Lung function in textile workers

EUGENIJA ŽUŠKIN¹, F. VALIĆ¹, D. BUTKOVIĆ¹, and A. BOUHUYS²

Andrija Štampar School of Public Health, Zagreb University, Zagreb, Yugoslavia¹, and Yale University Lung Research Center, New Haven, Connecticut USA²

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 ($DL_{CO}SB$) 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 FEV_{1.0} 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 FEV_{1.0} and FVC were decreased, $DL_{CO}SB$ 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 FEV_{1.0} in detecting acute ventilatory changes caused by the dust extract.

Most epidemiological studies of byssinosis have used a questionnaire interview and relatively simple function tests in order to detect symptoms and signs of airway obstruction in workers exposed to textile dusts. A few studies have included more complex tests, such as nitrogen washout curves (Bouhuys *et al.*, 1961), plethysmographic measurements of airway resistance (Bouhuys and Van de Woestijne, 1970) and static recoil curves of the lungs (Guyatt *et al.*, 1973). Recently, Lopez-Merino *et al.* (1973) demonstrated that acute exposure to hemp dust decreases the arterial oxygen tension. The present study provides further data on the acute changes of lung volumes, the one-second forced expiratory volume (FEV_{1.0}), and maximum expiratory flow-volume (MEFV) curves during dust exposure. In addition, diffusing capacity measurements were made in order to document any changes in the gas-exchanging function of the lungs in the absence of dust exposure. Lastly, we compared the sensitivity of different tests of airway obstruction in laboratory subjects exposed to hemp-dust extracts.

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

TABLE 1
PREVALENCE OF BYSSINOSIS AND OF CHRONIC RESPIRATORY SYMPTOMS IN TEXTILE WORKERS

Group	Sex	Age (yr)	Exposure (yr)	No.	Byssinosis grades 0 1/2 1 2 %	Chronic cough %	Chronic phlegm %	Chronic bronchitis %	Dyspnoea grade 3 or 4 %
Hemp	Female	40 (29-51)	16 (2-28)	14	21 0 36 43	79	57	50	64
Flax	Female	39 (30-53)	14 (2-24)	24	4 4 42 50	54	42	38	33
Cotton	Male	41 (32-54)	16 (1-31)	15	13 7 33 47	73	53	47	27
	Female	41 (34-49)	18 (2-27)	8	0 25 63 12	63	38	38	13

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 spiogram recorded with a spirometer (Godart Pulmonet), the forced vital capacity (FVC) and the FEV_{1.0} were obtained and the ratio FEV_{1.0}/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 spiograms 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_{He}) 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. Thus, 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 re-breathing period. Lung volumes were corrected to BTPS.

The single-breath pulmonary diffusing capacity for CO (DL_{CO}SB) 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). DL_{CO}SB 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 DL_{CO}SB 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 DL_{CO}SB were calculated using the equations of Cotes (1973). FVC and FEV_{1.0} 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, volume-displacement 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, MEFV 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 $FEV_{1.0}$ 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. $DL_{CO}SB$ 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 $FEV_{1.0}$ 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 $FEV_{1.0}$ and increased RV, the data for $DL_{CO}SB$ were within normal values. The group of workers tested for $DL_{CO}SB$ 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 $DL_{CO}SB$ in comparison with predicted values (80.8 and 88.8% of normal). Neither of them had Monday symptoms. The preshift $FEV_{1.0}$ 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 $FEV_{1.0}$ values before dust exposure. Workers without byssinosis symptoms or with grade 1/2 had, on the average, a normal $FEV_{1.0}$ (106 and 102% of expected), while those with grade 1 and, in particular, those with grade 2 byssinosis had lower average values of $FEV_{1.0}$ (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). $FEV_{1.0}$ decreased significantly in all groups; FVC decreased only slightly and this decrease was not significant in three out of four groups. The $FEV_{1.0}/FVC$ 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 PRESIFT $FEV_{1.0} < 70\%$ OF EXPECTED

