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Respiratory changes in two groups of flax workers with different exposure pattern[1]

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Zuskin, E., and Valić, F. (1973). *Thorax*, **28**, 579–583. **Respiratory changes in two groups of flax workers with different exposure pattern.** A high mean total concentration of flax particles (16·9 mg/m^3), of which about 20% were of respirable size, caused a high prevalence of byssinosis (69·9%) in 55 non-smoking female workers exposed to biologically retted flax over an average period of 11 years. A significant mean $FEV_{1\cdot0}$ decrease over the first work shift after the weekend break was recorded in both byssinotics and non-byssinotics but was more pronounced in the former. The mean acute $FEV_{1\cdot0}$ reductions over a work shift were smaller on the third than on the first day in the week.

Significant decreases in $FEV_{1\cdot0}$ and in maximum expiratory flow rate at 50% of vital capacity over the Monday work shift were recorded in a group of 17 seasonal male workers who had been exposed to flax for only two to three months each year for no more than three years.

A high prevalence of chronic cough, chronic sputum production, and chronic bronchitis was found in the female flax workers, especially among the byssinotics.

Carey *et al.* (1965) found that byssinotic flax workers in Northern Ireland had lower mean values for forced expiratory volume in one second ($FEV_{1\cdot0}$) and forced vital capacity (FVC) than comparable groups of non-byssinotic workers. A significant acute decrease of $FEV_{1\cdot0}$ was observed in flax workers on the first three days of the week by Carey and Merrett (1965). Elwood *et al.* (1966) reported in flax preparers a weak association between the dust exposure level and byssinosis, but not between dust exposure and chronic bronchitis. Mair, Smith, Wilson, and Lockhart (1960) found byssinosis of various grades in 30% of all workers in a flax mill. Chronic bronchitis, however, was no more prevalent among flax workers than among others. Elwood *et al.* (1965) found a marked association between byssinosis and chronic bronchitis in flax workers. Bouhuys, Hartogensis, and Korfage (1963) suggested that the agent in flax dust which causes symptoms of byssinosis originates during biological retting of flax and is absent from unretted flax. In a follow-up study, Elwood (1965) reported that the proportion of workers who had dyspnoea on exertion at the time of interview was significantly higher in those who had had byssinosis while in the mill than in those who had not. Recently, Velvart (1968, 1970) has reported flax byssinosis in textile workers in Czechoslovakia. Ferris, Anderson, and Burgess (1962), however, found no byssinosis among 161 flax-mill workers in the USA.

We now report the results obtained in a group of flax workers exposed to airborne dust of biologically retted flax in a mill which processes flax grown in the northern part of Yugoslavia. Flax is retted in concrete reservoirs containing water from a small river for about one week. The temperature of the water fluctuates between 26° and 30° C. The process of retting is carried out without adding any chemical or biological substances. After retting, the flax stem is allowed to dry for about three days. Dried flax stems are fed into turbine scutchers in which wooden stems are broken and removed from the lint fibres. Short fibres are then removed manually, so that only long, good quality fibres are used for further processing in the spinning mill. All the parts of the technological processes after retting are carried out in the same large workroom.

POPULATION AND METHODS

A group of 55 female workers were studied, all of them non-smokers. Seventeen seasonal young male workers were also studied, nine of them being smokers. The age range of the female workers was

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24 to 52 years (mean 36 years), and a duration of exposure to flax dust from 1 to 30 years (mean 11 years). The age range of the seasonal workers was 17 to 27 years (mean 19 years) with a duration of exposure to flax dust of two to three months per year for a period of two to three years.

RESPIRATORY SYMPTOMS Respiratory symptoms, smoking habits, and occupational histories were recorded using the British Medical Research Council questionnaire on chronic bronchitis supplemented by questions on byssinosis (Schilling *et al.*, 1964).

Chronic cough or phlegm: cough or phlegm production on most days for at least three months per year

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

Dyspnoea grade 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

Clinical grading of byssinosis was made according to Schilling *et al.* (1964):

Grade ½: occasional chest tightness on the first day of the working week;

Grade 1: chest tightness on every first day of the working week;

Grade 2: chest tightness on the first and other days of the working week;

Grade 3: grade 2 symptoms accompanied by reduced ventilatory capacity.

In addition, a functional grading of the effect of textile dust was used, as suggested by Bouhuys, Gilson, and Schilling (1970).

