Byssinosis and Chronic Bronchitis Among Cotton Textile Workers

JAMES A. MERCHANT, M.D., KAYE H. KILBURN, M.D., WILLIAM M. O'FALLON, Ph.D., JOHN D. HAMILTON, M.D., and JOHN C. LUMSDEN, B.Ch.E.,

Durham and Raleigh, North Carolina

A survey of a modern cotton-synthetic blend mill was conducted to determine the prevalence and distribution of byssinosis, the effects of smoking, aging, and cotton-dust exposure on the frequency and severity of byssinosis, chronic bronchitis, and dyspnea (defined by index ratings), and whether total-dust samples would indicate byssinosis risk. Twenty percent of those working in preparation areas, 2% of those in yarn processing areas, and 6% of all employees were diagnosed as byssinotic. Among men, the byssinosis index increased with smoking and the bronchitis index increased with smoking plus dust exposure. Byssinotic workers were found to have more chronic bronchitis and dyspnea than matched control workers. It is concluded that byssinosis and chronic bronchitis are both influenced by cotton-dust exposure and cigarette smoking. Total-dust samples, in this plant, gave no indication of byssinosis risk.

A PRIMARY OBJECTIVE of this study was to determine the prevalence of byssinosis among workers processing middling-grade cotton and synthetic-blend material in a modern manufacturing plant equipped with machine exhaust systems and air conditioning. In three recent surveys (1-3) of U.S. textile mills processing medium- to low-grade cottons, byssinosis was found in 25% to 30% of those working in preparation areas, 10% to 29% of workers in yarn processing areas, and in up to 10% of those in weaving. Although many manufacturing plants have converted from cotton to cotton-synthetic blends, no study of the prevalence of byssinosis in these expanding manufacturing conditions has been reported.

A second objective was to determine the prevalence of chronic bronchitis and the effects of smoking, aging, and cotton-dust exposure on the frequency and severity of byssinosis and chronic bronchitis. Byssinosis has been associated with an increased prevalence of chronic bronchitis (3-5) and decreased ventilatory capacity (6, 7). The mechanism of pulmonary disability in byssinosis is not known, although it has been stated that byssinotics frequently die with chronic bronchitis and emphysema (8). Whether chronic bronchitis and emphysema are the pathological processes responsible for the pulmonary disability of byssinosis has not been epidemiologically examined in either prospective clinical or pathological studies. The effect of cigarette smoking on byssinosis prevalence is not well established, although smoking apparently increases the susceptibility to byssinosis (4, 9). New statistical procedures enabled us to evaluate the relation of smoking, dust exposure, and age on the byssinosis, bronchitis, and dyspnea index ratings.

The third objective was to relate the prevalence of byssinosis to the total-dust levels to determine whether these levels might indicate byssinosis risk. The present threshold limit (TLV) for cotton dust is 1 mg/m^3 total lint and dust (10). There is evidence, however, that "respirable" dust is the important fraction in predicting byssinosis risk (11, 12); therefore some fractionated as well as total-dust samples were collected.

► From the Division of Environmental Medicine, Department of Internal Medicine, Duke University Medical Center, Durham; and Occupational Health Section, North Carolina State Board of Health, Raleigh; N.C.

Methods

THE STUDY POPULATION

There were 441 of a total of 443 employees present both days of the survey, and they participated in all phases of the survey. The yarn mill is located in Gaston County, N.C., which is the most concentrated area of cotton yarn manufacturing in the United States. The predominantly white population consisted of second- and third-generation textile workers, most of whom have had long exposure to cotton dust. Atmospheric pollution in this rural community is considered negligible.

THE MANUFACTURING PLANT

The manufacturing plant is a family-owned, three-mill complex processing fine-spun yarn, using strict middling cotton and synthetic material with counts ranging from 19 to 30. Mill 2 processed only cotton yarn. Mill 1 processed a 50% cotton, 50% polyester blend, and Mill 3 processed only synthetic yarn. All the mills are air conditioned and use both bag and media filters to remove dust and lint. All carding machines are exhaust ventilated, with 100% recirculation of workroom air after filtration.

SURVEY PROTOCOL

Questionnaire: A questionnaire that had been used at Duke University to screen hospitalized patients for pulmonary dysfunction, to which we added questions about byssinosis, was used to determine byssinosis, bronchitis, and dyspnea indexes, smoking history, and occupational exposure. The byssinosis index consisted of four ratings (0, 1, 2, 3) based on five weighted questions concerning cough, breathlessness, and chest tightness on Mondays or early in the workweek, improved breathing away from work, and improved breathing as the workweek proceeded. The bronchitis index consisted of five ratings (0, 1, 2, 3, 4) based on positive responses to four questions concerning daily cough, cough for 90 days per year, phlegm with cough, and two or more chest colds per year. The dyspnea index consisted of five ratings (0, 1, 2, 3, 4) based on positive responses to four questions concerning breathlessness considered to be below average for the age of the subject, breathlessness walking a slight incline or briskly on the level, "trouble with [his] lungs or difficulty breathing," and breathlessness at night*. The questionnaire was administered by five laymen employed by the Division of Epidemiology, North Carolina State Board of Health.

Medical Interviews: Those employees with a byssinosis index of 3, plus every tenth employee surveyed, were initially interviewed by J.H. It was evident that some employees with an index of less than 3 were byssinotic. Therefore, all employees with a byssinosis index greater than or equal to 1, all employees working in preparation areas, and all workers 50 years of age or older, a total of 230, were interviewed by J.H. and J.M. within 2 months of the survey to detect those workers with byssinosis, so they could be transferred to nondusty jobs. To establish a diagnosis of byssinosis by physician interview, chest tightness, Schilling's grade 1 or 2, was required (13): grade 1—chest tightness every Monday; grade 2—chest tightness every Monday and other workdays.

