American Journal of Industrial Medicine 26:103–115 (1994)

Follow-Up Study of Respiratory Function in Hemp Workers

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A 3-year follow-up study was performed on 38 women and 28 men from the originally studied textile workers employed in a soft hemp processing mill. Acute and chronic respiratory symptoms and ventilatory capacity were recorded during the cross-sectional and the follow-up studies. Maximum expiratory flow-volume (MEFV) curves were obtained on these workers, and forced vital capacity (FVC), 1-second forced expiratory volume (FEV_1) and flow rates at 50% and at 25% of the VC (FEF_{50}, FEF_{25}) were measured. High prevalences of acute and chronic respiratory symptoms persisted at the follow-up study. In particular, high prevalences of byssinosis were documented at both studies (women: 47.4% and 47.4%; men: 64.3% and 67.9%, respectively). Statistically significant mean across-shift reductions were recorded for all ventilatory capacity tests at the initial study. A large mean annual decline was calculated for FEV_1 in women and for all ventilatory capacity parameters in men; these declines were greater for workers with symptoms of byssinosis than for those without. The accelerated decline in FEV_1 noted in the women workers, who were predominantly nonsmokers, suggests an independent hemp effect. Exposures in the work environment were measured with Hexhlet filters and revealed very high dust concentrations (mean total: 21.4 mg/m^3, 22.4 mg/m^3; respirable: 8.4 mg/m^3, 9.9 mg/m^3) at both initial and follow-up studies. These levels are much higher than those found in mills processing organic materials in North America. Our data demonstrate that work in the hemp industry, particularly in small poorly regulated mills, continues to have deleterious effects on respiratory function.

Key words: hemp workers, respiratory symptoms, lung function, byssinosis, textile workers

INTRODUCTION

Cotton and hemp workers are at risk for both acute and chronic lung disease. They experience characteristic symptoms (i.e., byssinosis) and accelerated lung function loss [Barbero and Flores, 1967; Bouhuys et al., 1967, 1969; Valic and Zuskin, 1971; Kamat et al., 1981; Beck et al., 1982; Zuskin et al., 1991; Guyatt et al., 1973]. Bouhuys and Zuskin [1976] described a 7-year follow-up study of hemp workers in which workers demonstrated significantly higher prevalences of chronic cough and

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Accepted for publication July 16, 1993.

phlegm as well as dyspnea than control subjects, and significantly larger mean annual declines in 1-second forced expiratory volume (FEV1) than control subjects. Valic and Zuskin [1976] recorded a mean annual fall in FEV1 among hemp workers which was greater in workers with byssinosis than in those without byssinosis. Bouhuys et al. [1969] showed that respiratory disease among hemp workers is a serious and disabling illness.

The present 3-year follow-up study of respiratory function was conducted in a group of textile workers exposed to high levels of soft hemp dust (*Cannabis sativa*) in a small textile mill in Karlovac, Croatia. These workers, first studied in 1985 [Zuskin et al., 1990], were engaged in a hemp mill manufacturing rugs, ropes, and fire hose. The study was undertaken to examine airway disease among textile workers.

SUBJECTS AND METHODS

Subjects

The initial cross-sectional study was performed in a group of 77 hemp workers (48 women and 29 men). After a 3-year interval, all but 11 (16%) of the original cohort of workers were available for the follow-up study. The majority of these workers had retired. Two had left for health reasons (asthma). Of the remaining workers, 10% (5) of the women and 90% (26) of the men were regular smokers. At the follow-up, a group of 30 women and 25 men similar in age, duration of employment, and smoking habit, working as packers in the food industry but with no exposure to noxious agents, was studied as a control for the prevalence of respiratory symptoms. This study was reviewed and approved by the Institutional Review Board of the Andrija Stampar School of Public Health, and subjects gave informed written consent before participating.

Male textile workers were employed primarily in the opening of bales and the operating of carding machines, while women worked mostly with spinning and weaving machines. The textile processing machines were located in two large rooms which were only partially separated so that all workers, regardless of their primary task, were exposed to similar dust concentrations.

Environmental Dust Measurements

Airborne dust in the hemp mill was sampled during both studies with Hexhlet horizontal two-stage samplers during the 8-hour work shift at the work area of the examined workers. Dust concentrations were expressed separately for the total and respirable dust fractions.