VENTILATORY FUNCTION TESTS In order to determine the acute effect of flax dust, the ventilatory function was measured in all the examined subjects by recording $FEV_{1\cdot0}$ and FVC before and after the work shift. The forced expirograms were obtained with Bernstein type spirometers. Three measurements were made and the mean of the two highest values was taken as the result of the test. $FEV_{1\cdot0}$ and FVC were corrected to BTPS.

In 17 seasonal male workers maximum expiratory flow volume (MEFV) curves were registered with a portable spirometer that records expiratory flow rate versus lung volume (Peters, Mead, and van Ganse, 1969), in addition to the measurements of FVC and $FEV_{1\cdot0}$. Three forced expirations were made into the instrument, and the mean of the two highest readings was used.

The maximum flow rate at 50% of the control vital capacity before the shift ($\dot{V}_{max}$ 50% VC) was calculated from the MEFV curves.

All measurements were performed before and after the work shift on the first working day of the week (Monday) after a break of exposure to flax dust of two days. The measurements were repeated on the following Wednesday, again before and after the work shift.

At the end of the shift, on the first working day of the week, a bronchodilator (Alupent[1]) was administered by inhalation to 24 byssinotics and five non-byssinotics by a pocket nebulizer immediately after the measurements of ventilatory capacity. Three doses, 750 μg each, were administered to each subject. Ventilatory capacity measurements were repeated 15–20 minutes after the orciprenaline administration.

The $FEV_{1\cdot0}$ values measured before the first working shift were compared with the expected $FEV_{1\cdot0}$ obtained from the nomogram for spirometric standards for normal females (Morris, Koski, and Johnson, 1971).

DUST MEASUREMENT Total and respirable airborne dust samples were collected by Hexhlet two-stage samplers with a horizontal laminal elutriator (Casella). Samples were taken in all the working places of the workers examined. As all the flax processing machines were located in one large hall, no significant difference was to be expected in the dust exposure of the workers.

STATISTICAL ANALYSIS The significance of the fall in $FEV_{1\cdot0}$ and $\dot{V}_{max}$ 50% VC registered over the work shift was tested by the *t* test method for paired variables. The results are considered significant when the probability of obtaining the results by chance alone is less than 0·05. For a comparison of preshift $FEV_{1\cdot0}$ values in different groups, the $FEV_{1\cdot0}$ was adjusted to a standard age and standard height using the multiple linear regression analysis. The significance of the difference in the prevalence of respiratory symptoms was tested by the χ^2 test.

RESULTS

DUST CONCENTRATIONS Twelve samples of airborne particles of all sizes and five samples of respirable size particles (<7 μ aerodynamic diameter) were collected. Both the total (16·9 mg/m³) and respirable (3·4 mg/m³) mean dust concentrations were very high.

RESPIRATORY SYMPTOMS In the group of female workers, 69·9% had clinical symptoms of byssinosis, of whom 21·2% were grade ½, 39·4% grade 1, 36·8% grade 2, and 2·6% grade 3.

The prevalence of chronic respiratory symptoms in subjects with and without byssinosis is presented in Table I. Workers with symptoms of byssinosis had a significantly higher prevalence ($P<0·05$) of chronic cough (52·6%), chronic phlegm (42·1%), and chronic bronchitis (39·4%) than those without byssinosis (17·6%, 11·8%, and 5·9% respectively). For dyspnoea (grades 3 and 4) and nasal catarrh these differences were not statistically significant ($P>0·05$).

[1] Orciprenaline: 1-(3,5-dihydroxyphenyl)-2-isopropylaminoethanol sulphate.

TABLE I

PREVALENCE OF CHRONIC RESPIRATORY SYMPTOMS

Group	N	Av. Age (yr)	Av. Exp. (yr)	Chronic Cough	Chronic Phlegm	Chronic Bronchitis	Dyspnoea Grade 3 or 4	Nasal Catarrh
With byssinosis	38	34	12	20 (52·6%)	16 (42·1%)	15 (39·4%)	8 (21·1%)	16 (42·1%)
				< 0·05	< 0·05	< 0·05	NS	NS
Without byssinosis	17	38	9	3 (17·6%)	2 (11·8%)	1 (5·9%)	1 (5·9%)	8 (47·1%)
Total	55	36	11	23 (41·8%)	18 (32·7%)	16 (29·1%)	9 (16·4%)	24 (43·6%)

NS = difference statistically not significant (P > 0·05) (χ^2 test)