An internal control group of exposed cotton workers with no history of byssinosis, according to their physician interview, was selected at random after matching each byssinotic person with a nonbyssinotic of the same sex, age, race, smoking history, and work area.

Pulmonary Function Testing: After the questionnaire and interview, each employee was instructed in making forced expirations and then, from end expiration, inspired 100% oxygen through a demand valve and immediately forcefully expired into an electrical wedge spirometer, past the sampling port of nitrogen and carbon dioxide analyzers. The signals were observed on a cathode ray oscilloscope and recorded on an FM tape recorder, together with identification data. The procedure was repeated, if needed, to ensure that a full expiration was recorded without leakage or artifact. The analog (voltage) signals were run through an analog-to-digital converter and stored in digital form. From these curves the forced expiratory volume in one half second and in one second ($FEV_{0.5}$, FEV_1), the maximal expiratory flow (MEF), the maximal mid-expiratory flow (MMEF), the forced vital capacity (FVC), and the CO_2 and N_2 gradients could be calculated. The initial 198 curves could not be reconstructed satisfactorily because of a faulty recorder power source. Data were available for analysis on 141 males and 102 females, whose distribution in regard to dust exposure did not differ from the whole population. Both sex groups were categorized by age, smoking, FEV_1 and FVC and their respective percent of predicted (14) group values, plus the calculated MMEF.

Twenty-seven men employed in the opening, picking, and carding areas of Mills 1 and 2 were studied before exposure to cotton dust on a Monday after 2 days away from work and again after 6 hours of dust exposure, to detect changes in flow at 50% of vital capacity. The best of three forced expirations into a wedge, recorded on an X-Y* recorder, was accepted for each individual. The 27 carders were divided into three groups. Five had been diagnosed as grade 1 or 2 byssinotics by medical interview, four others were called "reactors" (those with marked decrements in flow at 50% FVC—greater than 15%—with dust exposure but no evidence of characteristic byssinosis symptoms) (15). Eighteen other carders had neither a history nor obvious functional evidence of response to cotton dust.

Dust Sampling: Total-dust samples were obtained by using 47-mm fiberglass filters and a Gelman† pump, sampling at 20 litres/minute, over 1 to 4 hours in the breathing zone. Thirty-nine total-dust samples were obtained at stations throughout all cotton processing areas during the first and second shifts, and each was weighed to the nearest 0.01 mg with an electronic balance. Two months after the survey six dust samples from Mill 2 were collected, using a cyclone separator that divided the dust into a fine fraction ($\leq 10\mu$), a middle fraction of between 11μ and 2 mm, and a lint fraction.

* See appendix for details of the formulation of indexes. For questionnaire order document NAPS 01744 from ASIS, National Auxiliary Publications Service, care of CCM Information Corp., 866 Third Ave., New York, N.Y. 10022; remitting $2.00 for each microfiche or $5.00 for each photocopy.

* X-Y Recorder, 7030A, Hewlett-Packard Co., Palo Alto, Calif.
† Gelman Instrument Co., Ann Arbor, Mich.

Table 1. Byssinosis Severity Index in All Males According to Smoking Habit

	Never Smoked			Current Smokers			Ex-Smokers		
Age, *yr*	15-34	35-49	50-70	15-34	35-49	50-70	15-34	35-49	50-70
Exposure									
High	1.333	1.125	1.200	1.657	1.897	1.714	1.400	1.200	1.727
Moderate	1.500	1.666	1.400	1.170	1.450	1.450	1.166	1.125	1.071

ANALYSIS OF DATA

The group of 25 byssinotics identified by medical interview and the 25 matched control workers were tested for differences in responses to questions concerning bronchitis, respiratory infections, and dyspnea by matched sample chi-square analysis (16). A *P* value of less than 0.05 was established as the level of significance.

To analyze the relation of dust exposure, smoking, and aging to the byssinosis, bronchitis, and dyspnea index ratings, the population was initially categorized by sex, age, exposure-risk area, and smoking history. For these analyses, data were available on 174 females and 234 males, who constituted a population of 408 out of 441 possible subjects. Pipe and cigar smokers (7), negroes (12), and those workers on whom we had incomplete data, which prevented categorization (14), were eliminated from this analysis. Each subpopulation of men and of women was categorized by age (15 to 34 years, 35 to 49 years, and 50 to 70 years), cigarette smoking history (never smoked, current smokers, ex-smokers), and occupational exposure. The high exposure-risk group, all men, included those currently working in opening, picking, and carding at all three mills. There were two moderate exposure-risk groups. The first included all men currently working in spinning, winding, or twisting at all three mills; the second, women working in spinning or winding in Mills 1 and 2 (cotton mills). The low exposure-risk group was composed of women working in spinning, winding, or twisting in the synthetic mill, Mill 3. Each risk group was rated for byssinosis, bronchitis, and dyspnea. No comparisons were made between sexes or the indexes of these conditions.

Each subject was rated according to the severity of each condition. This established an index rating scale of 0, 1, 2, and 3 for byssinosis and index ratings of 0, 1, 2, 3, and 4 for bronchitis and dyspnea. Because of low frequencies in some categories, the tables were reduced before final analysis. Very few subjects had index ratings of 4, and therefore the 4 rating was eliminated from analysis. Only 12 women were ex-smokers, and therefore they were excluded from analysis, which left a sample size of 120.