Respiratory Symptoms

Chronic respiratory symptoms were recorded by using the British Medical Research Council Committee questionnaire on respiratory symptoms [1960] with additional questions on occupational asthma [World Health Organization, 1986] and on byssinosis [Schilling et al., 1963]. In all workers, a detailed occupational history as well as questions about smoking habit were recorded. The following definitions were used:

1. Chronic cough or phlegm: cough and/or phlegm production for at least 3 months a year for not less than 2 successive years

2. Dyspnea grades: grade 3— shortness of breath when walking with other people at an ordinary pace on level ground; grade 4— shortness of breath when walking at own pace on level ground
3. Occupational asthma: recurring attacks of dyspnea, chest tightness, and pulmonary function impairment of the obstructive type diagnosed by physical examination and spirometric measurement during exposure to dust at or following work and confirmed by medical records
4. Byssinosis grades: grade 1/2— occasional chest tightness on Monday; grade 1— chest tightness and/or difficulty in breathing on Monday only; grade 2— chest tightness and/or difficulty in breathing on Mondays and other working days.

Acute symptoms that developed during a work shift were also recorded for all workers, during both studies. The shift-related symptoms studied included cough, irritation or dryness of the throat, secretion, dryness or bleeding of the nose, eye irritation, and headache.

Ventilatory Capacity

Ventilatory capacity was measured by recording maximum expiratory flow-volume (MEFV) curves on a spirometer, the Pneumoscreen (Jaeger, Germany). This instrument was calibrated daily, following the guidelines of the American Thoracic Society [Ferris, 1978]. The same instrument was used at both the initial and follow-up studies. The forced vital capacity (FVC), FEV_1, and maximum flow rates measured at 50% and at 25% of the VC above residual volume (FEF_{50}, FEF_{25}) were measured on the MEFV curves. During the initial study, measurements were performed on the first working day of the week (Monday) before and after the work shift (6 a.m. and 2 p.m.). During the follow-up study, ventilatory capacity was measured on Monday but only before the work shift (6 a.m.). At least three MEFV curves were recorded for each subject and the best value was used as the result of the test. Unacceptable MEFV curves (e.g., exhalation less than 6 seconds) between curve differences of more than 5% in FEV_1 were discarded. In subjects with severe obstruction (FEV_1 <1.5 L) we accepted the best curve if patient's effort was seen to be adequate. The measured Monday preshift values of ventilatory capacity were compared with the predicted normal values of Cherniack and Raber [1972].

Statistical Analysis

The results of ventilatory capacity measurements were analyzed by using the t-test for differences of paired (across-shift and baseline as a percent of predicted values) variables. The chi-squared test or when appropriate Fisher's exact test was used for testing differences in the prevalences of respiratory symptoms. $p < 0.05$ was considered statistically significant.

RESULTS

Environmental Dust Measurement

The mean total dust concentration at the follow-up study was 21.4 mg/m^3 (range: 4.1–45.6 mg/m^3) with a mean respirable fraction of 8.4 mg/m^3 (range: 1.5–27.6 mg/m^3). This was similar to the dust concentrations measured at the time

of the first study (mean total: 22.4 mg/m^3, range: 3.3–68.5 mg/m^3; mean respirable: 9.9 mg/m^3, range: 1.3–38.4 mg/m^3). These measurements are much greater than the maximum allowable concentrations for vegetable textile dust allowed by the Croatian government's occupational standards (total dust: 5 mg/m^3; respirable: 1 mg/m^3) as well as those of the United States for cotton. The Occupational Safety and Health Administration (OSHA) permissible exposure limits for lint-free respirable cotton dust in yarn manufacturing and cotton washing operations is 200 μg/m^3; for exposure to lower grade washed cotton in textile mill waste house operations or exposure in yarn manufacturing, it is 500 μg/m^3; and for exposure to lint-free respirable cotton dust in the slashing and weaving areas, it is 750 μg/m^3 averaged over an 8-hour period.

