

Lung Static Recoil and Airway Obstruction in Hemp Workers with Byssinosis^{1, 2}

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SUMMARY

Quasistatic lung static recoil curves and maximal expiratory flow-volume curves were measured in 23 hemp workers 56 to 69 years of age. Their vital capacities and 1-second forced expiratory volumes were significantly less than predicted (88.6 and 67.6 per cent, respectively), and all had dyspnea on effort to varying degrees. The 1-second forced expiratory volume did not correlate significantly with recoil pressure at total lung capacity, but the maximal expiratory flow at 50 per cent of vital capacity did. In this group, static recoil at total lung capacity correlated not with age but with the severity of disease as expressed in decreased values of maximal expiratory flow at 50 per cent of vital capacity. The data suggested that loss of elastic recoil contributed to the decrease of maximal expiratory flows in hemp workers who had been exposed to dust for many years and suggested that loss of parenchymal structure of the lungs occurs in the chronic stages of byssinosis of textile workers.

Introduction

The pathologic features of the lungs in the chronic stages of byssinosis have been studied only sporadically (1) because adequate correlative studies of physiologic and pathologic changes in this disease are difficult to implement. It was decided to measure the quasistatic lung recoil pressure in a group of

hemp workers, members of a population characterized physiologically in earlier studies (2-5), to obtain an indication of the elastic properties of their lungs.

Workers exposed to dust during processing of soft hemp fibers (*Cannabis sativa*) often suffer from byssinosis (2), and many of them become prematurely disabled with ventilatory insufficiency (3). Dust exposure in these workers induces reductions in maximal expiratory flows (2, 4). Maximal expiratory flows are determined by (1) the caliber of small airways, and (2) the elastic recoil pressure of the lungs (6). The acute reduction of flows on exposure to hemp dust is probably due to a reversible decrease in small airway caliber, because this response can be reversed by bronchodilator drugs (2, 4) and is not accompanied by changes in lung static recoil (4). In long-term workers with permanent ventilatory insufficiency, however, maximal expiratory flows are irreversibly decreased. This could be due to irreversible ob-

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TABLE 1
PHYSICAL CHARACTERISTICS AND LUNG FUNCTION
OF HEMP WORKERS, 1970

Characteristic	Mean	SD	Range
Age, years	63.6	4.1	56-59
Height, cm	164.0	6.3	152-173
VC, liter*	3.15	0.69	1.9-4.5
VC, % pred†	88.6	18.3	56-122
FEV ₁ , liter*	1.74	0.66	0.8-3.0
FEV ₁ , % pred†	67.6	24.1	30-107
ΔFEV ₁ , 1967 to 1970, liter**	-0.17	0.28	-0.77-+0.37
ΔFEV ₁ , after isoproterenol, liter**	+0.10	0.12	-0.10-+0.35
Duration of retirement, years	7.3	4.3	0-16

*All volumes corrected to conditions of body temperature and pressure saturated with water (BTPS).

†Predicted values from Cotes (8).

**Difference between measurements in 1967 and 1970, and before and after isoproterenol in 1970, respectively. Negative sign indicates FEV₁ in 1970 lower than in 1967, or FEV₁ lower after isoproterenol.

struction of small airways, to loss of lung elastic recoil pressure, or to a combination of the 2.

In the present study, quasistatic measurements of the elastic properties of the lungs were made in older hemp workers to determine whether loss of elastic recoil in the lungs was an important factor in reducing their maximal expiratory flows. The circumstances of the field study in Spain, although permitting the examination of hemp workers, limited the extent of the measurements primarily because of difficulty in training the subjects in complex respiratory maneuvers. To overcome this limitation, a quasistatic method of recording elastic recoil curves was used that provided a reasonably close approximation of the true elastic lung recoil curve (7).

Materials and Methods

The subjects were selected from a large group of active and retired hemp workers in Callosa de Segura, a population first studied in 1967 (3). The selection criteria were age of 50 to 70 years, 1-second forced expiratory volume (FEV₁) between 1.0 and 3.1 liter in 1967, and willingness to participate. Twenty-three men fulfilled all criteria; their physical characteristics and lung function are summarized in table 1, and their histories of dyspnea and smoking habits, in table 2. The experiments were done in the summer of 1970.