The data were then reduced by a severity-of-index function within each smoking-age-exposure category. This was done by assigning weights to severity ratings and then calculating the average weight in each category. Thus, the frequencies in the 48 female cells and 72 male cells are transformed to a single numeric quantity in each of 12 cells and 18 cells, respectively. This numeric quantity is large in those cells with high frequencies of subjects with high indexes, and small in those cells with low frequencies. Thus it is a rational severity index. Table 1, for the male byssinosis index, is an example of the effect of this transformation.

Such a table has a three-factor factorial design that lends itself to testing hypotheses about three different effects (smoking, age, and exposure) and their first-order interactions (smoking × age, smoking × risk, age × risk). New statistical procedures (17) permit the testing of seven hypotheses:

H1. The populations of nonsmokers, smokers, and ex-smokers all have the same mean index.

H2. The three age populations all have the same mean index.

H3. The paired exposure-risk populations all have the same mean index.

H4. There is no interaction between smoking history and age (that is, whatever differences there might be from one age group to the next are the same within each smoking group).

H5. There is no interaction between smoking habits and exposure-risk classification (that is, differences between exposure-risk groups are the same in each smoking group).

H6. There is no interaction between age and exposure-risk classification (that is, differences between exposure-risk groups are the same in each age class).

H7. There is no second-order interaction among the three variables (that is, whatever relationship exists between smoking and age, whether there is interaction or no interaction, is the same for each exposure group).

Results

The high-risk work areas of opening, picking, and carding are staffed by men, whereas women pre-

Table 2. Demographic and Environmental Exposure Characteristics of Study Population*

		%			%
Sex			Years of textile mill exposure		
Male	(259)	58.6	0-4	(99)	22.9
Female	(182)	41.4	5-9	(40)	9.6
Age by decade			10-14	(29)	6.6
10-19	(38)	8.6	15-19	(35)	7.9
20-29	(83)	18.8	20+	(238)	54.0
30-39	(64)	14.6			
40-49	(104)	23.6	Smoking history		
50-59	(107)	24.2	Never	(145)	33.3
60-69	(44)	10.0	Now	(238)	54.7
70	(1)	0.2	Previously	(52)	12.0
Mean age			Packs of cigarettes/day		
Male	(259)	39.3	<½	(73)	25.9
Female	(182)	43.5	½-1	(124)	41.0
Race			>1-1½	(62)	22.0
White	(429)	97.4	>1½	(23)	8.1
Nonwhite	(12)	2.6			

* Numbers of persons are indicated in parentheses.

Table 3. Byssinosis Index: Percentage of Subjects

Age, *yr*	Index Rating	Never Smoked				Current Smokers				Ex-Smokers				Total
		15-34	35-49	50-70	Total	15-34	35-49	50-70	Total	15-34	35-49	50-70	Total	
Men*														
Exposure-risk group														
High		n=9	n=4	n=10	n=23	n=35	n=29	n=21	n=85	n=5	n=5	n=11	n=21	n=129
	0	67	100	80	78	57	55	57	57	60	80	55	62	61.2
	1	33		20	22	29	21	29	26	40	20	27	29	25.6
	2					6	3		4			9	5	3.1
	3					9	21	14	14			9	5	10.1
Moderate		n=12	n=3	n=5	n=20	n=29	n=22	n=20	n=71	n=3	n=4	n=7	n=14	n=105
	0	58	33	80	60	86	73	70	78	100	100	100	100	77.0
	1	33	67		30	10	9	15	11					13.3
	2	8		20	10	4	18	15	11					9.5
Women†	3													
Exposure-risk group														
Moderate		n=14	n=18	n=35	n=67	n=21	n=24	n=10	n=55	n=1	n=6	n=3	n=10	n=132
	0	64	78	91	82	81	88	80	84	100	50	100	70	81.8
	1	21	17	6	12	19	4	20	13		17		10	12.1
	2		6		2		4		2		33		20	3.0
	3	14		3	5		4		2					3.0
Low		n=4	n=7	n=16	n=27	n=3	n=4	n=6	n=13	n=0	n=1	n=1	n=2	n=42
	0	50	86	81	78	67	100	83	85		100	100	100	80.9
	1		14	6	7			17	8					7.1
	2			13	7	33			8					7.1
	3	50			7									4.8

* H1: $P = 0.0115$; H2: N.S. (not significant); H3: N.S.; H4: N.S.; H5: $P = 0.0043$; H6: N.S.; H7: N.S. *See* Methods section in text for explanation of hypotheses.

† For women, hypotheses 1 through 7 are not significant.

dominate in the moderate-exposure areas of spinning, winding, and twisting (Table 2). Fifty-eight percent of the employees of this plant were 40 years of age or older, and over 97% were white. Mill 3 (synthetic) was staffed by former cotton-textile workers; only seven employees in this mill had never worked with cotton. Seventy-seven percent of the study population had worked 5 or more years in textiles, 54% had been employed for 20 or more years, and some had spent over 40 years in cotton-textile work. Over 80% of the men had smoked cigarettes, whereas only 45% of the women had ever smoked cigarettes. Slightly more ex-smoking men (16.3%) were found in the high-risk preparation areas than in the moderate-risk yarn producing areas (13.3%). Among women a similar trend was observed, with 7.6% ex-smokers in cotton-yarn producing areas and 4.7% ex-smokers in synthetic-yarn producing areas.