Respiratory Symptoms

Table I presents the prevalence of respiratory symptoms in the 38 female and 28 male hemp workers studied at the initial and the follow-up studies. A high prevalence of all respiratory symptoms was found at both occasions with a small, but nonsignificant, increase of most of the respiratory symptoms at the follow-up study. A high prevalence of byssinosis was documented in women at both studies (47.4%) and in men (64.3% and 67.9%, respectively). At the follow-up, the majority of symptoms for women workers were of lower grades. The prevalence of byssinosis grade 1/2 (10; 26.3%) was greatest, followed by grade 1 (5; 13.2%) and grade 2 (3; 7.9%) for women workers. For male hemp workers, higher grades of byssinosis were more common. The greatest prevalence was for byssinosis grade 2 (10; 35.7%), followed by grade 1 (8; 28.6%); none of the men had symptoms of grade 1/2.

At the follow-up study, comparison of chronic symptoms (Table II) demonstrated that female and male textile workers experienced higher prevalences of all symptoms than did controls. The differences in the prevalences of symptoms in women were statistically significant in women for chronic cough, chronic phlegm, chronic bronchitis, nasal catarrh, and sinusitis. For men, statistically significant differences were noted for chronic cough, chronic phlegm, chronic bronchitis, and sinusitis. Byssinotic symptoms were not found among control workers of either sex. Workers symptomatic at the cross-sectional study remained symptomatic at the follow-up.

The prevalence of chronic respiratory symptoms at the cross-sectional study among the 10 female hemp workers who were lost to follow-up had demonstrated the following frequencies: chronic cough six (60.0%), chronic phlegm four (40.0%), chronic bronchitis three (30.0%), dyspnea grade 3, five (50.0%), asthma one (10.0%), nasal catarrh four (40.0%), sinusitis three (30.0%), and byssinosis six (60.0%). The one man who was lost to the follow-up study had chronic bronchitis, dyspnea grade 3, and byssinosis grade 2. This suggests that many of the workers lost to follow-up may have left the industry because of health problems.

Table III shows the prevalence of acute symptoms during the work shift in female and male hemp workers at the cross-sectional and the follow-up studies. There were high prevalences of all acute symptoms during the work shift, with no significant differences in the prevalence between these two studies. The highest prevalences were recorded for cough, dyspnea, chest tightness, and irritation or dryness of the throat.

TABLE I. Prevalence of Chronic Respiratory Symptoms in Hemp Workers During the First (1) and the Follow-Up Study (2)

Sex	Measurement	Mean age (years)	Mean height (cm)	Mean exposure (years)	Chronic cough (%)	Chronic phlegm (%)	Chronic bronchitis (%)	Dyspnea grades 3 and 4 (%)	Asthma (%)	Nasal catarrh (%)	Sinusitis (%)	Byssinosis (%)
Female (N = 38)	1	35	163	12	19 (50.0)	11 (28.9)	10 (26.3)	8 (21.1)	4 (10.5)	15 (39.5)	8 (21.1)	18 (47.4)
					NS[a]	NS	NS	NS	NS	NS	NS	NS
	2	38	163	15	23 (60.5)	12 (31.6)	11 (28.9)	9 (23.7)	4 (10.5)	16 (42.1)	8 (21.1)	18 (47.4)
Male (N = 28)	1	43	170	18	16 (57.1)	11 (39.3)	11 (39.3)	6 (21.4)	2 (7.1)	7 (25.0)	7 (25.0)	18 (64.3)
					NS	NS	NS	NS	NS	NS	NS	NS
	2	46	170	21	17 (60.7)	16 (57.1)	16 (57.1)	8 (28.6)	2 (7.1)	8 (28.6)	9 (32.1)	19 (67.9)

[a]NS = difference not statistically significant ($p > 0.05$).

TABLE II. Prevalence of Chronic Respiratory Symptoms in Hemp Workers and in Control Subjects at Follow-Up Study

Sex	Mean age (years)	Mean exposure (years)	Chronic cough (%)	Chronic phlegm (%)	Chronic bronchitis (%)	Dyspnea grades 3 and 4 (%)	Asthma (%)	Nasal catarrh (%)	Sinusitis (%)	Byssinosis (%)
Female (N = 38)	40	17	23 (60.5)	12 (31.6)	11 (28.9)	9 (23.7)	4 (10.5)	16 (42.1)	8 (21.1)	18 (47.4)
p value			<0.01	<0.05	<0.05	<0.01	NS[a]	<0.01	=0.03	<0.01
Control (N = 30)	41	19	3 (10.0)	2 (6.7)	2 (6.7)	1 (3.3)	0 (0)	2 (6.7)	1 (3.3)	0 (0)
Male (N = 28)	48	23	17 (60.7)	16 (57.1)	16 (57.1)	8 (28.6)	2 (7.1)	8 (28.6)	9 (32.1)	19 (67.9)
p value			<0.05	<0.05	<0.05	NS	NS	NS	=0.03	<0.01
Control (N = 25)	49	25	8 (32.0)	7 (28.0)	7 (28.0)	3 (12.0)	0 (0)	2 (8.0)	2 (8.0)	0 (0)

[a]NS = difference not statistically significant ($p > 0.05$).

