self from employment so that no adverse effect can be statistically demonstrated in those remaining. We believe this to be unlikely, since this phenomenon has not eliminated significant differences in other segments of the cotton industry. Furthermore, two of the authors with more than 38 combined years of pulmonary practice in the San Joaquin Valley have failed to identify a single case of byssinosis. This negative experience was confirmed by a survey of more than 440 San Joaquin Valley physicians who might have had an opportunity to care for cotton gin workers.

Summary

No excess of obstructive airway disease was found in a group of 265 cotton gin workers when compared with other San Joaquin Valley agricultural workers. After an average of eight weeks' employment in San Joaquin Valley cotton gins, 125 workers showed no appreciable deterioration of pulmonary function compared with pre-employment measurements.

In studies of pulmonary function during a workshift, cotton gin workers showed slightly greater mean decrements than control agricultural workers. These differences did not reach a level of statistical significance and were lower than those usually found in byssinosis.

The unusual temporal pattern of employment in cotton gins in California precludes a simple approach to diagnosis by symptoms. No correlation was found in this study between symptoms of byssinosis and objective decrements in FEV_1. The questionnaire as proposed by the Cotton Dust Standard was found to be of no value in detecting reactors in this study of gin workers.

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The Relation of Lung Function to Subsequent Employment Status and Mortality in Cotton Textile Workers*

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Long-term occupational exposure to cotton textile dust has been associated with the development of chronic obstructive lung disease.[1,2] We investigated the relation of lung function in cotton textile workers to their subsequent employment status and mortality. We wanted to determine whether lung function in cotton textile workers who died or retired from the mill before age 65 years differed from lung function in those still active in the mill. Although many studies have investigated lung function in active cotton textile workers, only one (our previous study[1]) has examined lung function in retired workers. Our findings in the present study are based on the previous cross-sectional one as well as on the follow-up study of these same older active and retired cotton textile workers in Columbia, SC.

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Subjects and Methods

Our original study population of cotton textile workers included anyone who had worked for at least three years before 1955 in one or more of four mills in the Columbia, SC, area. Of the initial 692 workers studied in 1973,[1] we re-examined 408 in 1979, and an additional 89 were determined to have died between the two surveys. For comparison with the textile workers, we used as controls a like-aged population of nontextile workers from Lebanon,

Table 1—*Distribution of Follow-up Populations by Sex and Work Status in 1973 and 1979, Whites Age 45-64 Years*

	Controls (C)	Cotton Textile Workers*			
		Active-Active (A-A)	Active-Retired (A-R)	Retired-Retired (R-R)	Deceased (D)
Males	133	51	44	30	31
Females	124	50	54	59	11
Total	257	101	98	89	42

*A-A = active in 1973 and 1979; A-R = active in 1973, retired in 1979; R-R = retired in 1973 and 1979; and D = deceased in 1979.

Conn, whom we studied with similar methods in 1972[3] and again in 1978. The interval between studies was about six years for both controls and cotton textile workers.

Those who responded to the follow-up surveys were compared with those who did not respond (excluding the deceased) in each of the two studies, Lebanon and Columbia. Comparisons were made within sex, age, and smoking groups. Only isolated differences between respondents and nonrespondents were found when comparisons were made on 13 symptoms and on two lung function measures.[4]

Almost all of the cotton textile workers were white and older than 45 years. For the present study dealing with work status before the age of 65, we will limit the population to whites, ages 45 to 64 at the time of the original survey. The 330 textile workers meeting these criteria and followed up six years later are classified by sex and work status in Table 1. Active implies currently working in the mill; retired implies no longer working in the mill. The pairs A-A, A-R, and R-R refer to work status in 1973 and 1979, respectively. Excluded from the study were four workers who were retired in 1973, but who were again active in the mill in 1979. Deceased are those cotton textile workers examined in 1973 who died before the study in 1979. Table 1 also gives by sex the 257 white controls, 45 to 64 years of age, followed up in Lebanon.

A comparison of the smoking statuses among textile workers and controls for men and women is given in Table 2. The frequency distributions of smoking habits for cotton textile workers and controls do not significantly differ for men. However, for women there is a marginally significant difference ($P = .053$) owing to the fewer exsmokers (9 percent) among the textile workers than among the controls (20 percent). To control for any possible smoking differences, separate analyses were also done, classified by smoking habit. For amount smoked, the only significant differences between textile workers and controls occurred in exsmoking men, where the controls had a mean of 23.5 pack-years vs a mean of 47.3 pack-years in retired-retired textile workers. Male smokers, female smokers, and exsmokers did not differ in pack-years between controls and cotton textile workers in any of the work statuses.