BYSSINOSIS

The effect of cigarette smoking on the byssinosis index is apparent (Table 3). Among men with high-risk exposure, no never-smoker had a byssinosis index rating over 1, whereas 17.7% of those who currently smoked had ratings of 2 and 3 (reflecting a questionnaire history of cough, breathing difficulty, chest tightness, or shortness of breath at the beginning of the work week). The effect of smoking alone on the byssinosis index is significant ($P = 0.01$). Differences in byssinosis index ratings for the two male exposure-risk groups are evident only in the smoking and ex-smoking categories, but they are not statistically significant. However, the interaction between current smoking and current exposure-risk on the byssinosis index is highly significant ($P = 0.0043$). Aging had no apparent effect on the male byssinosis index. Among women, who as a group were exposed to lower levels of respirable cotton dust, no age, smoking, or exposure-risk effects were demonstrated. A few women working in the synthetic plant had positive byssinosis indexes, presumably resulting from their previous work in cotton. This was also true for men, particularly those with exertional dyspnea. Evidence for self-selection of byssinotic workers into less dusty areas, particularly into the synthetic mill, was found by physician interviews.

When the 25 grade 1 and 2 byssinotics were matched with 25 exposed but clinically nonbyssinotic control workers, both groups were found to be similar in cigarette smoking duration and consumption and in years of exposure to textile work (Table 4). Byssinosis prevalence (past or present history of byssinosis), according to physician interview, was 20% in all preparation areas (opening, picking, and carding) of all the mills, 2% in the yarn processing areas of all mills, and 6% for the entire population.

BRONCHITIS

Smoking among males has a significant effect on the bronchitis index ($P = 0.0012$) (Table 5). Higher bronchitis index ratings among smoking males are found in the higher age categories ($P = 0.0122$); this is most evident among males in the high exposure-risk group. Although differences in present work-area exposure among males did not have a significant effect on the byssinosis index, they had a highly significant effect on the bronchitis index ($P = 0.0003$). There were no first- or second-order interactions for the bronchitis index. In women, only smoking had a significant effect on the bronchitis index ($P = 0.0162$). No work-area exposure effect, aging effect, or first- or second-order interaction was evident.

When the 25 byssinotics were compared with the matched control workers and differences in cough, phlegm, and respiratory infections were tested, the byssinotic group had a consistently higher percentage of positive responses than the controls (Table 6). The byssinotic group also had a significantly greater number of persons with two or more chest colds per year.

Table 4. Demographic and Environmental Exposure Characteristics of 25 Byssinotic Workers and 25 Matched Control Workers

	Byssinotic Workers	Control Workers
Sex, *% men*	88.0	88.0
Mean age, *yr*	49.5	49.7
Race, *% white*	100.0	100.0
Cigarette smoke exposure		
Current cigarette smokers, *%*	80.0	80.0
Mean years smoking, *no.*	26.8	27.4
Mean pack years, *no.*	31.0	26.2
Cotton dust exposure		
20 years in textiles, *%*	76.0	72.0
Work area		
Preparation, *%*	80.0	80.0
Yarn processing, *%*	20.0	20.0

DYSPNEA

The smokers of the male, high exposure-risk group had relatively high dyspnea index ratings (Table 7). When the seven hypotheses were tested in men, however, no significant smoking, aging, or exposure effect nor any interaction of these effects was demonstrable. In women a positive interaction was found between smoking effect and age effect on dyspnea ($P = 0.00083$), but none of the other hypotheses were disproved.

When questionnaire responses to three questions dealing with breathlessness were compared for the 25 byssinotics and the matched control workers, the byssinotics again had consistently more positive responses than the controls (Table 8). Over 50% of the byssinotics reported that they had "lung

Table 5. Bronchitis Index: Percentage of Subjects

	Index Rating	Never Smoked				Current Smokers				Ex-Smokers				Total
Age, *yr*		15-34	35-49	50-70	Total	15-34	35-49	50-70	Total	15-34	35-49	50-70	Total	
Men*														
Exposure-risk group														
High		n=9	n=4	n=10	n=23	n=35	n=29	n=21	n=85	n=5	n=5	n=11	n=21	n=129
	0	56	25	50	48	34	24	19	27	40		36	29	31.0
	1	44	50	30	39	46	35	24	37	60		18	38	37.2
	2		25	10	9	11	28	43	23		40	46	33	23.3
	3			10	4	6	7	5	7					5.4
	4					3	7	10	6					3.0
Moderate		n=12	n=3	n=5	n=20	n=29	n=22	n=20	n=71	n=3	n=4	n=8	n=14	n=105
	0	58	67	60	60	45	46	40	47	100	50	57	64	49.5
	1	42	33	40	40	31	18	25	25		50	29	29	28.6
	2					17	18	15	17					11.4
	3					7	9	10	9			14	7	6.7
Women†	4						9	10	4					3.8
Exposure-risk group														
Moderate		n=14	n=18	n=35	n=67	n=21	n=24	n=10	n=55	n=1	n=6	n=3	n=10	n=132
	0	64	45	51	52	48	46	50	47		17	67	30	48.5
	1	21	39	40	36	14	25	20	20	100	67	33	60	31.1
	2	7	11	6	8	19	25	20	22					12.9
	3	7	6	3	5	19	4		9		17		10	6.8
	4							10	2					0.8
Low		n=4	n=7	n=16	n=27	n=3	n=4	n=6	n=13	n=0	n=1	n=1	n=2	n=42
	0	50	57	56	56	33	25	50	39		100	100	100	52.4
	1	50	29	44	41		25	33	24					33.3
	2		14		4	67	25	17	31					11.9
	3						25		7					2.4
	4													

* H1: $P = 0.0012$; H2: $P = 0.0122$; H3: $P = 0.0003$; H4: N.S. (not significant); H5: N.S.; H6: N.S.; H7: N.S. *See* Methods in text for explanation of hypotheses.
† H1: $P = 0.0162$; H2: N.S.; H3: N.S.; H4: N.S.; H5: N.S.; H6: N.S.; H7: N.S.

