There was a significant correlation between the amounts of airborne endotoxin and (1→3)-β-D-glucan (r=0.93; p<0.001).

Spirometry and airway responsiveness

The baseline FEV1 values (% pred) were significantly lower among workers as compared to controls (mean±SD 96±15 versus 103±12%, p<0.01), with similar results among non-smokers, non-smokers/nonasthmatics and non-asthmatics, but not among atopics, where the reduction in FEV1 was not significant.

<table>
<thead>
<tr>
<th>Filters</th>
<th>Endotoxin (ng m⁻³)</th>
<th>(1→3)-β-D-Glucan (ng m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
</tr>
<tr>
<td>BCU</td>
<td>12</td>
<td>97.7</td>
</tr>
<tr>
<td>RPP unit</td>
<td>4</td>
<td>18.2</td>
</tr>
<tr>
<td>RPS unit</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
<td>Controls</td>
<td>8</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The methacholine challenge test was performed by 85% of the workers and 93% of the controls. Of those who performed the test, there were four workers who could not be administered the highest dose of methacholine because they reacted with a sharp drop in FEV1 after a previous dose. The reduction in FEV1 after the highest dose of methacholine was significantly greater among workers than among controls (-8.0±7.0 versus -4.0±4.9%, p<0.01), with similar results among non-smokers, non-smokers/non-asthmatics, non-asthmatics, non-atopics and atopics. The reduction in FEV1 was independent of the number of years worked.

Inflammatory markers in serum

The concentration of ECP in serum was significantly higher among workers than among controls (7.7±5.7 versus 5.1±2.7 μg L⁻¹, p<0.01). Approximately the same proportional differences were found for the concentration of MPO (345±138 versus 279±82 μg L⁻¹, p<0.01), with similar results among non-smokers, non-smokers/non-asthmatics, non-asthmatics, non-atopics and atopics. The concentration of CRP was slightly decreased among workers as compared with controls (2.3±2.7 versus 3.6±5.0 μg L⁻¹, NS).

Questionnaire data

In general, a higher proportion of workers reported symptoms as compared with controls. The differences were significant for unusual tiredness (45 versus 16%, p<0.01), joint pains (27 versus 5%, p<0.01) and nasal irritation (28 versus 5%, p<0.01), with similar results among non-smokers and non-smokers/non-asthmatics/non-atopics.

A higher proportion of workers reported episodes of flu-like symptoms which had vanished completely the following day as compared with controls (27 versus 5%, p<0.01), with similar results among non-smokers and non-smokers/non-atopics. There were no differences between workers and controls regarding chronic bronchitis.

Regression analyses

Linear regression analyses were performed for the continuous variables (ECP levels, MPO levels, airway responsiveness and baseline FEV1) between workers and controls, and against airborne endotoxins and (1→3)-β-D-glucan. ECP concentration (μg L⁻¹), MPO (μg L⁻¹) and airway responsiveness (% change) were significantly higher and baseline FEV1 values (% pred) significantly lower among workers as compared with controls (Δ%=-38.3, CI=23.0–75.6, p<0.01; Δ%=-19.4, CI=4.3–36.6, p<0.05; Δ%=-28.9, CI=13.8–46.2, p<0.001 and Δ%=-6.3; CI=-11.5–1.0, p<0.05, respectively). ECP levels, MPO levels and airway responsiveness were also significantly higher among workers as compared with controls, when controlling for age, sex, cigarette smoking status and atopy (Δ%=-48.7, CI=15.7–91.1, p<0.01; Δ%=-23.5, CI=7.0–42.5, p<0.01, Δ%=-34.2, CI=16.5–54.3, p<0.001, respectively). Linear regression analyses for the continuous variables in relation to endotoxin exposure are shown in table 3. ECP concentration and airway responsiveness were increased over the exposure range. MPO concentration was
increased and baseline FEV1 values decreased as compared with the low exposure group, without a dose-response trend. The results were similar when controlling for age, sex, cigarette smoking status and atopy. Linear regression analyses for the continuous variables in relation to (1→3)-β-D-glucan exposure were similar to those related to endotoxin exposure (data not shown).

The adjusted odds ratios with 95% CIs for category variables are shown in tables 4 and 5. The adjusted odds ratios for cough with phlegm, irritation in the nose, congested nose, unusual tiredness, joint pains, and reports of flu-like symptoms were larger among workers as compared with controls. The adjusted odds ratios for cough with phlegm, throat irritation, congested nose, unusual tiredness, joint pains and reports of flu-like symptoms were increased in the high exposure group of endotoxin and (1→3)-β-D-glucan. The crude odds ratios with 95% CIs for category variables were similar to the adjusted odds ratios (data not shown).