Group	Sex	No.	$DL_{CO}SB$		$FEV_{1.0}$		FVC		RV		TLC_{He}	
			Actual ± SD	% of expected	Actual ± SD	% of expected	Actual ± SD	% of expected	Actual ± SD	% of expected	Actual ± SD	% of expected
Hemp	Female	9	23.52 ± 3.80	108.9	2.30 ± 0.73	85.4	3.00 ± 0.53	91.8	1.73 ± 0.41	128.1	4.73 ± 0.36	110.7
Flax	Female	11	25.63 ± 4.60	108.9	2.43 ± 0.51	83.9	3.46 ± 0.61	96.9	1.69 ± 0.73	108.6	5.15 ± 0.78	104.0
Cotton	Male	7	29.45 ± 4.80	101.9	2.61 ± 0.32	74.2	3.75 ± 0.42	82.5	2.61 ± 0.75	136.5	6.36 ± 1.26	103.1
	Female	3	23.01 ± 5.10	103.0	2.24 ± 0.46	87.3	2.68 ± 0.42	93.2	1.62 ± 0.74	119.5	4.30 ± 0.97	98.2
$FEV_{1.0} < 70\%$ of expected		7*	28.09 ± 4.73	107.4	1.96 ± 0.50	61.9	3.23 ± 0.96	79.6	2.54 ± 0.68	151.1	5.77 ± 1.54	107.7

No. = number in each group; * = four males and three females

$DL_{CO}SB$ 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

Mill	Sex	No.	FEV _{1.0}			FVC			FEV _{1.0} /FVC %			RV		
			Before shift ± SE	ΔFEV _{1.0} % P		Before shift ± SE	ΔFVC % P		Before shift ± SE	FEV _{1.0} /FVC % P		Before shift ± SE	ΔRV % P	
Hemp	Female	14	2.44 ±0.67	-17 % <0.01		3.06 ±0.20	-6 % NS		79.9 ±3.4	-12 % <0.01		1.66 ±0.10	+18 % <0.01	
Flax	Female	24	2.53 ±0.11	-9 % <0.01		3.28 ±0.13	-2 % NS		77.1 ±2.4	-7 % <0.05		1.77 ±0.14	+8 % <0.025	
Cotton	Male	15	2.98 ±0.17	-14 % <0.01		3.92 ±0.25	-7 % <0.025		75.9 ±5.0	-7 % NS		2.46 ±0.30	+18 % <0.025	
	Female	8	2.47 ±0.19	-10 % <0.025		3.00 ±0.28	-4 % NS		82.5 ±5.3	-6 % NS		1.62 ±0.28	+18 % NS	

Data before shift for FEV_{1.0}, FVC, and RV are shown in litres

TABLE 3B
MEAN ACUTE CHANGES IN FRC, TLC_{H_e}, RV/LC %, AND MEF50 % OVER WORK SHIFT
ON MONDAY

Mill	Sex	No.	FRC			TLC _{H_e}			RV/TLC %			MEF50 %		
			Before shift ± SE	ΔFRC % P		Before shift ± SE	ΔTLC % P		Before shift ± SE	ΔRV/TLC % P		Before shift ± SE	ΔMEF50 % % P	
Hemp	Female	14	2.58 ±0.12	+10 % <0.05		4.72 ±0.43	+2 % NS		35.16 ±3.16	+15 % <0.025		2.45 ±0.28	-38 % <0.01	
Flax	Female	24	2.75 ±0.17	+3 % NS		5.05 ±0.16	+2 % NS		34.97 ±2.15	+6 % <0.01		3.85 ±0.23	-22 % <0.01	
Cotton	Male	15	3.87 ±0.28	+6 % NS		6.38 ±0.40	+2 % NS		38.55 ±2.84	+15 % <0.01		3.61 ±0.37	-23 % <0.01	
	Female	8	2.63 ±0.23	0 % NS		4.62 ±0.29	+3 % NS		35.10 ±5.10	+14 % NS		3.76 ±0.38	-25 % 0.025	

Data before shift for FRC and TLC_{H_e} 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

Sex	No.	Δ RV (% of increase)			Δ FEV _{1.0} (% of decrease)			Δ MEF 50% (% of decrease)		
		10	20	30	10	20	30	10	20	30
F	38									
M	3									
	12									

FIG. 1. Mean acute changes in residual volume (RV), in one-second forced expiratory volume (FEV_{1.0}) 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 FEV_{1.0} and MEF50% as percentage decrease of preshift values.