Table 6. Questionnaire Assessment of Cough, Phelgm, and Colds*

	Byssinotic Workers	Control Workers	*P* Value†
		%	
Cough for 90 days per year	44	20	N.S.
Cough daily	44	24	N.S.
Production of phlegm	68	36	N.S.
Chronic cough plus phlegm	40	16	N.S.
≥Two chest colds per year	52	24	<0.05
≥Two head colds per year	56	48	N.S.

* For 25 byssinotic workers and 25 matched control workers.
† N.S. = not significant.

trouble" or "difficulty breathing." No byssinotic thought he could do heavy labor without excessive shortness of breath better than the average man of his age. Thirty-two percent of the byssinotics indicated that they became breathless walking an incline, and some were dyspneic with less exertion.

PULMONARY FUNCTION TESTS

Of the 27 preparation-area workers studied by flow-volume loop, 5 were byssinotics. Four, who had no history by physician interview of grade 1 or 2 byssinosis but who had decrements in flow of 15% or more at 50% of vital capacity, were categorized as "reactors." The mean flow rate of the four reactors (0.79 litres/second) was somewhat lower than the five byssinotics (1.04 litres/second). The 18 other employees had a mean flow rate more than twice as great as the byssinotics or reactors (2.14 litres/second). Both byssinotic (−29%) and reactor groups (−39%) had marked decrements in flow at 50% of volume after 6 hours of dust exposure, whereas the 18 other employees increased their flow rate minimally (+8%).

When spirometry results on 134 males and 100 females were categorized by sex, age, and smoking history, the numbers were insufficient to allow comparison of some categories (Table 9). Among men, the lowest values were in the smokers who worked in high exposure-risk areas. The mean FEV_1 for 66 men in this category was only 76% of predicted, and their FVC was 90% of that predicted. Forty-six male smokers working in the less dusty spinning, winding, and twisting areas had consistently higher mean levels in each category. Nonsmoking men in both exposure areas had better pulmonary function than their smoking co-workers. Among women, those currently working in the synthetic mill had slightly lower mean levels than those working in cotton, but the differences were small. As in the male subpopulation, nonsmoking females in both exposure

Table 7. Dyspnea Index: Percentage of Subjects

	Index Rating	Never Smoked				Current Smokers				Ex-Smokers				Total
Age, *yr*		15-34	35-49	50-70	Total	15-34	35-49	50-70	Total	15-34	35-49	50-70	Total	
Men*														
Exposure-risk group														
High														
		n=9	n=4	n=10	n=23	n=35	n=29	n=21	n=85	n=5	n=5	n=11	n=21	n=129
	0	89	100	70	83	74	67	63	68	80	100	55	72	71.3
	1	11		20	13	17	13	26	18	20		27	19	17.1
	2			10	4	9	10	11	9					7.0
	3						10		2					1.5
	4							11	2			18	10	3.1
Moderate		n=12	n=3	n=5	n=20	n=29	n=22	n=20	n=71	n=3	n=4	n=7	n=14	n=105
	0	83	100	60	80	79	77	70	76	67	50	57	57	74.3
	1	17		20	15	10		10	7		25	29	21	10.5
	2			20	5	10	14	5	10	33	25	14	21	10.5
	3						9	15	7					4.8
Women*	4													
Exposure-risk group														
Moderate		n=14	n=18	n=35	n=67	n=21	n=24	n=10	n=55	n=1	n=6	n=3	n=10	n=132
	0	100	78	77	82	57	62	80	64		33	67	40	71.2
	1		17	14	12	24	33	10	26		50	33	40	19.7
	2		6		2	19	4		9	100	17		20	6.1
	3			6	3									1.5
	4			3	2			10	2					1.5
Low		n=4	n=7	n=16	n=27	n=3	n=4	n=6	n=13	n=0	n=1	n=1	n=2	n=42
	0	100	71	63	70	67	50	50	54		100	100	100	66.7
	1		14	19	15	33		33	23					16.7
	2		14	6	7		25	17	15					9.5
	3			13	7		25		8					7.1
	4													

* For men, hypotheses 1 through 7 are not significant (N.S.); for women, H1: N.S.; H2: N.S.; H3: N.S.; H4: $P = 0.0038$; H5: N.S.; H6: N.S.; H7: N.S. *See* Methods in text for explanation of hypotheses.

groups had consistently better function than their smoking counterparts.

DUST SAMPLES

No indication of byssinosis risk could be derived from total-dust levels in this plant (Table 10). The highest total-dust level, 2.8 mg/m^3, was obtained in the winding and spinning areas of Mill 2, where the byssinosis prevalence was below 5%, whereas somewhat lower total-dust levels were found in the opening, picking, and carding areas, where the byssinosis prevalence was greater than 20%. In synthetic-blend Mill 1, there appears to be little difference in total-dust level between the carding and spinning areas.

Only six samples were collected by the cyclone dust separator. One lint sample was lost, and the lint samples from the carding area are so low that it is thought they represent partial samples. There is just one sample from the yarn processing areas, where there was a very low "respirable" fraction of 0.02 mg/m^3.

Discussion

Like all cross-sectional industrial surveys that attempt to assess risk factors, the fact that the study population is composed of survivors influences the estimation of risk to an unknown degree. This is especially true in this plant, where workers have the opportunity to select a less hazardous work area. Because of the workers' limited recall for past events, it was often not possible to determine the time of onset of byssinosis, where this occurred in the mill, or its relation to variables such as smoking, chronic cough, and phlegm. To estimate exposure risk, it was therefore necessary to use the current work area, which is probably a good indicator of byssinosis risk but a less accurate indication of bronchitis risk, and it is frequently misleading in estimating dyspnea risk.