TABLE II

MEAN $FEV_{1\cdot0}$ REDUCTIONS (ml) ON FIRST AND THIRD WORKING DAYS OF THE WEEK

Group	N	First Day: Before Shift 1	First Day: After Shift 2	First Day: Difference 1–2 ml	First Day: Difference 1–2 %	First Day: P	Third Day: Before Shift 1	Third Day: After Shift 2	Third Day: Difference 1–2 ml	Third Day: Difference 1–2 %	Third Day: P
With byssinosis	38	2,614 (2,584)[1]	2,334	−280	−10·7	< 0·01	2,513	2363	−155	−6·2	< 0·01
				< 0·05					NS		
Without byssinosis	17	2,548 (2,591)[1]	2,383	−165	−6·5	< 0·01	2,457	2317	−140	−5·7	< 0·01

[1] $FEV_{1\cdot0}$ values adjusted to age 36 years and height 162 cm.
NS = difference statistically not significant (P > 0·05).

Among 17 seasonal workers, 41·1% (seven, of whom two were smokers) had characteristic Monday symptoms. However, most of them complained of chest tightness, dry cough, and headache during the shifts with very high dust exposures regardless of the day of the week.

VENTILATORY FUNCTION A significant mean $FEV_{1\cdot0}$ decrease over a work shift was recorded ($P<0·01$) in all the examined workers on the first working day (Table II). The acute reductions were significantly greater ($P<0·05$) in byssinotics (10·7%) than in non-byssinotics (6·5%). In byssinotics the mean $FEV_{1\cdot0}$ reductions over a work shift were significantly smaller on the third than on the first day (Monday 280 ml, Wednesday 155 ml; $P<0·01$), while this difference was not statistically significant in non-byssinotics (Monday 165 ml, Wednesday 140 ml; $P>0·05$). On the third day there was no significant difference in the mean $FEV_{1\cdot0}$ reductions over a work shift between those with and without byssinosis ($P>0·05$).

Subjects with byssinosis and chronic bronchitis had a slightly greater mean acute Monday $FEV_{1\cdot0}$ reduction (12%) than those with byssinosis but without chronic bronchitis (10%).

Unexpectedly, the subjects with byssinosis had somewhat higher preshift $FEV_{1\cdot0}$ values than those without these symptoms. A more detailed analysis of their age and height distributions, however, showed that the subjects without byssinosis were older (28–52, mean 38 years) and shorter (150–165, mean 162 cm) than the byssinotics (24–50, mean 34 years; 156–174, mean 165 cm). To allow a comparison of $FEV_{1\cdot0}$ preshift values on Monday between byssinotics and non-byssinotics, the $FEV_{1\cdot0}$ data were adjusted to a standard age of 36 years and a standard height of 162 cm by multiple linear regression (regression equation of the type: $y=a+b\times\text{age}+c\times\text{height}$, where y is the value of the ventilatory function and ***a, b, c*** are the regression coefficients). As can be seen from Table II, the adjusted mean $FEV_{1\cdot0}$ before the shift on Monday in subjects with byssinosis is almost the same as the mean $FEV_{1\cdot0}$ in those without byssinosis (byssinotics 2,584 ml, non-byssinotics 2,591 ml).

Inhalation of orciprenaline at the end of the work shift in 24 byssinotics significantly increased their $FEV_{1\cdot0}$ values ($P<0·01$). Their mean acute $FEV_{1\cdot0}$ reduction over a shift was 287 ml (11%) while after bronchodilator administration it was only 77 ml (3%) in relation to the preshift value. However, their mean $FEV_{1\cdot0}$ after inhalation of the bronchodilator still remained significantly lower than the mean $FEV_{1\cdot0}$ before the work shift ($P<0·05$). In five non-byssinotics with a mean acute reduction in $FEV_{1\cdot0}$ of 178 ml, inhalation of orciprenaline increased the mean value after the shift slightly above that recorded before the shift (before the shift 2,724 ml; after inhalation of the bronchodilator after the shift 2,786 ml).

The distribution of functional grades of byssinosis in the female workers studied (based on FEV_1 measurements on Mondays) is presented in Table III. Analysis of the functional grade 2 and 3 cases (F2 and F3) in relation to clinical grades of byssinosis has shown that of two subjects in grade F3 ($FEV_{1\cdot0}$ less than 60% of the predicted value), only one gave a definite history of clinical symptoms of byssinosis. Out of six subjects in grade F2, four had clinical symptoms of byssinosis. According to the clinical grades, 69·9% workers had symptoms of byssinosis. This corresponds closely to the percentage of subjects with functional grades F1, F2, and F3 (61·8%). If the subjects with functional grade F1/2 are also considered as being affected by dust, then the percentage of workers with some respiratory difficulties rises to 92·7%.

