Lung function in textile workers

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Žuškin, E., Valić, F., Butković, D., and Bouhuys, A. (1975). British Journal of Industrial Medicine, 32, 283-288. Lung function in textile workers. Acute changes in ventilatory function during a workshift with exposure to hemp, flax, and cotton dust were measured on Mondays in a group of 61 textile workers, all working on carding machines. In addition, single-breath diffusing capacity (DLCOSB) was measured before dust exposure on Monday in 30 of the 61 workers. Large acute reductions during dust exposure were recorded in maximum expiratory flow rate at 50% VC (MEF50%), ranging from 38 to 22%. Acute reductions of FEV1.0 were considerably smaller, ranging from 17 to 9%. There was a statistically significant increase in residual volume (RV) with very small and insignificant changes in total lung capacity (TLC). Although preshift FEV1.0 and FVC were decreased, DLCOSB was within normal limits. Plethysmographic measurements in six healthy volunteers exposed to hemp-dust extract confirmed the results obtained in textile workers, that is, that TLC does not change significantly during dust-induced airway constriction and that maximum expiratory flow rate at 50% VC (MEF50%) is a more sensitive test than FEV1.0 in detecting acute ventilatory changes caused by the dust extract.

Subjects and methods

Subjects
The study group included all carding machine operators in three Yugoslavian textile mills (n = 61; 14 female hemp workers, 24 female flax workers, eight female cotton workers, and 15 male cotton workers). All female workers were non-smokers, but 80% of the male workers smoked, on the average, 20 cigarettes daily. The mean and range for age and duration of exposure to textile dusts for each group of workers is shown in Table 1.

Six healthy nonsmoking volunteers (four men and two women; age 20-26 years) participated in laboratory experiments with hemp-dust extract aerosol inhalation. The Medical Research Council Committee questionnaire (1960) was used to assess the prevalence of chronic respiratory symptoms in textile workers. Byssinosis was graded according to Schilling et al. (1963).

Definitions
Chronic cough and/or phlegm: cough and/or phlegm production on most days for at least three months per year;
Chronic bronchitis: cough and phlegm for a minimum
Pulmonary function
We measured rates and the FEV1.0/FVC% spirometer (Peters, ) were measured volume was connected was calculated.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (yr)</th>
<th>Exposure (yr)</th>
<th>No.</th>
<th>Byssinosis grades</th>
<th>Chronic cough %</th>
<th>Chronic phlegm %</th>
<th>Chronic bronchitis %</th>
<th>Dyspnoea grade 3 or 4 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemp</td>
<td>Female</td>
<td>40 (29-51)</td>
<td>16 (2-28)</td>
<td>14</td>
<td>21 0 36 43</td>
<td>79</td>
<td>57</td>
<td>50</td>
</tr>
<tr>
<td>Flax</td>
<td>Female</td>
<td>39 (30-53)</td>
<td>14 (2-24)</td>
<td>24</td>
<td>4 4 42 50</td>
<td>54</td>
<td>42</td>
<td>38</td>
</tr>
<tr>
<td>Cotton</td>
<td>Male</td>
<td>41 (32-54)</td>
<td>16 (1-31)</td>
<td>15</td>
<td>13 7 33 47</td>
<td>73</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>Cotton</td>
<td>Female</td>
<td>41 (34-49)</td>
<td>18 (2-27)</td>
<td>8</td>
<td>0 25 63 12</td>
<td>63</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

The first number in each age and exposure column is the mean of the ages and exposures. The numbers in parentheses are the ranges.

of three months in the year and for not less than two successive years;
Dyspnoea grades: 3 = shortness of breath when walking with other people at an ordinary pace on the level; grade 4 = shortness of breath when walking at own pace on the level;
Byssinosis grades: 0 = no symptoms on Mondays; 1/2 = occasional symptoms (chest tightness, dyspnoea, or cough) on Mondays; 1 = such symptoms regularly on most Mondays; 2 = similar symptoms on Mondays and other workdays.

Pulmonary function measurements in textile workers
We measured acute changes in lung volumes and flow rates on the first working day of the week (Monday) before and after the work shift in all 61 workers.

From the forced expiratory spirogram recorded with a spirometer (Godart Pulmonet), the forced vital capacity (FVC) and the FEV1.0 were obtained and the ratio FEV1.0/FVC% was calculated.

MEFV curves were recorded with a portable flow-volume spirometer (Peters, Mead, and Van Ganse, 1969). The maximum flow rates at 50% of the control vital capacity (MEF50%) were read from these curves. Three forced expiratory spiromgrams and three MEFV curves were recorded each time and the mean of the two highest values was used as the result of the test.