Other methodological problems, most of which have been resolved in subsequent studies, arose in this, our initial survey of a textile population. The well-standardized British Medical Research Council Respiratory Questionnaire, modified for byssinosis, is the preferred questionnaire. Although there is no evidence that the elimination of pulmonary function data on 198 subjects biased the data reported, it did limit the numbers available in some categories, which prevented meaningful statistical analysis of this information. Simple, reliable testing equipment is preferable to sophisticated laboratory devices for such surveys. To eliminate the acute decreases in expiratory flow caused by inhalation of cotton dust, all subjects should be tested before starting work on Monday.

Table 8. Questionnaire Assessment of Breathing Ability and Shortness of Breath*

	Byssinotic Workers	Control Workers	*P* Value†
	%		
Trouble with lungs or difficulty breathing	52	16	<0.025
Heavy labor without excessive shortness of breath			
$\geq$Average for age	64	88	N.S.
$<$Average for age	36	12	
Dyspnea walking on incline, level, at rest, lying down	32	12	N.S.

* For 25 byssinotic workers and 25 matched control workers.
† N.S. = not significant.

BYSSINOSIS

Although this textile plant had a modern ventilation and filtration system and an exhaust system on carding engines, and it processed a middling (medium) grade of cotton plus synthetic material, 20% of those employed in preparation areas gave characteristic histories of grade 1 or 2 byssinosis. This prevalence confirms previous findings (1-3) in U.S. mills processing only cotton. Although some reduction in byssinosis prevalence would be expected for any given grade of cotton blended with synthetic, there would still be a relation of prevalence to the amount of cotton dust in the raw cotton. Therefore, workers in the preparation areas of mills blending substantial percentages of low and medium grades of cotton with synthetic material are expected to have a substantial byssinosis risk. The prevalence of 2% in yarn processing areas in this mill complex is much lower than that found in previous U.S. surveys. This is probably owing to the use of a medium grade of cotton with only a moderate initial dust content, combing of the cotton during preparation, and yarn processes that are segregated from the preparation areas both physically and by ventilation design. Thus, the yarn was the only carrier of biologically active dust to these areas. When a low grade of cotton is used or when yarn processing areas are contiguous with preparation areas physicially or by ventilation design, the prevalence of byssinosis should be higher and may equal that in preparation areas (1). Construction of walls and design of ventilation systems to isolate the preparation area can substantially reduce the hazard for other workers.

Statistical analysis indicates that cigarette smoking increases the frequency and severity of byssinosis, as shown by the index ratings. This is consistent with the findings of Elwood and associates (4), in their study of flax operatives. McKerrow and Schilling (9) suggested that cigarette smoking potentiates the

Table 9. Spirometry

Age, *yr*	Variable*	Never Smoked 15-34	Never Smoked 35-49	Never Smoked 50-70	Never Smoked Total	Current Smokers 15-34	Current Smokers 35-49	Current Smokers 50-70	Current Smokers Total	Total
Men										
Exposure-risk group										
High		n=4	n=1	n=3	n=8	n=27	n=20	n=19	n=66	n=74
	FEV_1, *litres*	4.43	2.86	2.86	3.65	3.19	2.89	2.53	2.90	2.99
	% predicted	101.4	77.0	80.2	90.4	76.0	76.0	75.3	76.0	77.4
	FVC, *litres*	6.31	5.41	4.18	5.40	4.80	4.15	3.77	4.31	4.42
	% predicted	120.5	117.5	91.2	109.1	95.3	86.5	86.0	90.0	92.0
	MMEF, *litres/sec*	5.68	2.70	2.99	4.33	3.53	2.38	2.08	2.74	2.88
Moderate		n=8	n=2	n=4	n=14	n=22	n=17	n=7	n=46	n=60
	FEV_1, *litres*	4.40	4.26	3.17	4.02	3.62	3.16	2.87	3.34	3.50
	% predicted	103.0	115.2	92.5	102.0	85.0	82.3	86.0	84.4	88.4
	FVC, *litres*	5.48	5.35	3.82	4.99	5.29	4.88	3.89	4.93	4.94
	% predicted	109.0	115.2	84.3	103.0	104.0	103.0	89.2	101.1	101.4
	MMEF, *litres/sec*	5.10	3.84	4.02	4.62	3.77	3.04	1.96	3.23	3.55
Women										
Exposure-risk group										
Moderate		n=9	n=3	n=10	n=22	n=21	n=21	n=12	n=54	n=76
	FEV_1, *litres*	3.07	2.17	2.12	2.51	2.34	1.23	1.98	2.11	2.26
	% predicted	99.0	76.0	86.0	90.0	74.4	70.3	82.0	86.0	91.0
	FVC, *litres*	3.64	4.25	2.92	3.32	3.53	2.95	2.69	3.11	3.17
	% predicted	105.1	112.0	99.5	103.4	100.2	92.0	94.0	95.5	98.0
	MMEF, *litres/sec*	3.08	3.36	2.62	2.90	2.35	1.72	1.77	1.97	2.24
Low		n=2	n=1	n=4	n=7	n=2	n=7	n=8	n=17	n=24
	FEV_1, *litres*	3.46	2.90	2.32	2.73	2.38	2.31	1.94	2.15	2.31
	% predicted	104.2	103.0	98.0	100.3	79.1	81.0	78.5	80.0	86.0
	FVC, *litres*	4.25	3.71	2.92	3.41	3.76	3.24	7.72	3.05	3.16
	% predicted	114.0	113.0	103.3	108.0	112.0	99.0	93.0	97.5	100.5
	MMEF, *litres/sec*	4.17	3.86	2.67	3.27	2.96	2.44	1.73	2.17	2.49

* FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; MMEF = maximal mid-expiratory flow.

effect of cotton dust inhalation. The highly significant interaction between smoking and dust exposure, on the byssinosis index, supports this impression. The smoker exposed to high amounts of cotton dust is, by all the variables considered in this study, the individual most likely to suffer ill effects from his occupational exposure. Therefore a prudent policy would exclude moderate and heavy smokers from areas of high exposure to cotton dust.