Linear regression analyses were performed to evaluate the relationships between ECP concentration, MPO concentration and airway responsiveness. When controlling for age, sex, atopy and cigarette smoking status, ECP concentration was found to relate to airway responsiveness and to MPO concentration (b% = 2.6, CI = 0.6–4.8, p < 0.05; b% = 0.3, CI = 0.2–0.4, p < 0.001, respectively).

Discussion

This study reports an increased prevalence of subjective respiratory and general symptoms among workers at certain worksites in a pulp/paper mill. In view of previous discussions at the worksites, it cannot be excluded that part of this increase was caused by overreporting of symptoms. The increase in symptomatology was, however, related to objective measurements of inflammation, and overreporting, if present, could thus only partially explain the increase. The number of controls in the study was smaller than the number of workers, but no further controls were available.

The method of evaluating bronchial reactivity used in this study differs from traditional clinical testing methods. Instead of titrating the dose required for a certain effect, e.g. the provocative dose causing a 20% fall in FEV1, the mean reaction to the highest cumulative dose given in a

<table>
<thead>
<tr>
<th>Subjects n</th>
<th>Throat irritation</th>
<th>Nose irritation</th>
<th>Dry cough</th>
<th>Chronic bronchitis</th>
<th>Cough with phlegm</th>
<th>Congested nose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>40</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Workers</td>
<td>80</td>
<td>2.6 (0.7–10.0)</td>
<td>19.2 (2.3–158.7)</td>
<td>2.9 (0.3–31.2)</td>
<td>0.9 (0.2–4.0)</td>
<td>3.3 (0.8–13.1)</td>
</tr>
<tr>
<td>Endotoxin ng·m⁻³</td>
<td>0–1</td>
<td>40</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2–20</td>
<td>33</td>
<td>0.7 (0.1–4.8)</td>
<td>31.8 (3.6–285.7)</td>
<td>8.7 (0.5–138.9)</td>
<td>1.3 (0.2–6.8)</td>
</tr>
<tr>
<td></td>
<td>21–98</td>
<td>44</td>
<td>4.6 (1.1–19.1)</td>
<td>13.5 (1.5–119.0)</td>
<td>1.0 (0–22.2)</td>
<td>0.7 (0.1–3.9)</td>
</tr>
<tr>
<td>Glucan ng·m⁻³</td>
<td>0–9</td>
<td>35</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>10–38</td>
<td>38</td>
<td>0.5 (0.1–3.3)</td>
<td>–</td>
<td>–</td>
<td>0.9 (0.2–5.0)</td>
</tr>
<tr>
<td></td>
<td>39–245</td>
<td>44</td>
<td>3.7 (0.9–15.9)</td>
<td>–</td>
<td>–</td>
<td>0.6 (0.1–3.3)</td>
</tr>
</tbody>
</table>

Values represent adjusted odds ratios with 95% confidence intervals in parentheses, controlling for age, sex, cigarette smoking status and atopy.
Markers of inflammation in sputum or bronchoalveolar lavage fluid.

Present findings need to be verified by means of measurement. Serum can only be regarded as an indirect evaluation. The clinical method is not suitable for field studies. The same procedure has been used in other similar studies to evaluate the effects of methacholine challenges and relationships to exposure have been shown [2, 4].

The results demonstrated several differences between workers at the paper mill and controls in terms of symmetry, airway responsiveness and symptoms. These results are similar to those found in previous studies on persons exposed to organic dusts in other environments [2, 3, 5, 16] and suggest the presence of inflammation of the airways. They were independent of atopy, suggesting that they were specific and not related to antigen sensitization. Further support for the presence of airways inflammation comes from markers of inflammation in serum. Workers had higher levels of ECP and MPO, independent of age, sex, smoking, asthma and atopy. A relationship between ECP concentration and airway responsiveness was found, suggesting that ECP levels in serum reflect changes in the airways. However, the assessment of airways inflammation via levels of inflammatory markers in serum can only be regarded as an indirect evaluation. The present findings need to be verified by means of measuring markers in sputum or bronchoalveolar lavage fluid.

Increased levels of ECP and MPO have been found in previous studies on airborne endotoxin or (1→3)-β-D-glucan exposure, it is not possible to conclude which of the two agents was the most relevant. In view of previous endotoxin measurements, the suggested presence of inflammation of the airways and lung parenchyma. In view of this, the term “toxic pneumonitis” has been suggested [6].