TABLE III. Prevalence of Acute Symptoms in Hemp Workers During a Work Shift

Sex	Measurement	Cough (%)	Dyspnea (%)	Chest tightness (%)	Throat		Eye Irritation (%)	Nose			Headache
					Irritation (%)	Dryness (%)		Secretion (%)	Dryness (%)	Bleeding (%)	
Female	1	29	25	27	27	31	26	9	25	11	18
(N = 38)		(76.3)	(65.8)	(71.1)	(71.1)	(81.5)	(68.4)	(23.7)	(65.8)	(28.9)	(47.4)
		NS[a]	NS	NS	NS	NS	NS	NS	NS	NS	NS
	2	30	22	27	29	35	33	9	26	12	20
		(78.9)	(78.9)	(71.1)	(76.3)	(92.1)	(86.8)	(23.7)	(68.4)	(31.6)	(52.6)
Male	1	20	20	23	19	19	23	5	17	9	23
(N = 28)		(71.4)	(71.4)	(82.1)	(67.9)	(67.9)	(82.1)	(17.9)	(60.7)	(28.0)	(82.1)
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	2	20	22	24	20	20	24	5	18	8	23
		(71.4)	(78.5)	(85.7)	(71.4)	(71.4)	(85.7)	(17.9)	(64.3)	(28.6)	(82.1)

[a]NS = difference not statistically significant ($p > 0.05$).

Ventilatory Capacity

Table IV displays ventilatory capacity data in female and male hemp workers at the cross-sectional and the follow-up studies.

There were significant across-shift reductions for all test parameters measured at the cross-sectional study, the largest being for FEF_{25} (women: −15.4%; men: −17.2%; $p < 0.01$). Compared to predicted normal values, the measured mean FEF_{50} and FEF_{25} in men and FEF_{25} in women were below 80% of predicted at both the initial and the follow-up studies. For the 10 women who left the industry by the time of the follow-up study, the initial (study) mean across-shift changes in lung function was greater than the change of those women workers seen at the follow-up study (FVC: −10.5%; FEV_1: −12.5%; FEF_{50}: −13.2%; FEF_{25}: −16.9%). Additionally, the mean percent of predicted baseline lung function values for these 10 female hemp workers was lower than for the group included in the follow-up study (FVC: 85%; FEV_1: 81%; FEF_{50}: 75%; FEF_{25}: 65%).

By comparing the preshift ventilatory capacity data of the cross-sectional and the follow-up study (Table V), the mean annual declines in women and in men were denoted. The mean annual decline of all ventilatory capacity tests was greater in female and male hemp workers with byssinosis than in those without such symptoms. Analyzing the data for individual female hemp workers, the largest annual decline for FVC was 0.057 L/year, for individual workers for FEV_1 0.095 L/year, for FEF_{50} 0.12 L/s/year, and for FEF_{25} 0.08 L/s/year. In male hemp workers, the largest individual annual decline for FVC was 0.098 L/year, for FEV_1 0.110 L/year, for FEF_{50} 0.35 L/s/year, and for FEF_{25} 0.24 L/s/year.

A calculation of the predicted annual decrease in pulmonary function parameters was compiled from various researchers 1978–1986 (Table VI). The mean annual decline in FEV_1 for hemp workers was more than twice that of the predicted groups. In particular, women workers, who were primarily nonsmokers, had a greater than predicted rate of decline for FEV_1.