Functional residual capacity (FRC) and residual volume (RV) were measured with a closed-circuit helium dilution technique, using the Godart-Pulmonet spirometer and a helium analyser. From the RV and FVC, the total lung capacity (TLC) and the ratio RV/TLC were calculated. To obtain FRC we used a technique described by Hathirat, Renzetti, and Mitchell (1970). The subject was connected to the spirometer circuit at the end of a normal expiration, and the helium concentration during mixing was recorded every 15 seconds. The subject breathed quietly until two successive readings were identical. At this point, he performed two vital capacity manoeuvres followed by a few quiet breaths for a final helium reading. He was then disconnected from the system. A further decrease in helium concentration caused by the VC manoeuvre indicates that a poorly ventilated portion of the lung had been opened by performing VC. This method provides an RV value which includes certain poorly ventilated spaces. Oxygen was supplied continuously at a constant rate to maintain a constant volume of the spirometer system throughout the rebreathing period. Lung volumes were corrected to BTPS.

The single-breath pulmonary diffusing capacity for CO (DLcoSB) was measured with commercially available equipment (Warren E. Collins, Inc.) in a smaller group of workers (nine hemp and 11 flax, and seven male and three female cotton workers; 31-51 years old). DLcoSB was calculated from single breath helium dilution during breath holding. Duration of exposure to textile dust varied from one to 26 years (mean 15 years). For DLcoSB measurement the 30 workers were brought to a hospital and therefore testing was performed on another Monday and only before dust exposure.

Normal values
Data for RV and TLC were compared with the predicted normal values of Goldman and Becklake (1959). Normal values for DLcoSB were calculated using the equations of Cotes (1973). FVC and FEV1.0 were compared with predicted normal values of Kory et al. (1961).

Laboratory studies
These were performed before and after exposure to an aerosol of hemp-dust extract in six healthy volunteers (age 20-27 years) who had participated in previous experiments with textile dust extracts. Hemp-dust extract was made from dust collected in the hemp mill where the textile workers were studied. Dust extract was prepared from a mixture containing 1 g hemp dust and 6 ml Tyrode’s solution boiled for one hour, centrifuged and immediately sterilized by filtering through a 0.45-micron grid membrane (Nalge Sybron Corp.). Each subject was exposed for 10 minutes to hemp-dust extract aerosolized by a Dautrebande D-30 nebulizer under a pressure of 103.5 kN. Pulmonary function was measured 10 minutes...
after exposure and again every 20 minutes over a one-hour period. Thoracic gas volume (TGV) was measured with DuBois’ technique, using an air-conditioned, volumedisplacement body plethysmograph. Total lung capacity (TLC) was calculated from the measurements of TGV and simultaneous recording of lung volume. RV was calculated as TLC – FVC. In this series of experiments, MEVF curves were recorded on a Brush 500 High Performance XY Recorder (Gould, Inc.) with lung volume changes on the abscissa and expiratory flow rate on the ordinate (Virgulto and Bouhuys, 1973).

**Results**

More than 80% of all textile workers had chest tightness or other Monday symptoms while working in dust (Table 1). In addition, there was a high prevalence of chronic respiratory symptoms and of dyspnoea. These symptoms were accompanied by changes in lung function, even in the absence of dust exposure (Table 2). On the average FEV₁₀ was decreased in comparison with expected values, while RV was increased. FVC decreased slightly in all groups, while TLC was close to predicted values with the exception of an 11% increase in the female hemp workers. DLCOSB was, on the average, slightly higher than predicted in all groups. Within each group there were considerable individual variations, as indicated by the standard deviations (SD) of each measurement. In the group of 30 individuals (Table 2) seven (23%) had an FEV₁₀ less than 70% of the predicted values (mean age of seven: 42 years; mean exposure 16 years). The data for this group are shown separately in Table 2. In spite of a considerably decreased FEV₁₀ and increased RV, the data for DLCOSB were within normal values. The group of workers tested for DLCOSB is representative of the total population of workers working in the carding sections. In comparison with normal values, two female hemp workers had the lowest DLCOSB in comparison with predicted values (80.8 and 88.8% of normal). Neither of them had Monday symptoms. The preshift FEV₁₀ of the first one (exposed for 15 years) was 96% of the expected; that of the second (exposed for 23 years) was 80% of the expected. Both had a normal VC.