Relationships were found between the amount of airborne endotoxin and several of the effect variables. As there was a close relationship between endotoxin and (1→3)-β-D-glucan exposure, it is not possible to conclude which of the two agents was the most relevant. In view of previous endotoxin measurements, the abundance of information on endotoxin, its relations with several effect variables among exposed persons and the suggested patterns of symptoms as well as an increased number of neutrophils in the blood and the airways [21, 22]. A decrease in carbon monoxide transfer [24] and an acute invasion of neutrophils into the lung walls of guinea-pigs, with a peak 4–12 h after LPS challenge [25], have previously been reported. These findings suggest inflammation of the airways and lung parenchyma. In view of this, the term “toxic pneumonitis” has been suggested [6].

From a mechanistic point of view, these relationships are reasonable. After inhalation, endotoxins induce a series of intracellular changes in macrophages, which can be collectively referred to as activation. This activation results in the production of chemotactic factors. It has been shown that neutrophil invasion in the lung results from the secretion of chemotactic agents by alveolar macrophages [26]. Endotoxin-induced activation of macrophages also results in an increased production of different cytokines, such as interleukin-1 and tumour necrosis factor-α.

(1→3)-β-D-glucan was also related to several of the effect variables. As there was a close relationship between endotoxin and (1→3)-β-D-glucan exposure, it is not possible to conclude which of the two agents was the most relevant. In view of previous endotoxin measurements, the abundance of information on endotoxin, its relations with several effect variables among exposed persons and the suggested guidelines for exposure [6], this agent is currently the best indicator for the observed effects.

In the present study, the environmental measurements focused on endotoxin and (1→3)-β-D-glucan. The aerosols of process water in the paper mill and particles from bark and wood and other constituents of the exposure may contain several other bioactive agents [7]. Previous workplace measurements of α-pinene, β-pinene, 3-carene and hydrogen sulphide had however not shown increased values. Recent measurements in the BCU of the amounts of airborne terpenes and hydrogen sulphide, performed after this study but in the same season, again showed very low values (data not shown).

In conclusion, the results suggest an increased prevalence of subjective respiratory symptoms and more reports of flu-like symptoms (‘toxic pneumonitis”) among relatively short time was calculated. This method was chosen because the clinical method is not suitable for field studies. The same procedure has been used in other similar studies to evaluate the effects of methacholine challenges and relationships to exposure have been shown [2, 4].

Table 5.—Logistic regression analyses evaluating the relationships between workers and controls, airborne endotoxin or (1→3)-β-D-glucan or general symptoms

<table>
<thead>
<tr>
<th></th>
<th>CRP levels</th>
<th>Headache</th>
<th>Joint pains</th>
<th>Unusual tiredness</th>
<th>Flu-like symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>40</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Workers</td>
<td>80</td>
<td>1.8 (0.7–4.4)</td>
<td>2.0 (0.3–11.8)</td>
<td>14.2 (1.7–116.3)</td>
<td>4.1 (1.5–11.3)</td>
</tr>
<tr>
<td>Endotoxin ng-m$^{-3}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–1</td>
<td>40</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2–20</td>
<td>33</td>
<td>2.1 (0.7–5.9)</td>
<td>2.5 (0.3–18.3)</td>
<td>10.9 (1.2–98.0)</td>
<td>2.3 (0.7–7.6)</td>
</tr>
<tr>
<td>21–98</td>
<td>44</td>
<td>1.4 (0.5–3.7)</td>
<td>1.7 (0.2–12.1)</td>
<td>19.6 (2.3–166.7)</td>
<td>5.8 (2.0–17.5)</td>
</tr>
<tr>
<td>Glucan ng-m$^{-3}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–9</td>
<td>35</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10–38</td>
<td>38</td>
<td>1.4 (0.5–4.1)</td>
<td>1.8 (0.2–13.4)</td>
<td>9.0 (1.0–81.3)</td>
<td>1.6 (0.5–5.4)</td>
</tr>
<tr>
<td>39–245</td>
<td>44</td>
<td>1.1 (0.4–3.2)</td>
<td>1.4 (0.2–10.6)</td>
<td>18.3 (2.1–158.7)</td>
<td>5.0 (1.6–15.2)</td>
</tr>
</tbody>
</table>

Values represent adjusted odds ratios with 95% confidence intervals in parentheses, controlling for age, sex, cigarette smoking status and atopy.
workers exposed to an aerosol containing endotoxin and (1→3)-ß-D-glucan. The workers had an increased airway responsiveness as compared with controls. There was also a relationship between the amount of serum eosinophil cationic protein and airway responsiveness. Taken together, these results suggest the presence of airways inflammation.

Acknowledgements. The assistance of K. Franson, A. Lindqvist and all participants are gratefully acknowledged. The authors thank K. Törén for valuable comments.

References