DISCUSSION

Our data confirm that exposure to hemp dust in poorly regulated dusty mills is associated with the development of high prevalence of acute and chronic respiratory symptoms, and demonstrates lung function abnormalities in the workers. An earlier study by Barbero and Flores [1967] described a high prevalence of chronic respiratory symptoms among active and retired hemp workers in Spain. These authors reported that many hemp workers die at an early age presumably as a consequence of their exposure. By studying the effect of different vegetable dusts in Eastern European textile workers, Valic and Zuskin [1972] found that the highest prevalences of byssinosis were reported by hemp (44%) and flax workers (43%) followed by those working with cotton (27%). Then, as now, these high prevalences reflect dusty work conditions and possibly some intrinsic property of hemp dust.

The prevalence of byssinosis in the present study is similar to that reported in our previous studies of hemp workers two decades ago; these prevalences ranged from 39–67% [Valic and Zuskin, 1971; Zuskin et al., 1990; Valic et al., 1968]. Kondakis et al. [1967] described that 13% of textile workers exposed to hemp and sisal had symptoms of byssinosis; 30% of those workers had chronic bronchitis and

TABLE IV. Ventilatory Capacity in Hemp Workers During the First (1) and the Follow-Up Studies (2)

		FVC			FEV_1			FEF_{50}			FEF_{25}		
		Before shift	Difference before-after shift		Before shift	Difference before-after shift		Before shift	Difference before-after shift		Before shift	Difference before-after shift	
Sex	Measurement	L	%	p	L	%	p	L/s	%	p	L/s	%	p
Female	1	3.68 ± 0.59 93.4[a]	−9.8	<0.01	2.84 ± 0.47 92.8[a]	−10.0	<0.01	3.86 ± 0.87 83.2[a]	−11.4	<0.01	1.76 ± 0.53 69.3[a]	−15.4	<0.01
	2	3.63 ± 0.63 92.6[a]			2.67 ± 0.52 89.2[a]			3.77 ± 0.97 81.5[a]			1.64 ± 0.55 67.3[a]		
Male	1	4.40 ± 1.17 85.8[a]	−8.1	<0.01	3.32 ± 1.02 83.2[a]	−11.1		4.39 ± 1.83 79.9[a]	−15.4	<0.01	2.10 ± 0.67 79.1[a]	−17.2	<0.01
	2	4.23 ± 1.23 83.6[a]			3.17 ± 1.07 81.2[a]			3.82 ± 1.43 71.3[a]			1.74 ± 0.67 67.9[a]		

FVC, forced vital capacity; FEV, forced expiratory volume; FEF, forced expiratory flow.
[a]Percentage of predicted normal values.

TABLE V. Mean Annual Fall of Ventilatory Capacity Tests in Hemp Workers Over a 3-Year Period

Sex	N	FVC L	FEV_1 L	FEF_{50} L/s	FEF_{25} L/s
Female	38	0.017	0.057	0.03	0.04
Female with byssinosis	18	0.021	0.068	0.04	0.05
Female without byssinosis	20	0.014	0.048	0.02	0.03
Male	28	0.057	0.050	0.19	0.12
Male with byssinosis	18	0.065	0.061	0.22	0.15
Male without byssinosis	10	0.049	0.041	0.15	0.10

FVC, forced vital capacity; FEV, forced expiratory volume; FEF, forced expiratory flow.

TABLE VI. Mean Predicted Annual Decrease of FVC, FEV1, FEF50, and FEF25 Calculated According to the Predicted Equations in Studies of Healthy Subjects

	Female				Male			
Authors	FEV L	FEV_1 L	FEF_{50} L/s	FEF_{25} L/s	FVC L	FEV_1 L	FEF_{50} L/s	FEF_{25} L/s
Schoenberg et al. [1978]	0.019	0.022	0.027	0.034	0.037	0.029	0.026	0.010
Knudson et al. [1983]	0.017	0.020	0.029	0.026	0.029	0.029	0.037	0.023
Quanjer [1983]	0.025	0.025	0.025	0.025	0.026	0.029	0.031	0.026
Cherniack and Raber [1972]	0.015	0.019	0.023	0.034	0.014	0.022	0.030	0.041
Miller et al. [1986]	0.023	0.025	0.031	0.029	0.021	0.023	0.032	0.028

FVC, forced vital capacity; FEV, forced expiratory volume; FEF, forced expiratory flow.

respiratory insufficiency. In a study by Zuskin and Valic [1973] a higher prevalence of chronic respiratory symptoms was found in workers with byssinosis than among those without byssinosis during simultaneous exposure to hemp and flax. In the hemp workers followed longitudinally by Valic and Zuskin [1976], the prevalence of byssinosis and other chronic respiratory symptoms increased following a 10-year interval. In an earlier follow-up study of hemp workers, Bouhuys and Zuskin [1976] have previously shown that the prevalence of most chronic respiratory symptoms and particularly dyspnea increased significantly over a 7-year interval. This suggests that intervals of longer than 3 years are necessary to observe progression of symptoms. Data on individual workers leaving the industry suggest that the sickest workers leave their jobs, being unable to continue in the industry.

