

Respiratory response in simultaneous exposure to flax and hemp dust

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Žuškin, E., and Valić, F. (1973). *British Journal of Industrial Medicine*, 30, 375-380. **Respiratory response in simultaneous exposure to flax and hemp dust.** The effect of exposure to high concentrations of mixtures of hemp and flax dust was studied in 124 workers in two textile mills (mill A: 65-70% hemp and the rest flax, mean dust concentration 13.9 mg/m³; and mill B: about 35% hemp and the rest flax, mean dust concentration 15.8 mg/m³). A high prevalence of byssinosis was found in both mills (80% in mill B; 46.8% in mill A) after a mean exposure of no more than 13 years. In both mills, byssinotics had a higher prevalence of all chronic respiratory symptoms than non-byssinotics. This difference was more pronounced in mill A. Forty-eight percent of byssinotic women and 43% of byssinotic men had byssinosis of grade 2 or 3. Significant mean acute reductions in FEV_{1.0} and \dot{V}_{\max} 50% VC on Monday were recorded in subjects with and without byssinosis with a significantly larger mean reduction in byssinotics (FEV_{1.0}, $P < 0.01$; \dot{V}_{\max} 50% VC, $P < 0.05$). \dot{V}_{\max} 50% VC proved to be a more sensitive test for detecting acute effects of vegetable dust than FEV_{1.0}. The acute respiratory response of the subjects exposed to similar concentrations of flax and mixtures of two different proportions of flax and hemp dust was found to be equal.

It has already been reported that soft hemp and flax dust cause the development of byssinosis and other chronic respiratory symptoms accompanied by acute and chronic changes in ventilatory capacity (Bouhuys, Hartogensis, and Korfage, 1963; Carey and Merrett, 1965; Bouhuys *et al.*, 1967; Valić *et al.*, 1968). However, in only one paper have the effects of mixed exposure to hemp and flax dust on the respiratory function (Smith, Coles, Schilling, and Walford, 1969) been described. Acute respiratory response, however, was not studied in the paper. We are therefore reporting an investigation carried out in 124 workers exposed to mixed soft hemp and flax dust, comparing the results with those obtained in two previously studied groups of workers exposed to similar concentrations of pure hemp (Valić and Žuškin, 1971) and flax dust (Žuškin and Valić, 1973) respectively. The mills included in the study processed flax and/or hemp grown in the same area of Yugoslavia and pretreated in the same way.

Population and methods

Population

In mill A the workers examined were exposed to dust consisting of about 65-70% soft hemp (*Cannabis sativa*) and the rest was flax dust (*Linum usitatissimum*). In mill B, the workers were mostly exposed to flax dust (about 65%) and to a much lesser extent to hemp dust.

In mill A, workers from carding and spinning departments were included in the study. Machines were located in two freely interconnecting rooms. In mill B, all the examined subjects worked on turbine scutchers in one large room.

The study was conducted in 64 female nonsmoking textile workers in mill A, and in a group of 40 female nonsmokers and 20 male smokers in mill B. The groups examined represented 96% of the workers engaged in the carding and spinning departments in mill A and 95% of the workers in mill B. The mean age, height, and duration of exposure to hemp or flax dust are presented in Table 1.

Respiratory symptoms

Respiratory symptoms were recorded using the British

Medical Research Council questionnaire on respiratory symptoms with additional questions on byssinosis (Schilling *et al.*, 1963).

Chronic cough and/or phlegm: cough and/or phlegm production on most days for at least three months each year

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

Clinical grades of byssinosis:

grade $\frac{1}{2}$ —occasional chest tightness or difficulty in breathing at work on Mondays

grade 1—chest tightness and/or difficulty in breathing at work on every Monday

grade 2—chest tightness and/or difficulty in breathing during work on Mondays and other working days

grade 3—grade 2 accompanied by evidence of reduced ventilatory capacity

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.

A detailed occupational history was taken from each subject, and standing height and weight were measured in all workers.

Ventilatory function

The one-second forced expiratory volume (FEV_{1.0}) and maximum expiratory flow-volume (MEFV) curves were recorded before and after the work shift on the first working day of the week (Monday). FEV_{1.0} was measured on Bernstein type spirometers and corrected to BTPS. The average of the two highest FEV_{1.0} values among four blows was taken as the result of the test. MEFV curves were recorded with a portable spirometer (Peters, Mead, and van Ganse, 1969). From the flow-volume curves the maximum flow rate at 50% of the control vital capacity (\dot{V}_{\max} 50% VC), i.e., at 50% VC before the shift, was calculated. Out of the three MEFV curves obtained in each examinee the highest \dot{V}_{\max} 50% VC was taken as the result of the test.