Table 2—*Distribution of Cotton Textile Worker (CTW) and Control (C) Cohorts by Sex and Smoking Status in 1973, Whites Age 45-64 Years*

	Non-smokers	Ex-smokers	Smokers	Total*
Males, No. (%)				
CTW	26 (22)	47 (40)	45 (38)	118 (100)
C	27 (24)	56 (49)	31 (27)	114 (100)
Females, No. (%)				
CTW	103 (64)	15 (9)	44 (27)	162 (100)
C	68 (55)	25 (20)	31 (25)	124 (100)

*Excludes pipe and cigar or ex-pipe and ex-cigar smokers and deceased.

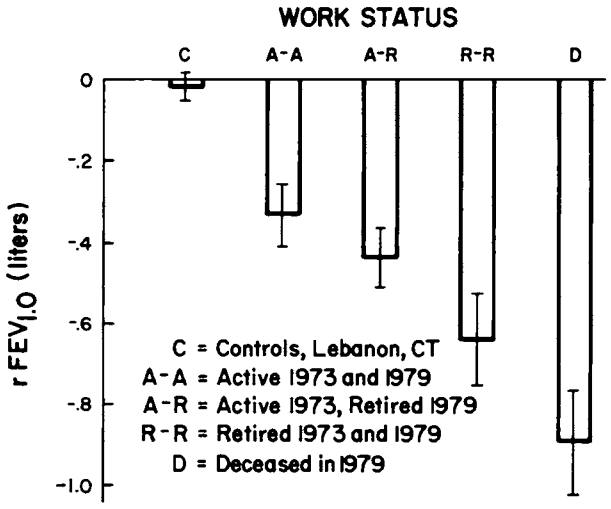

FIGURE 1. Mean (±SEM) residual lung function ($rFEV_1$) in 1973 by work status in 1973 and 1979, in white men age 45-64 years.

To measure lung function, each person performed at least five acceptable maximally forced expirations. The maximum expiratory flow volume (MEFV) curves were recorded, and the average of the two best blows (largest forced expiratory volume, FEV_1) was used for analysis.[5] The test and quality control features (including correction to BTPS volumes) used to obtain the MEFV curves have been given by Bouhuys and Virgulto.[6] This study concentrates on the FEV_1 as a measure of lung function but the maximum expiratory flow at 50% of the forced expiratory volume (MEF50%) was also examined. To account for differences in sex, age, height and weight, the degree of lung function abnormality for each person is evaluated using the residual, that is, the observed value minus the predicted value based on healthy nonsmoking persons in three community populations.[7] A negative residual, then, indicates a loss of lung function compared to a healthy nonsmoker and is expressed in terms of liters for FEV_1 (or L/sec for MEF50%).

The amount of lung function loss in an individual can also be used to define his degree of disability. One criterion for disability proposed by Bouhuys[8] defines total disability as an FEV_1 of less than 50 percent of predicted. One is defined as partially disabled if the FEV_1 is less than 1.96 SE below predicted FEV_1 but greater than or equal to 50 percent of predicted. These degrees of lung function disability will be related to the various work status groups of cotton textile workers.

RESULTS

The mean residual FEV_1 ($rFEV_1$) in 1973 was compared among the control and various work status groups. Figure 1 shows a clear trend of decreasing mean residual lung function for men. The greater losses occur in those workers who retire early or die. A one-way analysis of variance shows significant differences ($P < .0001$) among the mean losses over all groups. The control group is significantly different