The ventilatory function data of 17 seasonal workers are presented in Table IV. In the whole group there was a significant mean decrease in $FEV_{1\cdot0}$ (3·7%) and in $\dot{V}_{max}$ 50% VC (7·0%) over the first working shift in the week. Six of the workers showed no functional effects of dust exposure, four were in group F1/2, and seven in group F1.

TABLE III

FUNCTIONAL GRADES OF TEXTILE DUST EFFECTS

Grade	Δ $FEV_{1\cdot0}$ [1] (litres)	$FEV_{1\cdot0}$ [2] (% of predicted)	No. of Subjects N	%
F0	−0·05 to 0; or +	>80	4	7·3
F1/2	−0·06 to −0·20	>80	17	30·9
F1	> −0·20	>80	26	47·3
F2		60–79	6	10·9
F3		<60	2	3·6

[1] Difference between $FEV_{1\cdot0}$ before and after the work shift on first working day of the week (Monday)

[2] $FEV_{1\cdot0}$ in the absence of dust exposure (two days or longer)

TABLE IV

MEAN CHANGES IN VENTILATORY FUNCTION IN 17 SEASONAL WORKERS

Test	Before Shift 1	After Shift 2	Difference 1–2 ml	Difference 1–2 %	P 1–2
$FEV_{1\cdot0}$ (ml)	3,937	3,792	−145	−3·7	<0·01
$\dot{V}_{max}$ 50% VC (l/sec)	5·7	5·3	−0·4	−7·0	<0·01

DISCUSSION

Exposure to a comparatively high mean total flax particle concentration (16·9 mg/m³) with a fair proportion of respirable sizes (3·4 mg/m³ respirable particles) caused a high prevalence of byssinosis (69·9%) in the examined non-smoking female population. The prevalence is comparable to that reported by Bouhuys, van Duyn, and van Lennep (1961) and Velvart (1968) but considerably higher than that found by Mair *et al.* (1960). In contrast to these findings, Ferris *et al.* (1962) did not find a single case of byssinosis among their flax workers. As they did not indicate whether the flax to which the subjects were exposed was biologically or chemically retted, it is difficult to interpret their findings. The airborne flax particles in their mills seem to have been biologically inactive.

A significant mean $FEV_{1\cdot0}$ decrease ($P<0\cdot01$) over the first work shift after the weekend break was recorded in the present study in both byssinotics and non-byssinotics, significantly more pronounced in the former ($P<0\cdot05$). This is in agreement with our previous findings in hemp workers (Valić and Žuškin, 1971) and in cotton workers (Žuškin and Valić, 1972). The mean acute $FEV_{1\cdot0}$ reductions over a work shift in our flax workers were smaller on the third than on the first day, but still highly significant ($P<0\cdot01$). This is not in agreement with either the results of Bouhuys *et al.* (1961), who found a significant $FEV_{0\cdot75}$ decrease during work on Monday but not on Wednesday, or those of Velvart (1970), who found a higher $FEV_{1\cdot0}$ fall on Thursday than on Monday both in healthy flax workers and in flax byssinotics of stages I and II. Velvart's findings are difficult to explain if the histamine-releasing effect of flax dust is assumed to be similar to that proposed for the action of hemp (Bouhuys *et al.*, 1967), cotton (Bouhuys and Nicholls, 1967), and sisal dust (Nicholls, Evans, Valić, and Žuškin, 1973). If flax contains a histamine-liberating agent, then airways-constricting effects should be stronger on the first than on the third or fourth days of the week when the available lung tissue histamine content is already partially exhausted.

One woman, who complained of severe byssinotic symptoms after exposure to flax dust for less than one year, also showed a fall in $FEV_{1\cdot0}$ of more than 18% over a work shift on Monday. Practically all seasonal workers complained of chest tightness during exposure to high concentrations of flax dust and had a significant $FEV_{1\cdot0}$ and $\dot{V}_{max}$ 50% VC decrease over the Monday work shift after only two to three months' exposure per year for no more than three years. It is evident that flax byssinosis may develop after a relatively short exposure to flax dust.

In contrast to the findings of Velvart (1968, 1970), we found a high prevalence of chronic bronchitis, chronic cough, and chronic phlegm in our flax workers, especially among those with byssinosis.

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