In each worker a bronchodilator (orciprenaline¹) was administered at the end of the work shift to determine the degree of reversibility of the reduced ventilatory capacity. Each subject inhaled three doses of the aerosol from a pocket nebulizer (Dosier-Aerosol) delivering 750 μ g of active aerosol per puff. By applying three puffs and considering the aerosol penetration into the respiratory tract to be 70-75% (Zidek, 1963), the subject was exposed to a total dose of about 1.6 mg orciprenaline. Ventilatory capacity measurements were repeated 15 minutes after the inhalation.

The values of FEV_{1.0} before the shift were compared with the normal predicted values calculated by the regression equations of Morris, Koski, and Johnson (1971).

Dust measurement

Dust was sampled by means of Hexhlet two-stage samplers with a horizontal laminal elutriator to determine total and fine dust concentrations separately (Wright, 1954). A filter was used as the second stage of the sampler. Eighteen dust samples were taken in mill A

¹Alupent: 1-/3,5-dihydroxyphenyl-(2-isopropylaminoethanol sulphate).

and 14 in mill B. The periods of sampling were 1 to 3 hours.

Statistical analysis

The results of ventilatory function measurements were analysed by using the *t* test for differences of paired and unpaired variables. The χ^2 test was used for testing differences in the prevalence of respiratory symptoms. The results were considered significant when the probability of obtaining the results by chance alone was less than 0.05.

Results

Airborne dust concentrations

The dust concentrations in mills A and B were found to be similar. The mean total dust concentration in mill A was 13.9 mg/m³ (range 7.3-17.7 mg/m³) with the respirable fraction of 3.0 mg/m³ (range 0.5-5.9 mg/m³). In mill B, the mean total and respirable dust concentrations were somewhat higher, i.e., 15.8 mg/m³ (range 10.4-24.2 mg/m³) and 4.5 mg/m³ (range 4.3-6.3 mg/m³).

Respiratory symptoms

The prevalence of chronic respiratory symptoms in workers in both mills is presented in Table 1. In mill A, 46.8% of female workers suffered from byssinosis. In mill B, a significantly larger proportion of workers ($P < 0.01$) had clinical symptoms of byssinosis (80% for both men and women). The distribution of clinical grades of byssinosis is presented in Table 2. The byssinosis grades $\frac{1}{2}$ or 1 were found in workers with a different length of exposure to hemp and flax, varying from 1 to 28 years, while all the workers with grade 2 or 3 had been exposed to this type of dust for more than seven years.

In byssinotics of mill A, the prevalence of all the chronic respiratory symptoms (chronic cough 60.0%, chronic phlegm 40.0%, chronic bronchitis 33.3%, and dyspnoea grade 3 or 4 30.0%) was found to be significantly higher ($P < 0.01$) than in non-byssinotics (17.6%, 5.9%, 5.9%, 2.9% respectively). Six byssinotic women (20% of the byssinotic women in mill A) had dyspnoea grade 3, and three (10%) had grade 4. Among non-byssinotics only one woman (2.9%) was found in dyspnoea grade 3. The prevalence of nasal catarrh in these two groups was not significantly different.

In mill B, the women with byssinosis also had a higher prevalence of chronic respiratory symptoms than those without byssinosis, but the differences were not statistically significant ($P > 0.05$). The same was observed in men, the byssinotics having a considerably higher (but not statistically significant, $P > 0.05$) prevalence of chronic cough (56.3%), chronic phlegm (56.3%), chronic bronchitis (56.3%), and dyspnoea (18.7%) than those without byssinosis (25.0% for chronic cough, chronic phlegm, and chronic bronchitis and none with dyspnoea).