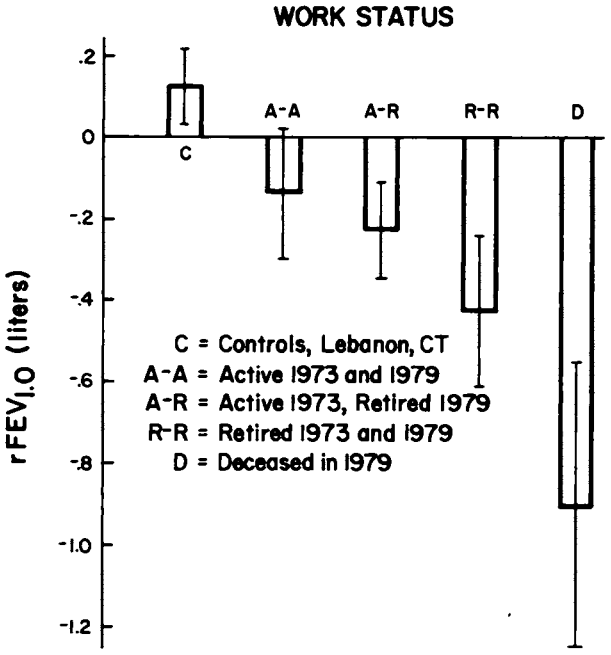

FIGURE 2. Mean (±SEM) residual lung function ($rFEV_1$) in 1973 by work status in 1973 and 1979 in white male nonsmokers age 45-64 years.

($P < .0005$) from each of the cotton textile worker groups. Within textile workers, the active-active and active-retired groups have less loss than the deceased group ($P < .001$), and the retired-retired group has greater loss of FEV_1 than the active-active group ($P = .016$). The same pattern occurred when the analysis was done for residual MEF50%.

The relationship of lung function loss in terms of FEV_1 and work status and mortality within men was further examined separately for nonsmokers, exsmokers, and smokers. The same general pattern as observed in all men was found in each of the smoking status groups. The results in nonsmoking men are shown in Figure 2. As with all men, the differences among the groups were very significant ($P = .003$). The control and active-active groups differed from the deceased group ($P = .003$ and .01, respectively), while the controls differed only marginally from the retired-retired group ($P = .054$).

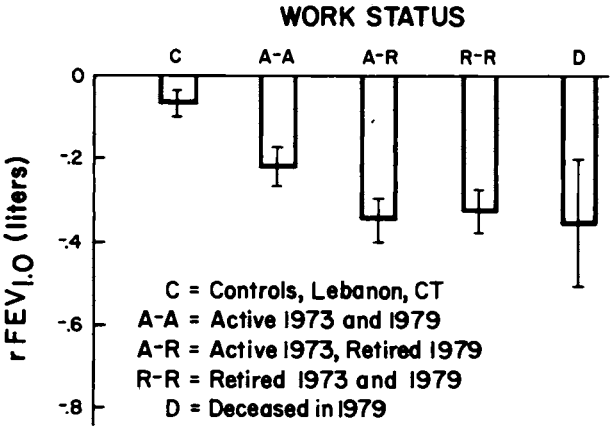

FIGURE 3. Mean (±SEM) residual lung function ($rFEV_1$) in 1973 by work status in 1973 and 1979, in white women age 45-64 years.

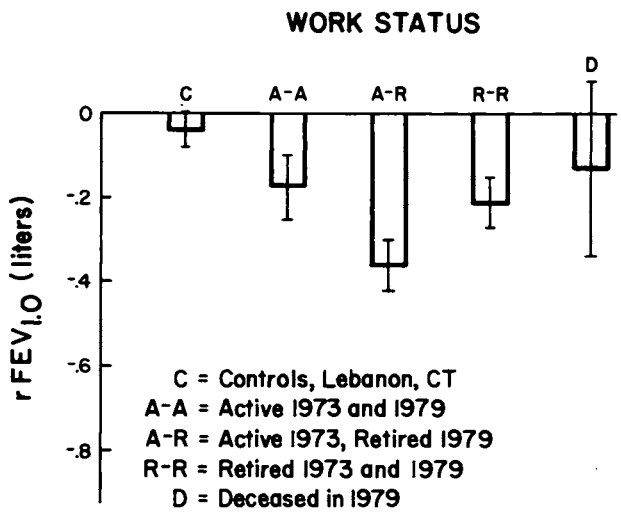

FIGURE 4. Mean (±SEM) residual lung function ($rFEV_1$) in 1973 by work status in 1973 and 1979, in white women nonsmokers age 45-64 years.

This trend in lung function decrement across work status groups is not due to differences in the length of cotton dust exposure or amount smoked. There was no increase (or decrease) in mean number of years worked in the mill across work status groups. For men, the largest mean number of years worked in the mill occurred in the active-retired group except for the smoker subgroup. For smokers, the deceased group had the largest length of exposure (36.8 years), but this was nearly the same as in the active-retired group (35.7 years). There was an increasing trend in amount smoked in pack-years across work status groups. (One pack-year = 20 cigarettes smoked per day for one year.) However, the means did not differ significantly between controls and cotton textile workers except in exsmoking retired-retired men. When adjusting for pack-years with an analysis of covariance, the significant differences in $rFEV_1$ among work status groups remained as before.