Acute symptoms noted during the work shift were very common in this study, suggesting that hemp dust is a very potent airway irritant. Similar findings have previously been reported for other organic dusts in small poorly regulated mills [Zuskin et al., 1988a,b, 1989].

The largest across-shift change in lung function noted for the hemp workers at the cross-sectional study was found for FEF_{25}, varying from 15.4–17.2%. Such data are consistent with brief but recurrent acute obstructive changes possibly involving smaller airways. In clinical challenge studies, it has been shown that these changes are particularly dramatic on partial expiratory flow-volume curves, further suggesting the possibility of small airway inflammation [Zuskin and Bouhuys, 1975; Schachter et al., 1981a,b].

In the female hemp workers we studied (predominantly nonsmokers), we found high mean annual decreases in lung function tests. The annual FEV_1 decrease in hemp workers is similar to the data reported by Valic and Zuskin, who found a mean annual fall in FEV_1 among hemp workers varying from 27–55 ml per year [1976]. Bouhuys and Zuskin [1976] and Zuskin and Valic [1975] found a mean annual FEV_1 decrease in cotton workers varying from 40 ml/year to 111 ml/year. Zuskin et al. [1991] reported that in cotton workers they found a mean annual decline in FVC of 0.036 L/year and in FEV_1 of 0.059 L/year. The mean annual decline in FVC and FEV_1 for men and women in our hemp workers was considerably larger than the expected annual decline of 14–31 ml/year for healthy subjects (Table VI). Additionally, the individual worker data suggested that some workers might be experiencing very large annual declines.

Other textile industries have shown similar accelerated declines in lung function. Beck et al. [1982] reported a similar loss of lung function over 6 years in female and male workers in both smokers and nonsmokers. In the 3-year follow-up study of Berry et al. [1973], the mean annual decline in FEV_1 for cotton workers was 54 ml/year compared with 32 ml/year for workers in man-made fiber mill. Beck and Schachter [1983] demonstrated a decline of 42 ml/year in FEV_1 for cotton workers compared with 25 ml/year in control subjects. In a study by Fox et al. [1973] regression on the average percent predicted FEV_1 showed a decrease of 0.14% per year for the cotton textile workers, compared to only 0.02% per year for the control population.

Cigarette smoking has been associated with lung function impairment, and the degree of dysfunction is dose related [Beck et al., 1981]. Beck and Schachter [1983] reported that when classified by smoking status, cotton textile workers had larger than expected losses of FEV_1 (or residual FEV_1) than did controls, independently of the smoking habit. The effects of textile dust and cigarette smoke were in fact additive in this study. In the female hemp workers studied here, who were mostly nonsmokers, findings suggest that an accelerated loss of lung function is, at least in part, independent of any smoking effects. The more pronounced effects seen in men indicate that, as with cotton dust, there may be an additive effect between smoking and textile dust exposure.

Dust levels at the studied mill were nearly an order of magnitude greater than those commonly found in similar industries in the United States. The respiratory findings described in this study therefore reflect levels of respiratory disease associated with an essentially unregulated industry and probably are not relevant to larger well-regulated mills in the United States. However, workers in smaller mills with poor quality control may be at risk.

This study confirms that hemp dust exposure in small poorly regulated mills leads to acute and chronic respiratory changes independently of cigarette smoking. Dust levels in small mills need to be strictly monitored and controlled. In addition,

based on the high prevalence of respiratory disease in such settings we suggest that workers will benefit from medical surveillance.

ACKNOWLEDGMENTS

Supported in part by YF 733 from the National Institutes of Health, Bethesda, MD, ROI-OHO-2593-01A1 from the Centers for Disease Control, National Institute for Occupational Safety and Health, Atlanta, GA, and by the Henry and Catherine Gaisman Foundation, New York, NY.

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