TABLE 1
PREVALENCE OF RESPIRATORY SYMPTOMS

Mill	Sex	Group	N	Mean age (yr)	Mean height (cm)	Mean exposure (yr)	Chronic cough		Chronic phlegm		Chronic bronchitis		Dyspnoea grades 3 or 4		Nasal catarrh	
							N	%	N	%	N	%	N	%	N	
A	F	With byssinosis	30 (46.8%)	38	159	13	18	60.0	12	40.0	10	33.3	9	30.0	11	36.7
		Without byssinosis	34	34	160	9	<0.01 6	17.6	<0.01 2	5.9	<0.05 2	5.9	<0.01 1	2.9	8	23.5
B	F	With byssinosis	32 (80.0%)	36	164	13	17	53.1	12	37.5	10	31.3	7	21.8	10	31.3
		Without byssinosis	8	37	159	9	NS 2	25.0	NS 2	25.0	NS 2	25.0	NS 1	12.5	2	25.0
	M	With byssinosis	16 (80.0%)	39	174	11	9	56.3	9	56.3	9	56.3	3	18.7	1	6.3
		Without byssinosis	4	33	171	8	NS 1	25.0	NS 1	25.0	NS 1	25.0	NS 0	0	1	25.0

NS = difference not significant ($P > 0.05$)

TABLE 2
CLINICAL GRADES OF BYSSINOSIS

Mill	Sex	Grade of byssinosis							
		½		1		2		3	
		N	%	N	%	N	%	N	%
A	F	3	10.0	13	43.3	10	33.3	4	13.3
B	F	2	6.3	14	43.8	15	46.8	1	3.1
	M	1	6.3	8	50.0	6	37.5	1	6.3

Pulmonary function

The mean forced expiratory volume in the first second (Table 3) decreased significantly during the first working day in all female workers and in male workers with byssinosis ($P < 0.01$). Because there were only four male workers without byssinosis the significance of their acute $FEV_{1.0}$ drop was not tested. The mean \dot{V}_{max} 50% VC (Table 4) was significantly decreased over the work shift in all female workers in mill A, and in male and female byssinotics in mill B ($P < 0.01$). The mean acute \dot{V}_{max} 50% VC reduction in eight female non-byssinotics in mill B was not significant ($P > 0.05$); in four male non-byssinotics the acute reductions in \dot{V}_{max} 50% VC were not tested because of the small number of workers. The mean reductions in both tests were significantly greater in female workers with byssinosis than in those without byssinosis ($P < 0.01$ for $FEV_{1.0}$; $P < 0.05$ for \dot{V}_{max} 50% VC). The difference in acute reductions in $FEV_{1.0}$ and \dot{V}_{max} 50% VC between male workers with and

without byssinosis was not tested, although the former had considerably larger acute reductions in both tests. A comparison of the mean acute reduction of \dot{V}_{max} 50% VC with the mean acute reduction of $FEV_{1.0}$ in female byssinotics showed that the relative change of \dot{V}_{max} 50% VC (mill A -27.3%; mill B -21.1%) was significantly greater than that of $FEV_{1.0}$ (-11.7%) ($P < 0.01$). In non-byssinotics these differences were significantly different in mill A only (\dot{V}_{max} 50% VC -13.9%; $FEV_{1.0}$ -5.4%; $P < 0.01$). Male byssinotics also had a significantly larger mean reduction in \dot{V}_{max} 50% VC (25.0%) than in $FEV_{1.0}$ (10.7%) ($P < 0.01$).

The application of the bronchodilator after the shift has shown that the acute reductions of ventilatory capacity are fully reversible in non-byssinotics (Tables 3 and 4). In byssinotic women, in spite of a significant increase of both $FEV_{1.0}$ and \dot{V}_{max} 50% VC after the inhalation of a bronchodilator ($P < 0.01$), the mean ventilatory capacity after the shift still remained significantly lower than

TABLE 3
MEAN FEV_{1.0} CHANGES ON FIRST WORKING DAY IN WEEK

Mill	Sex	Group	N	Before shift 1	After shift 2	Difference 1-2			After broncho-dilator 3	Difference 2-3	
						ml	%	P		P	P
A	F	With byssinosis	30	2 617 (2 727) ¹	2 310	307	11.7	<0.01	2 561	<0.01	<0.05
		Without byssinosis	34	2 895 (2 954) ¹	2 739	156	5.4	<0.01	2 890	<0.01	NS
B	F	With byssinosis	32	2 696 (2 691) ¹	2 379	317	11.7	<0.01	2 535	<0.01	<0.01
		Without byssinosis	8	2 571 (2 806) ¹	2 416	155	6.0	<0.01	2 528	<0.01	NS
	M	With byssinosis	16	3 175 (3 303) ¹	2 836	339	10.7	<0.01	3 050	<0.01	NS
		Without byssinosis	4	3 795 (3 782) ¹	3 695	100	2.6		3 855		

¹FEV_{1.0} values adjusted to standard age and height
NS = difference not significant (P > 0.05)

before the shift (mill A: P_{FEV} < 0.05, P_{V_{max}} < 0.01; mill B: P_{FEV} < 0.01, P_{V_{max}} < 0.05). In byssinotic men after the application of the bronchodilator the difference between the preshift and postinhalation values became statistically nonsignificant (P > 0.05), although some differences still remained.