A similar analysis for women was done to relate lung function in 1973 with work status. The results for all women combined are shown in Figure 3. There are significant differences ($P < .0001$) in mean $rFEV_1$ among the five groups shown; however, the trend seen in men is no longer present. The controls differ significantly from each of the cotton textile worker groups ($P < .02$) but the latter do not differ among themselves. When analyzed separately for the three smoking status groups, no general trends appear. For example, the results for women nonsmokers are shown in Figure 4. Here the active-retired workers have the largest decrement in FEV_1 and are different from controls ($P < .0001$) and from the active-active group ($P = .035$). The retired-retired group differed from the controls ($P = .017$) but not from the other groups, while the deceased (only four of them) did not show a significant loss. The same results occurred when residual MEF50% was analyzed.

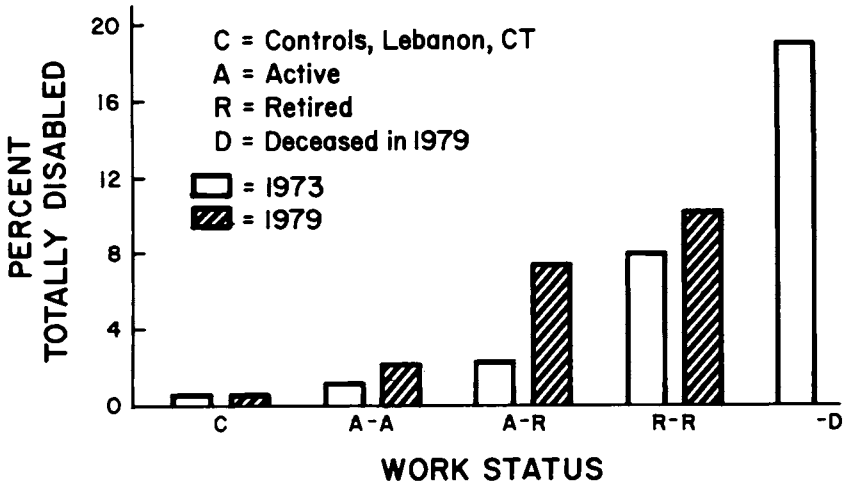

FIGURE 5. Percent totally disabled (FEV_1 < 50% pred) in 1973 and 1979 by work status, whites aged 45-64 years.

The degree of loss in FEV_1 over the various work status groups in women is not explained by differences in mean length of work in the mill or pack-years. The mean lengths of work for all women in the active-retired and deceased groups were nearly identical (38 years); and they were larger ($P < .06$) than the means for each of the other two groups (31 years). The same pattern occurred in nonsmoking women. The amount smoked in pack-years did not differ among any of the work status groups and the control group. Therefore, the amount smoked does not explain the lung function differences found between the controls and the cotton textile worker groups in women.

In addition to residual lung function, we used categories of partial and total disability as defined previously to relate pulmonary dysfunction to work status. The percentages of cotton textile workers with partial disability or total disability in 1973 or 1979 were compared with the percentages in the controls. Figure 5 shows increasing percentages ($P < .0001$) of totally disabled persons in 1973 and in 1979 across the work status groups. When analyzed separately for nonsmokers, exsmokers, and smokers (based on the smoking status in the same year as disability was determined), similar trends of increasing total disability occur. In addition, for cotton textile workers, the percentages of disability in 1979 are always higher than in 1973.

The prevalences of partial disability in 1973 and 1979 by work status are shown in Figure 6. There is no increasing trend of the percentages of disability across the work status groups of cotton textile workers. There are, however, highly significant differences ($P < .004$) in the percentage of partially disabled persons between the control group and each of the cotton textile worker groups for both 1973 and 1979. The same pattern holds when looking at the percentages of partially disabled for each of the three smoking status groups used before.