CHRONIC BRONCHITIS

The similarity in the distribution of byssinosis and chronic bronchitis prevalence and the frequent findings of chronic cough and phlegm in byssinotics exposed to flax dust led Elwood to the concept that byssinosis is "basically a chronic bronchitic process with superimposed acute phenomena" (18). The characteristic Monday acute features of chest tightness and decreased expiratory flow rate distinguish byssinosis from chronic bronchitis. In the late stages of byssinosis, when the weekly periodicity is lost, differentiation becomes more difficult because longer periods away from dust exposure are needed to effect a perceptible improvement in symptoms.

One problem in relating byssinosis and chronic bronchitis concerns definitions. Byssinosis as defined by Schilling's grading system (13) is based only on acute symptoms, except in grade 3, in which there must be evidence of disability. Chronic bronchitis is always defined by symptoms persisting for months (19) and may require exertional dyspnea to fulfill the definition (20). From our bronchitis and byssinosis indexes, the frequency of bronchitis in the population of this study is higher than that of byssinosis. Responses were reversed in other studies that used standard definitions (4, 21). There is a much higher percentage of this population with a bronchitis index of 1 + than a byssinosis index of 1 +. Male smokers in the high exposure-risk area had the highest bronchitis indexes, with over 80% of those in the group 50 years of age or older having an index of 1 or more. Statistical analysis showed both smoking and aging effects, in addition to a highly significant exposure-risk effect ($P = 0.0003$). When the index ratings of all three conditons were analyzed for the effect of exposure-risk alone, only the effect on bronchitis index ratings was significant. Despite differences between our bronchitis index and standard definitions, which make interpretation of the magnitude of bronchitis difficult, this analysis does suggest that chronic bronchitis is strongly associated with cotton-dust exposure.

The strong effect of cigarette smoking on index ratings for byssinosis and bronchitis suggests that the effect on the airway in byssinosis may be similar to or the same as that in bronchitis. This, coupled with the strong effect of cotton dust on bronchitis, suggests that chronic bronchitis may be the basic pathologic process resulting in pulmonary dysfunction in cotton textile workers with byssinosis. The high prevalence of bronchitis symptoms among the 25 byssinotic workers supports this concept. Of special interest were workers with typical byssinosis who stopped smoking cigarettes without changing their work area and observed that their byssinosis symptoms disappeared. Some workers stated they got "a fresh chest cold" after returning to the mill after a holiday of several days away from the mill. The hypothesis that byssinosis is basically chronic bronchitis could account for the chronic effects of byssinosis and could also explain susceptibility in byssinosis (4). It is suggested that one determinant of byssinosis susceptibility is the presence of chronic bronchitis. Individuals in whom airway clearance is impaired (smokers and bronchitics) probably accumulate larger quantities of biologically active dust in their small airways, which may produce greater airway responses. The pattern of physiological response (decrement in flow rates) and the symptoms may depend upon the clearance of biologically active dust.

From the data on this investigation it may be concluded that both byssinosis and chronic bronchitis, as defined by their respective indexes, were frequent clinical manifestations of cotton-dust exposure and cigarette smoking. In this cotton-dust exposed population, cigarette smoking apparently contributes more to the severity of these diseases than does work exposure. One cannot conclude, however, that smoking is more significant than cotton-dust exposure without a control group with no exposure to cotton dust and under these circumstances of investigation.

DYSPNEA

There was more dyspnea in the high exposure-risk group of men, but in women this trend was reversed. The group of 25 byssinotics consistently reported more breathlessness than the control group. Several factors complicate the analysis of this symptom in this population. The questionnaire did not specify whether the worker should judge his dyspnea on the weekend while away from the mill or during the workweek. It is therefore likely that some of the increase in breathlessness reported by the byssinotics reflected acute symptoms on Monday, thereby making the comparison of these two groups less meaningful. In considering the population as a whole, other factors frustrate the understanding of breathlessness.

Early symptoms of byssinosis and chronic bronchitis are rarely severe enough to make the worker seek medical advice, stop smoking, or seek a less dusty working environment. But breathlessness stimulates the worker to eliminate or reduce this distress, as evidenced by the higher percentage of ex-smokers in the high-risk areas and higher dyspnea-index ratings in both males and females in the synthetics work area. Physician interviews of dyspneic workers in this plant support these observations. Some leave the mill, which represents another self-selective process away from a harmful environment (22).

Table 10. Total-Dust and Cyclone-Fractionated Dust Samples

Dust Samples	Work Area						
	Opening	Picking	Carding	Combing	Roving	Spinning	Winding
Total-dust samples							
Mill 1*							
Number of samples	—	—	2	1	1	4	—
Mean weight, *mg/m³*	—	—	1.5	1.7	1.8	1.5	—
Mill 2*							
Number of samples	4†		4	2	6	6	6
Mean weight, *mg/m³*	1.5†		1.5	2.3	1.8	2.8	2.8
Cyclone-fractionated samples							
Mill 2							
Number of samples	1	1	2 (a & b)‡	1		1	
Fraction, *mg/m³*							
Respirable§	0.13	0.24	0.11 (a) 0.12 (b)	0.15		0.02	
Middle§	0.24	1.04	0.08 (a) 0.20 (b)	1.53		0.60	
Lint	Lost	3.86	0.04 (a) 0.03 (b)	1.20		1.22	
Total fractions, *mg/m³*	—	5.14	0.23 (a) 0.35 (b)	2.88		1.84	

* Mill 1 produces 50% polyester, 50% cotton; Mill 2 produces 100% cotton.
† These samples from opening and picking areas combined.
‡ Separate values are given for the two samples from the carding area.
§ A respirable fraction is less than or equal to 10 μ; a middle fraction is between 11 μ and 2 mm.