In a preliminary session with all subjects, a questionnaire on respiratory symptoms was administered and the FEV₁ was measured, both before and after administration of a metered dose of an isoproterenol aerosol (2, 3). A few days later, maximal expiratory flow-volume (MEFV) curves and the quasistatic expiratory compliance

TABLE 2
HISTORY OF DYSPNEA AND SMOKING HABITS, 1970

Dyspnea grade*	1	2	3	4	5
N†	0	7	6	5	5
Smoking habits**	non	ex	1-15/day	16+/day	
N†	6	3	9	5	

*Grade 1 = no dyspnea on effort; grades 2 to 5 = increasing effort dyspnea; grade 5 = dyspnea at rest or with minimal exercise, based on answers to standard questionnaire.

†N = number of subjects in each category.

**Nonsmokers, ex-smokers, and current smokers of 1 to 15 and of 16 or more cigarettes per day, respectively.

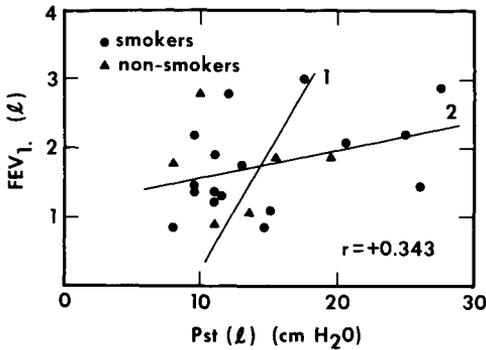


Fig. 1. One-second forced expiratory volume (FEV_1), as a function of static recoil pressure $Pst(1)$, at total lung capacity in hemp workers. For this and the other figures, the statistical analysis was for nonsmokers and smokers together. The correlation coefficient was not significant. 1 and 2 indicate the regression equations: (1) $y = 9.241 + 2.913x$; (2) $y = 1.173 + 0.039x$.

curve were recorded. To obtain these curves, expiratory volumes were recorded, using a transducer linked to a spirometer; expiratory flows were obtained with a Fleisch No. 3 pneumotachygraph and a Satham PM15 pressure transducer; esophageal pressure was measured with a balloon introduced 38 to 42 cm into the esophagus and a Satham PM6 pressure transducer, using the technique of Milic-Emili and associates (9). All signals were displayed on a storage oscilloscope and photographed with a Polaroid camera. The procedure for recording MEFV curves consisted of 3 successive forced expiratory maneuvers preceded by maximal inspirations to total lung capacity (TLC). Vital capacity (VC) was taken as the largest volume observed on the 3 curves, and maximal expiratory flows were measured from the curve with the highest flows. Flow was measured at a volume equal to 50 per cent of the VC, i.e., TLC -50 per cent ($\dot{V}_{max 50}$). Before each quasistatic recoil curve was recorded, the subject made 3 VC maneuvers and was then instructed to breathe out slowly from TLC at a rate of approximately 0.3 liter per sec. Transpulmonary pressures [$Pst(1)$], were measured at the point of maximal inspiration and compliance [$Cst(1)$] was estimated as the slope of the quasistatic pressure-volume curve over the tidal volume range. Five separate determinations of the quasistatic recoil curve were made, and the highest values of $Pst(1)$ observed were measured. Duplicate readings of $Pst(1)$, made independently by another observer, did not differ by more than 1 cm H₂O from the values presented herein.

Results

This group of subjects included many persons with severe obstructive lung disease. Nearly all of them had a previous history of regular chest tightness on Mondays while working in hemp dust (byssinosis). The average VC and FEV_1 were significantly less than predicted ($P < 0.01$ and < 0.001 , respectively) (table 1). In most subjects, isoproterenol produced little improvement in FEV_1 (table 1). The mean decrement of FEV_1 during the 3-year period 1967 to 1970 was at least twice that expected for healthy persons in this age group. All but 2 of the men had retired from the hemp industry and thus had had no recent dust exposure. All subjects admitted to dyspnea, and 10 men, mostly older (average age: 66 years), had severe shortness of breath during very light work or at rest.