There was a rough correlation between the grade of byssinosis as derived from the symptoms and the FEV₁₀ values before dust exposure. Workers without byssinosis symptoms or with grade 1/2 had, on the average, a normal FEV₁₀ (106 and 102% of expected), while those with grade 1 and, in particular, those with grade 2 byssinosis had lower average values of FEV₁₀ (91 and 77% of expected, respectively). Measurements before and after work on Monday showed consistent and in many cases significant changes of functional values during dust exposure (Table 3A and 3B). FEV₁₀ decreased significantly in all groups; FVC decreased only slightly and this decrease was not significant in three out of four groups. The FEV₁₀/FVC ratio declined significantly in the hemp and flax workers only. These groups also showed a significant increase in RV. FRC and TLC increased slightly but insignificantly in most instances. The largest decreases occurred in

### TABLE 2

**DIFFUSION CAPACITY AND OTHER FUNCTION TESTS BEFORE DUST EXPOSURE IN 30 TEXTILE WORKERS AND SEPARATELY IN THOSE WITH PRESHIFT FEV₁₀ < 70% OF EXPECTED**

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th>No.</th>
<th>DLCOSB Actual ± SD</th>
<th>% of expected</th>
<th>FEV₁₀ Actual ± SD</th>
<th>% of expected</th>
<th>FVC Actual ± SD</th>
<th>% of expected</th>
<th>RV Actual ± SD</th>
<th>% of expected</th>
<th>TLChₑ Actual ± SD</th>
<th>% of expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemp</td>
<td>Female</td>
<td>9</td>
<td>23.52 ± 3.80</td>
<td>108.9</td>
<td>2.30 ± 0.73</td>
<td>85.4</td>
<td>3.00 ± 0.53</td>
<td>91.8</td>
<td>1.73 ± 0.41</td>
<td>128.1</td>
<td>4.73 ± 0.36</td>
<td>110.7</td>
</tr>
<tr>
<td>Flax</td>
<td>Female</td>
<td>11</td>
<td>25.63 ± 4.60</td>
<td>108.9</td>
<td>2.43 ± 0.51</td>
<td>83.9</td>
<td>3.46 ± 0.61</td>
<td>96.9</td>
<td>1.69 ± 0.73</td>
<td>108.6</td>
<td>5.15 ± 0.78</td>
<td>104.0</td>
</tr>
<tr>
<td>Cotton</td>
<td>Male</td>
<td>7</td>
<td>29.45 ± 4.80</td>
<td>101.9</td>
<td>2.61 ± 0.32</td>
<td>74.2</td>
<td>3.75 ± 0.42</td>
<td>82.5</td>
<td>2.61 ± 0.75</td>
<td>136.5</td>
<td>6.36 ± 1.26</td>
<td>103.1</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>23.01 ± 5.10</td>
<td>103.0</td>
<td>2.24 ± 0.46</td>
<td>87.3</td>
<td>2.68 ± 0.42</td>
<td>93.2</td>
<td>1.62 ± 0.74</td>
<td>119.5</td>
<td>4.30 ± 0.97</td>
<td>98.2</td>
</tr>
<tr>
<td>FEV₁₀ &lt; 70% of expected</td>
<td>7*</td>
<td>28.09 ± 4.73</td>
<td>107.4</td>
<td>1.96 ± 0.50</td>
<td>61.9</td>
<td>3.23 ± 0.96</td>
<td>79.6</td>
<td>2.54 ± 0.68</td>
<td>151.1</td>
<td>5.77 ± 1.54</td>
<td>107.7</td>
<td></td>
</tr>
</tbody>
</table>

No. = number in each group; * = four males and three females
DLCOSB in ccm CO/min/mmHg; lung volumes in litres
Average values ± standard deviations; expected values, see reference in text
TABLE 3A
MEAN ACUTE CHANGES IN FEV$_{1.0}$, FVC, FEV$_{1.0}$/FVC%, and RV OVER WORK SHIFT ON MONDAY

<table>
<thead>
<tr>
<th>Mill</th>
<th>Sex</th>
<th>No.</th>
<th>FEV$_{1.0}$</th>
<th>FVC</th>
<th>FEV$_{1.0}$/FVC%</th>
<th>RV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Before shift</td>
<td>%</td>
<td>Before shift</td>
<td>%</td>
</tr>
<tr>
<td>Hemp</td>
<td>Female</td>
<td>14</td>
<td>2.44 ± 0.67</td>
<td>17 ± 0.01</td>
<td>6.00 ± 0.20</td>
<td>12 ± 0.01</td>
</tr>
<tr>
<td>Flax</td>
<td>Female</td>
<td>24</td>
<td>2.53 ± 0.11</td>
<td>9 ± 0.01</td>
<td>3.28 ± 0.13</td>
<td>2 ± 0.01</td>
</tr>
<tr>
<td>Cotton</td>
<td>Male</td>
<td>15</td>
<td>2.98 ± 0.01</td>
<td>14 ± 0.01</td>
<td>3.92 ± 0.25</td>
<td>7 ± 0.01</td>
</tr>
<tr>
<td>Cotton</td>
<td>Female</td>
<td>8</td>
<td>2.47 ± 0.19</td>
<td>10 ± 0.02</td>
<td>3.00 ± 0.28</td>
<td>4 ± 0.01</td>
</tr>
</tbody>
</table>

Data before shift for FEV$_{1.0}$, FVC, and RV are shown in litres.