SPIROMETRY

A summary of the portion of this small population for which adequate pulmonary function data were available indicates two trends. The first is consistently lower expiratory flow rates in smokers than in nonsmokers in all exposure-risk areas among men and women. The second is a trend toward lower values in the higher exposure-risk areas. Because the study was conducted during the work shifts, almost all workers had been exposed to cotton dust before spirometry. Since the survey was conducted on a Monday and Tuesday, some of the differences may reflect acute effects of dust exposure on expiratory flow rates and vital capacity. It is improbable, however, that all of the difference between the high and moderate exposure-risk groups of the male workers (a 10% difference in FEV_1) is due to acute dust exposure.

Of greatest interest are the relatively low mean values for an employed population. A larger exposed population, particularly an adequate number of nonsmokers, and a satisfactory control population of unexposed workers studied prospectively is needed to determine the effect of cotton-dust exposure alone and in combination with cigarette-smoke exposure on ventilatory capacity among cotton-textile workers.

DUST SAMPLING

The present TLV for cotton dust of 1 mg/m^3 total dust is based on the early work of Roach and Schilling (23), who studied only carding operatives. More recent studies suggest that the "respirable" fraction of dust is the most important fraction for indicating byssinosis risk (11, 12). Many U.S. mills are partially or completely air-conditioned, resulting in filtration and the elimination of much lint and larger dust particles. Often cardrooms that have carding exhaust systems will appear free of lint and dust, but they may have significant levels of "respirable" dust. In contrast, some yarn processing areas may have high levels of cotton lint in the air that are well in excess of the present TLV, yet have little "respirable" dust and, thus, a low risk for byssinosis. The samples collected in this plant, which had both a cardroom exhaust system and air conditioning, suggest that total-dust samples under such conditions are not an indication of byssinosis risk.

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► Requests for reprints should be addressed to James A. Merchant, M.D., Division of Environmental Medicine, Department of Internal Medicine, Duke University Medical Center, Durham, N.C. 27706.

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Appendix

BYSSINOSIS INDEX QUESTIONS

1. Have you in the past, or do you now, develop a cough at work? Yes______ No______

2. Have you in the past, or do you now, develop a tight feeling in your chest while at work? Yes______ No______

3. Have you in the past, or do you now, become short of breath at work? Yes______ No______

If yes for 1, 2, 3, did or does this occur: primarily during the latter part of the week, especially on Friday______; primarily in the first part of the week, especially on Monday______; only on Monday______; only on Friday______; on no particular day______.

If yes, plus underlined response: [1] cough = 4 points; [2] tightness = 8 points; [3] shortness of breath = 8 points.

4. Is your breathing better when you are away from work? Yes = 2 points; No = 0 points.

5. Have you in the past or do you now have trouble breathing normally at the beginning of the workweek but find that your breathing improves as the week goes on? Yes = 6 points; No = 0 points.

Index Rating		Total Points
0	=	<2
1	=	2-5
2	=	6-9
3	=	10+

BRONCHITIS INDEX QUESTIONS

1. Do you have a cough?
   Only with colds
   Daily on arising
   Throughout the day
   Never

2. Do you have a cough for as many as 90 days a year?

3. Do you bring up phlegm when you cough?

4. How many chest colds do you have a year?
   One
   Two
   Three
   More than three
   None

One criteria per question, if yes or any underlined response.

Index Rating		Number of Criteria
0	=	0
1	=	1
2	=	2
3	=	3
4	=	4

DYSPNEA INDEX QUESTIONS

1. Do you feel you can do heavy labor without excessive shortness of breath?
   Better than average for age
   Average for age
   Below average for age

2. Do you have shortness of breath?
   Climbing 2 flights of stairs
   Climbing 1 flight of stairs
   Walking up a slight incline or briskly on the level
   Walking on the level
   At rest
   Lying down
   Never

3. Do you have trouble with your lungs or difficulty breathing?

4. Do you wake up short of breath at night?

One criteria per question, if yes or any underlined response.

Index Rating		Number of Criteria
0	=	0
1	=	1
2	=	2
3	=	3
4	=	4

The Patient

MY ANXIETY is that today, with the continuing shortage of doctors, the increasing complexities of medicine and surgery, the inevitable change in doctor-patient relationships brought about by the National Health Service, and the influence of other pressures in modern society, we are in danger of losing sight of the precious heritage of respect for human dignity and consideration for the individual for which British medicine is so deservedly renowned.

It is surely a sad reflection on the medical profession in Great Britain today that there should be a place for a flourishing organization known as 'The Patients' Association', the stated purpose of which is to safeguard the rights and dignities of those entrusted to our care!

That well-known prayer composed by the late Sir Robert Hutchison touches on the subject: 'From inability to let well alone; from too much zeal for what is new, and contempt for what is old; from putting knowledge before wisdom, science before art, and cleverness before commonsense; *from treating patients as cases;* and from making the cure of the disease more grievous than its endurance, Good Lord deliver us!'

K. F. STEPHENS
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