In six women with symptoms of byssinosis in mill A, the FEV_{1.0} on Monday before work was less than 80% of their respective normal FEV_{1.0} calculated by the regression equation of Morris *et al.* (1971). Of these, three were found with the FEV_{1.0} less than 60% of the expected value. Only in one

TABLE 4
MEAN \dot{V}_{max} 50% VC CHANGES ON FIRST WORKING DAY IN WEEK

Mill	Sex	Group	N	Before shift 1	After shift 2	Difference 1-2			After broncho-dilator 3	Difference 2-3	
						l/sec	%	P		P	P
A	F	With byssinosis	30	3.3	2.4	0.9	27.3	<0.01	2.9	<0.01	<0.01
		Without byssinosis	34	3.6	3.1	0.5	13.9	<0.01	3.5	<0.01	NS
B	F	With byssinosis	32	3.8	3.0	0.8	21.0	<0.01	3.5	<0.01	<0.05
		Without byssinosis	8	4.2	3.9	0.3	7.1	NS	4.4	<0.05	NS
	M	With byssinosis	16	4.4	3.3	1.1	25.0	<0.01	4.1	<0.01	NS
		Without byssinosis	4	5.4	5.2	0.2	3.7		6.1		

NS = difference not significant (P > 0.05)

woman without byssinosis was the FEV_{1.0} less than 80% of the expected value. In mill B among female workers with symptoms of byssinosis, seven were found with the Monday preshift FEV_{1.0} less than 80% of the normal FEV_{1.0}. In four of these women the FEV_{1.0} was less than 60% of the expected FEV_{1.0}. Among non-byssinotics in mill B, only in one woman was the preshift FEV_{1.0} less than 80% of the expected value. In five male byssinotics the preshift FEV_{1.0} was less than 70% of the normal FEV_{1.0}. Among four men without byssinosis, none was found with the FEV_{1.0} less than 80% of the expected value.

In order to find out whether there is a difference in chronic effects on the ventilatory capacity between byssinotics and non-byssinotics their mean preshift FEV_{1.0} values (before the superimposed acute effect of dust over the shift) were compared. As the height and age distributions of the workers in these two groups were not identical, it was considered unjustifiable directly to compare their mean preshift FEV_{1.0} values. All the preshift FEV_{1.0} data of the female workers were therefore adjusted to a standard age of 36 years and a standard height of 162 cm, and those of the male examinees to a standard age of 36 years and a standard height of 172 cm, using a multiple linear regression equation of the type $y = a + b \times \text{age} + c \times \text{height}$ ($y = \text{FEV}_{1.0}$; a, b, c - regression coefficients). The adjusted means are shown in Table 3 in parentheses. The mean adjusted Monday preshift values were found to be significantly lower ($P < 0.05$) in byssinotics than in non-byssinotics in the examined group of women in mill A. In mill B, this difference was not statistically significant ($P > 0.05$). The men with byssinosis had a considerably lower adjusted mean preshift FEV_{1.0} (3 303 ml) than those without byssinosis (3 782 ml) but this difference was not tested for significance because of the small number of non-byssinotic workers.

There was no difference in the mean acute FEV_{1.0} reduction over the shift between byssinotic female workers with or without chronic bronchitis in mill A (13.1 and 12.8% respectively), while female byssinotics with chronic bronchitis had slightly larger FEV_{1.0} reductions (11.9%) than those without chronic bronchitis (9.7%) in mill B. Male byssinotics with chronic bronchitis, however, had a considerably larger mean FEV_{1.0} reduction (13.5%) than those without chronic bronchitis (6.9%).