FIG. 2. Mean acute changes in total lung capacity (TLC), RV, FEV_{1.0}, and MEF50% in six volunteers after hemp-dust extract exposure over a period of one hour.

dusts than measurements of FEV_{1.0}. 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 DL_{CO}SB 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).

This investigation was supported in part by Public Health Service Grant PL 480 Project 02-006-3 from the Bureau of Occupational Safety and Health, US Department of Health, Education and Welfare, and Grant No. OH-00304, National Institute for Occupational Safety and Health, Public Health Service, Department of Health, Education and Welfare.

References

- Bouhuys, A., Hunt, V. R., Kim, B. M., and Zapletal, A. (1969). Maximum expiratory flow rates in induced bronchoconstriction in man. *Journal of Clinical Investigation*, **48**, 1159-1168.
- , Lichtneckert, S., Lundgren, C., and Lundin, G. (1961). Voluntary changes in breathing pattern and N₂ clearance from lungs. *Journal of Applied Physiology*, **16**, 1039-1042.
- , Mitchell, C. A., Schilling, R. S. F., and Žuškin, E. (1973). A physiological study of byssinosis in colonial America. *Transactions of the New York Academy of Sciences*, **35**, 537-546.
- and Van de Woestijne, K. P. (1970). Respiratory mechanics and dust exposure in byssinosis. *Journal of Clinical Investigation*, **49**, 106-118.
- Cotes, J. E. (1973). *Lung function*. Davis, Philadelphia.
- Goldman, H. I. and Becklake, M. R. (1959). Respiratory function tests: normal values at median altitudes and the prediction of normal results. *American Review of Tuberculosis*, **79**, 457-467.
- Guyatt, A. R., Douglas, J. S., Žuškin, E., and Bouhuys, A. (1973). Lung static recoil and airway obstruction in hemp workers with byssinosis. *American Review of Respiratory Diseases*, **108**, 1111-1115.
- Hathirat, S., Renzetti, A. D., and Mitchell, M. (1970). Measurement of the total lung capacity by helium dilution in a constant volume system. *American Review of Respiratory Diseases*, **102**, 760-770.

- Kory, R. C., Callahan, R., Boren, H. G., Syner, J. C. (1961). Clinical spirometry in normal men. *American Journal of Medicine*, **30**, 243–258.
- Lopez-Merino, V., Llopis Lombart, R., Flores Marco, R., Barbero Carnicero, A., Gomez Guillen, F., and Bouhuys, A. (1973). Arterial blood tensions and lung function during acute responses to hemp dust. *American Review of Respiratory Diseases*, **107**, 809–815.
- Medical Research Council Committee on the Aetiology of Chronic Bronchitis (1960). *British Medical Journal*, **2**, 1665.
- Peters, J. M., Mead, J., and Van Ganse, W. F. (1969). A simple flow-volume device for measuring ventilatory function in the field. *American Review of Respiratory Diseases*, **99**, 617–622.
- Schilling, R. S. F., Vigliani, E. C., Lammers, B., Valić, F., and Gilson, J. C. (1963). A report on a conference on byssinosis. *Proceedings of the 14th International Congress on Occupational Health, Madrid*, 137–145.
- Valić, F. and Žuškin, E. (1973). Pharmacological prevention of acute ventilatory capacity reduction in flax dust exposure. *British Journal of Industrial Medicine*, **30**, 381–384.
- Virgulto, J. and Bouhuys, A. (1973). Electronic circuits for recording of maximum expiratory flow-volume (MEFV) curves. *Journal of Applied Physiology*, **35**, 145–147.
- Žuškin, E. and Valić, F. (1973). Respiratory response in simultaneous exposure to flax and hemp dust. *British Journal of Industrial Medicine*, **30**, 375–380.

Paper received for publication 17 March 1975

Paper accepted for publication 12 May 1975