Many of the subjects with low FEV_1 values also had low static recoil pressures at TLC (figure 1), although in the whole group, there was only a weak correlation ($r = +0.343$) between these 2 values. Compliance over the tidal volume range was clearly related neither to the value of the FEV_1 nor to other parameters of the forced expiratory maneuvers, so that these data are not presented in detail. The $Pst(1)$ at TLC showed a more significant correlation with $\dot{V}_{max 50}$ ($r = +0.448$) (figure 2) than with FEV_1 .

There was a close correlation between FEV_1 and $\dot{V}_{max 50}$ ($r = +0.830$) (figure 3). In addition, these measurements of forced expiratory flows showed a positive correlation with the duration of the workers' retirement from the hemp industry. Thus, length of retirement correlated significantly with FEV_1 and $\dot{V}_{max 50}$ ($P < 0.01$) and with $Pst(1)$ at just above the 5 per cent level. For age, on the other hand, the only significant correlation was with the FEV_1 .

Smoking habits varied widely in this small group of subjects; a separate analysis of its role was not feasible because of the small number in each subgroup. The 6 nonsmokers did not differ clearly from the others with regard to the relationship between flow and recoil pressure (figures 1 to 3). The heavy smokers had relatively high values of FEV_1

and $\dot{V}_{\max 50}$. Smoking habits correlated neither with grade of dyspnea nor with the duration of retirement.

Discussion

In healthy men, the static recoil of the lungs decreases with age (10), as do maximal expiratory flows (11). In the present group of subjects, static recoil was not related to age, but correlated significantly with $\dot{V}_{\max 50}$. Thus, it appeared that the expected effect of age on static recoil was obscured by the high prevalence of lung disease associated with a decrease in maximal expiratory flows.

The measurement of static recoil of the lung involves many sources of technical errors (9) and discriminates poorly between normal and diseased persons (12). Nevertheless, the measurement of Pst(1) at TLC has proved valuable in distinguishing subjects with and without emphysema (13). Most of the hemp workers had abnormally low values for Pst(1) at TLC suggesting a loss in elastic recoil.

The positive correlation between $\dot{V}_{\max 50}$ measured from MEFV curves, and Pst(1) at full inspiration (figure 2) suggested that loss

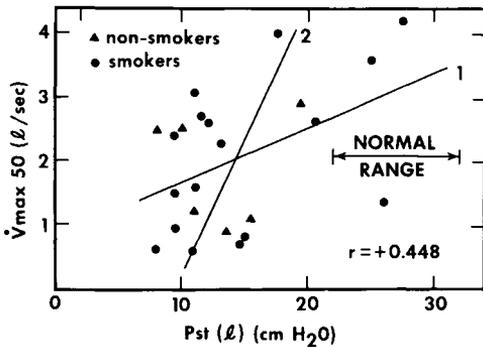


Fig. 2. Maximal flow at 50 per cent of vital capacity ($\dot{V}_{\max 50}$) measured from maximal expiratory flow-volume curves, as a function of static recoil pressure Pst(1), at total lung capacity in hemp workers. The normal range of Pst(1) values for a group of 6 healthy, older subjects (53 to 61 years of age) was obtained from Turner and co-workers (10). The correlation coefficient was significant at $P < 0.05$. Regression equations: (1) $y = 0.796 + 0.086x$; (2) $x = 9.599 + 2.333y$.

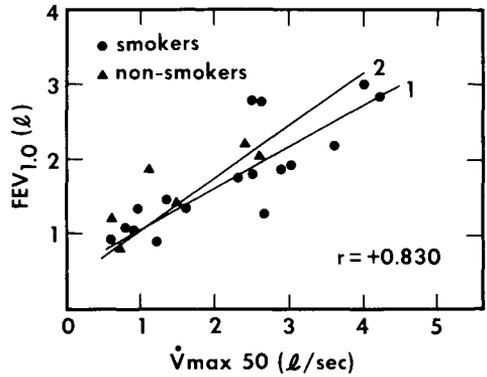


Fig. 3. Relationship between 1-second forced expiratory volume (FEV₁) and maximal flow at 50 per cent of vital capacity ($\dot{V}_{\max 50}$) in hemp workers. The correlation coefficient was significant ($P < 0.01$). Regression equations (1) $y = 0.730 + 0.498x$, and (2) $x = -0.379 + 1.3842y$.

of elastic recoil was one factor contributing to the decrease of maximal expiratory flows in these subjects. Nevertheless, maximal flows vary widely among men with similar, low values of Pst(1), perhaps because of variations in the patency of peripheral airways. The same relation exists between FEV₁ and Pst(1) at full inspiration (figure 1). This correlation was, however, weaker, probably because the FEV₁ value was influenced by the effort-dependent peak flow ($\dot{V}_{\max 50}$ was measured on the effort-independent part of the MEFV curve).