Discussion

In contrast to the findings of Smith *et al.* (1969), who reported only six cases of byssinosis in their group of 54 men and 22 women exposed to mixed soft hemp and flax dust (byssinosis prevalence 7.9%), we have found a byssinosis prevalence of 45.8% and

80% respectively in the two plants studied, in spite of a shorter duration of total exposure to dust in our groups. The mean duration of dust exposure in our group was 11 years for men and 13 years for women while the byssinotic subjects reported by Smith *et al.* (1969) had long exposures ranging from 16 to 44 years (except for one with two years' exposure only). Such a substantial difference in the findings is undoubtedly due primarily to a great difference of exposure levels. The average airborne dust concentrations of 13.9 and 15.8 mg/m³ respectively in the workrooms we studied were 8 to 10 times as high as the average concentration in the dustier parts of the English factory described by Smith *et al.* (1969). Under such a heavy exposure to an active vegetable dust a high prevalence of byssinosis was to be expected. The distribution of clinical grades of byssinosis of our cases (Table 2) gives an insight into the severity of the disease. Over 48% of byssinotic women and over 43% of byssinotic men had byssinosis grades 2 or 3. All had been exposed to dust for more than seven years.

The prevalence of chronic respiratory symptoms (chronic cough, chronic phlegm, chronic bronchitis, dyspnoea grades 3 or 4) was considerably higher in subjects with than in those without byssinosis (Table 1), indicating an association between the development of byssinosis and a nonspecific respiratory impairment in mixed hemp and flax exposure.

Exposure to mixed soft hemp and flax dust causes a significant acute reduction of ventilatory capacity over the shift which is considerably more pronounced in subjects with byssinosis (Tables 3 and 4). \dot{V}_{max} 50% VC proved to be a significantly more sensitive test of this reduction than FEV_{1.0}, indicating that the effect of the inhaled mixed hemp and flax dust is more pronounced in small airways.

In order to evaluate the relative effects of soft hemp, flax, and mixed hemp and flax on ventilatory capacity we have compared the acute FEV_{1.0} drops over the shift measured in four groups of nonsmoking female workers exposed to similar concentrations of hemp dust, flax dust, mixed hemp and flax dust containing approximately 65-70% hemp, and mixed hemp and flax dust with approximately 35% hemp, respectively. The mean total exposures to dust in the four groups were almost identical. The number of workers, mean total and respirable dust concentrations, mean lengths of exposure to dust, and the acute mean falls of FEV_{1.0} over the shift are presented in Table 5. Hemp and flax used in the plants with flax and mixed hemp and flax exposures were grown in the same area in northern Yugoslavia in the same season (1970-71) while hemp in the plant with pure hemp exposure was grown in the same area but in 1967-68.

The acute respiratory response of the subjects exposed to similar concentrations of flax and mixtures

TABLE 5
MEAN DUST CONCENTRATIONS AND ACUTE FEV_{1.0} REDUCTIONS IN FEMALE WORKERS EXPOSED TO HEMP FLAX, AND MIXED HEMP AND FLAX DUST

Exposure group	N	Mean dust concentration (mg/m ³)		Mean exposure (yr)	ΔFEV _{1.0}	
		Total	Respirable		ml	%
Mixed A (65-70% hemp)	64	13.9	3.0	11	-234	- 8.5
Mixed B (65% flax)	40	15.8	4.5	12	-253	- 9.5
Hemp ¹	102	16.2	1.8	10	-425	-15.4
Flax ²	55	16.9	3.4	11	-234	- 9.0

¹Valič and Žuškin (1971)

²Žuškin and Valič (1973).

of flax and hemp in two different proportions (roughly 1:2 and 2:1) was found to be practically identical (8.5-9.5% FEV_{1.0} fall over the shift). The acute response to pure hemp exposure was much greater (FEV_{1.0} fall 15.4%) but it would be unjustifiable to compare this effect with the effects of other exposures as the hemp grown in 1967-68 might have been pharmacologically more potent and might therefore have caused a more intense histamine liberation from lung tissue and, consequently, a stronger smooth muscle contraction and a subsequently higher reduction of ventilatory capacity.

Slightly in contrast to our previous results (Valič and Žuškin, 1972), the smooth muscle contracting potency (possibly direct and indirect through histamine release) of our 1970-71 hemp and flax was practically equal, while that of the 1967-68 hemp seems to have been considerably stronger. Experiments are in progress to verify this hypothesis pharmacologically (on smooth muscle preparations) and biochemically (histamine release determination). At the moment the hypothesis is based on indirect evidence obtained from a comparison of the relative acute respiratory responses of workers exposed to the respective dust.

There is no doubt that exposure to a high concentration of mixed hemp and flax dust represents an occupational health hazard equal to that produced by exposure to pure active hemp or flax dust. Exposure causes the development of byssinosis in a considerable proportion of workers and may eventually lead to the development of chronic respiratory impairment.

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