DISCUSSION

We have shown that white cotton textile workers age 45 to 64, regardless of work status, have lower mean lung function than a control population of nontextile workers. This result could not be explained by differences in numbers of smokers or exsmokers or in

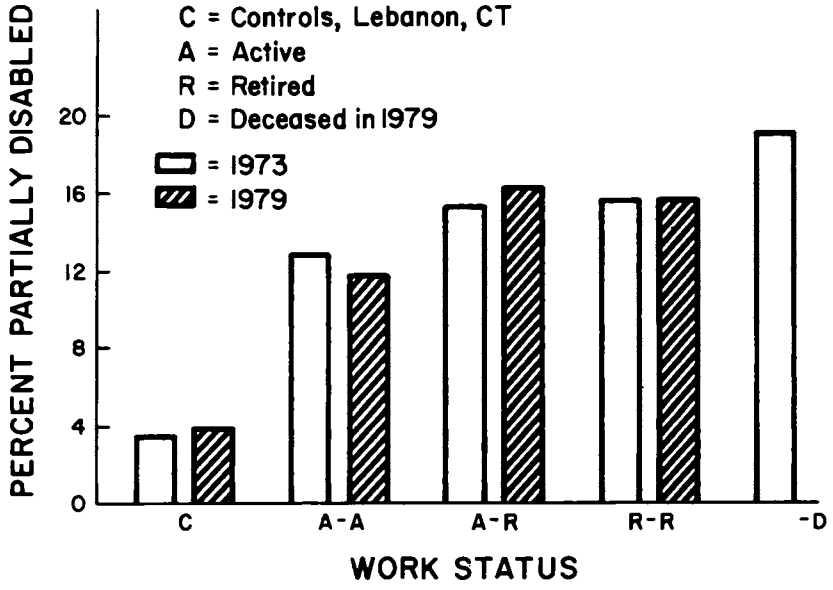

FIGURE 6. Percent partially disabled (50% pred ≤ FEV_1 < pred − 1.96 SE) in 1973 and 1979 by work status in whites age 45-64 years.

amount smoked between the textile workers and controls. These findings on persons who were followed up are similar to the conclusions from the original cross-sectional study.[1]

Our study documents for the first time that in male cotton textile workers there is a relationship between early retirement from the mills or mortality and lung function decrement. This is also true for men in smoking subcategories. The trend of increasing loss of lung function for those men who retired early or who died was not due to differences among the work status groups in amount smoked or number of years worked in the mill.

This trend was not apparent in female cotton textile workers. The reason for this is not clear. Women in all work status groups had nearly identical mean ages and also number of years worked in the mill as the men. The actual lung function losses among nonsmokers in women workers are greater than in the corresponding men for the active-active and active-retired groups. However, the retired-retired female nonsmokers have less lung function loss than corresponding men. This may imply that nonsmoking women who were retired in 1973 have recovered some lung function compared with similar men.

There are in general more totally and partially disabled cotton textile workers than controls. Total disability also correlates with early retirement or mortality in the mill workers. There is some indication (Fig 5) that the percentage of workers totally disabled has increased over the six years between the two surveys. This is true even in workers who retire early and are no longer exposed to cotton dust. This would indicate that the rate of lung function loss in these retired workers is large enough over this short period to result in an increased risk of total disability.

In summary, the older cotton textile workers in our study have lower lung function and greater disability than similarly aged controls. Furthermore, there is a relationship between early retirement or mortality and lung function decrement in men and with total disability in all workers. Therefore, our study indicates that observing only active cotton textile workers may seriously underestimate the prevalence of lung disease.

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Respiratory Health in Cottonseed Crushing Mills*

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This presentation summarizes our experience in three cross-sectional studies of respiratory health in cottonseed crushing mills. These studies were done in 1975, 1977, and 1978. Three mills were visited on all three occasions, another twice, and another once. In the course of these studies, health data were collected on a total of 444 subjects in the five mills.

In the United States, crushing mills receive cotton-seed directly from the gins, with fibrous linters firmly adherent to each seed. This fibrous portion is contaminated with bracts, stems, dirt, and other contaminants similar to those of baled cotton fiber.[1] The major steps in production include storage, removal from storage, cleaning with mechanical shakers, delinting with circular saws, hull removal with mechanical knives, cooking of meats, oil extraction by press or solvent extraction, and production of cake or meal from the meat residue. Linters, hulls, oil, cake, and meal are all of commercial value and are processed for storage and shipment.

The dryness of most of the products and the application of high velocity mechanical force at several steps in processing result in dustiness of the workplace. Table 1 summarizes some results of 486 air samples taken in the first study[2] in 1975. Mean dust levels are presented for various areas (elutriated dust) and several jobs (total dust obtained by personal dust sampler) in four mills. Many of these values are clearly in excess of the 0.5 mg/m^3 standard promulgated by the US Department of Labor for nontextile cotton dust exposures.[3] Our initial attempt to quantify exposure was to characterize jobs as having high, intermediate,

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