In a group of older men, selection biases must always be suspected. These men, who worked in an atmosphere with noxious dust for many years, constituted a survivor population. The heavy smokers among them had relatively well preserved flows. A more detailed analysis of the smoking habits of the total population of hemp workers in this age group suggested that the smoking habits of these men were highly influenced by their response to hemp dust; men who suffered severe functional loss as a consequence of dust exposure stopped smoking (5). The present data, obtained in a portion of that population, reflected the same observation. Duration of retirement had not been previously analyzed. In part, the correlation between lung function and time since retirement was

probably due to continued deterioration of the subjects after cessation of dust exposure. In the total group of older hemp workers seen in 1967 and 1970, the decrease in FEV₁ was significantly larger than that among control subjects with similar initial FEV₁ values.³ It is also likely that the men who were most severely affected by dust ceased working with hemp earlier and had been retired longer when studied.

The study of the total population (3) indicated that older hemp workers had a high prevalence of severe, irreversible airway obstruction that could be attributed to long-term exposure to hemp dust. The present study showed that airway obstruction in these men, as measured by the FEV₁ and by $\dot{V}_{\max 50}$ was correlated with the Pst(1). Thus, the reduction in flows observed in older hemp workers can be partly attributed to loss of lung elastic recoil, and partly to intrinsic obstruction of small airways. These functional observations suggest that, as in emphysema, loss of parenchymal structure of the lungs occurs in the chronic stages of byssinosis of textile workers.

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References

- Schilling, R. S. F.: Byssinosis in cotton and other textile workers, *Lancet*, 1956, 2, 261.
- Bouhuys, A., Barbero, A., Lindell, S.-E., Roach, S. A., and Schilling, R. S. F.: Byssinosis in hemp workers, *Arch. Environ. Health (Chicago)*, 1967, 14, 533.
- Bouhuys, A., Barbero, A., Schilling, R. S. F., and van de Woestijne, K. P.: Chronic respiratory disease in hemp workers, *Amer. J. Med.*, 1969, 46, 526.
- Bouhuys, A., and van de Woestijne, K. P.: Respiratory mechanics and dust exposure in byssinosis, *J. Clin. Invest.*, 1970, 49, 106.
- Bouhuys, A., Schilling, R. S. F., and van de Woestijne, K. P.: Cigarette smoking, occupational dust exposure and ventilatory capacity, *Arch. Environ. Health (Chicago)*, 1969, 19, 793.
- Mead, J., Turner, J. M., Macklem, P. T., and Little, J. B.: Significance of the relationship between static recoil and maximum expiratory flow, *J. Appl. Physiol.*, 1967, 22, 95.
- Bouhuys, A.: Airflow control by auditory feedback; Respiratory mechanics and wind instruments, *Science*, 1966, 154, 797.
- Cotes, J. E.: Lung Function; Assessment and Application in Medicine, Blackwell Scientific Publications, Oxford and Edinburgh, 1968.
- Milic-Emili, J., Mead, J., Turner, J. M., and Glauser, E. M.: Improved technique for estimating pleural pressure from esophageal balloons, *J. Appl. Physiol.*, 1964, 19, 207.
- Turner, J. M., Mead, J., and Wohl, M. E.: Elasticity of human lungs in relation to age, *J. Appl. Physiol.*, 1968, 25, 664.
- Cherniack, R. M., and Raber, M. B.: Normal standards for ventilatory function using an automated wedge spirometer, *Amer. Rev. Resp. Dis.*, 1972, 106, 38.
- Jonson, B.: Pulmonary mechanics in normal men, studied with the flow regulator method, *Scand. J. Clin. Lab. Invest.*, 1970, 25, 363.
- Macklem, P. T., and Becklake, M. R.: The relationship between the mechanical and diffusing properties of the lung in health and disease, *Amer. Rev. Resp. Dis.*, 1963, 87, 47.

³ Zuskin, E., and Bouhuys, A.: Unpublished data.