TABLE 3B
MEAN ACUTE CHANGES IN FRC, TLC$_{He}$, RV/TLC%, and MEF50% OVER WORK SHIFT ON MONDAY

<table>
<thead>
<tr>
<th>Mill</th>
<th>Sex</th>
<th>No.</th>
<th>FRC</th>
<th>TLC$_{He}$</th>
<th>RV/TLC%</th>
<th>MEF50%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Before shift</td>
<td>%</td>
<td>Before shift</td>
<td>%</td>
</tr>
<tr>
<td>Hemp</td>
<td>Female</td>
<td>14</td>
<td>2.58 ± 0.12</td>
<td>10 ± 0.05</td>
<td>4.72 ± 0.43</td>
<td>2 ± 0.01</td>
</tr>
<tr>
<td>Flax</td>
<td>Female</td>
<td>24</td>
<td>2.75 ± 0.17</td>
<td>3 ± 0.01</td>
<td>5.05 ± 0.16</td>
<td>2 ± 0.01</td>
</tr>
<tr>
<td>Cotton</td>
<td>Male</td>
<td>15</td>
<td>3.87 ± 0.28</td>
<td>6 ± 0.01</td>
<td>6.38 ± 0.40</td>
<td>2 ± 0.01</td>
</tr>
<tr>
<td>Cotton</td>
<td>Female</td>
<td>8</td>
<td>2.63 ± 0.23</td>
<td>0 ± 0.01</td>
<td>4.62 ± 0.29</td>
<td>3 ± 0.01</td>
</tr>
</tbody>
</table>

Data before shift for FRC and TLC$_{He}$ are shown in litres, MEF50% in litres/second.

The maximum expiratory flow rate at 50% of the control vital capacity. These acute changes in lung function are related to the severity of symptoms of byssinosis in Fig. 1. On the whole, workers with grade 1 or 2 symptoms had larger decreases of FEV$_{1.0}$ and MEF50%, while their RV increased after dust exposure. However, the differences between the two groups were not significant and it is clear that significant changes in lung function occur in persons who do not regularly experience symptoms of chest tightness and dyspnoea during dust exposure on Mondays.

The data obtained in the laboratory studies (Fig. 2) show a pattern of lung function changes after inhalation of hemp-dust extract which is similar to the changes observed in the textile workers described above. Thus, MEF50% shows the greatest decrease, while FEV$_{1.0}$ decreases less but still significantly. RV increased slightly, but not significantly, in this small group, while TLC mostly remained unchanged through the period of observation.

Discussion

The present data confirm previous studies (Bouhuys et al., 1969; Valić and Žuškin, 1973; Žuškin and Valić, 1973; Bouhuys et al., 1973) which have shown that measurements of flow rates on MEFV curves are more sensitive indicators of airway constriction caused by pharmacological agents and by textile
Lung function in textile workers

Fig. 1. Mean acute changes in residual volume (RV), in one-second forced expiratory volume (FEV1.0), and in maximum expiratory flow rate at 50% VC (MEF50%) over work shift on Monday in textile workers with byssinosis grade 1 and 2, and with byssinosis grade 0 and 1/2. The data for RV are presented as a percentage increase of preshift values, and for FEV1.0 and MEF50% as percentage decrease of preshift values.

Fig. 2. Mean acute changes in total lung capacity (TLC), RV, FEV1.0, and MEF50% in six volunteers after hemp-dust extract exposure over a period of one hour.

dusts than measurements of FEV1.0. The data also confirm that TLC does not vary significantly during dust-induced airway constriction (Bouhuys and Van de Woestijne, 1970). This was found to be true for measurement of TLC with the helium-dilution method in industrial workers as well as for plethysmographic measurement of TLC before and after inhalation of a dust extract in the laboratory. For practical purposes this means that one can make valid comparison of MEFV curves before and after dust exposure by superimposing them at the point of maximum inspiration, as has been the practice in several previous studies where TLC was not measured.

In older hemp workers, Guyatt et al. (1973) found that lung elastic recoil pressures at TLC were frequently reduced, suggesting that these workers had a significant degree of emphysema. Our workers were a younger group still active in the industry, while the subjects in the study of Guyatt were retired and had considerable disability because of ventilatory function loss. Their ages varied from 56-69 years, while the present group of workers ranged in age from 31 to 51 with an average of 40 years. The normal values for DLCO and RV in our group suggest that they do not have a significant degree of emphysema, even though many of them had evidence of airway obstruction even in the absence of dust exposure. Further studies on the development of functional changes consistent with emphysema are therefore necessary, using both measurements of diffusing capacity and of lung static recoil curves. However, on the basis of the information now available it appears that emphysematous changes in the lungs of textile workers develop only after at least 20 to 30 years of exposure, as was the case with the workers studied (Guyatt et al., 1973).

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References


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