Long-term Effects of Work Cessation on Respiratory Health of Textile Workers

A 25-Year Follow-up Study

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***Rationale*: The degree to which chronic respiratory health effects caused by exposures to cotton dust and endotoxin is reversible after cessation of textile work is unknown.**

***Objectives*: To investigate changes in lung function and respiratory symptoms after cessation of textile work and to determine whether past exposure to cotton dust and endotoxin or smoking history modify the associations.**

***Methods*: We performed a prospective cohort study consisting of 447 cotton textile workers exposed to cotton dust and 472 unexposed silk textile workers, with a 25-year follow-up. Spirometry testing and respiratory questionnaires were conducted at 5-year intervals. Generalized estimated equations were used to model the average 5-year change in FEV_1 and odds ratios of respiratory symptom prevalence.**

***Measurements and Main Results*: Years since cessation of textile work was positively associated with 11.3 ml/yr and 5.6 ml/yr gains in 5-year FEV_1 change for cotton and silk workers, respectively. Among male cotton workers, smokers gained more FEV_1 per year after cessation of exposure than did nonsmokers, and the risk of symptoms of chronic bronchitis and byssinosis was larger for smoking than for nonsmoking male cotton workers.**

***Conclusions*: Cessation of textile work was significantly associated with improvement in lung function and respiratory symptoms. The positive effect of work cessation was greater for cotton workers than for silk workers. For cotton workers, the improvement in lung function loss after cessation of textile work was greater among smokers, but no differences were observed for silk workers.**

Keywords: respiratory disease; environmental health; cotton textile workers; endotoxin exposure; occupational health

> **AT A GLANCE COMMENTARY**
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> **Scientific Knowledge on the Subject**
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> Occupational exposures to cotton dust and associated endotoxin cause acute and chronic respiratory health effects, but questions remain regarding the reversibility of such effects after cessation of long-term cotton textile work.
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> **What This Study Adds to the Field**
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> Cessation of textile work was associated with improvement in lung function. Lung function, as measured by FEV_1, increased with years since work cessation among exposed cotton workers and unexposed silk workers, but the effect was twice as great for cotton workers. This improvement after work cessation was greater for male cotton workers who smoked.

Occupational exposure to cotton dust can induce acute airway responses such as byssinosis and chronic airways diseases, including chronic respiratory symptoms and excessive decline in lung function. Endotoxin, which is present in cotton dust, may be the causative agent of acute and chronic lung function declines in exposed workers (1–4). Airborne endotoxin exposure has been described as a risk factor for increased annual decline in lung function (5, 6). Cross-sectional and longitudinal studies indicate that the effects of cotton dust exposure and cigarette smoking on lung function decline appear to be additive (7–9). A 5-year longitudinal study suggested that smoking exacerbates the effects of working in cotton yarn preparation (10). Although the chronic respiratory effects of cotton dust exposure are well known, it is not clear whether such effects are reversible after exposure cessation (e.g., after retirement) or whether improvement of exposure-related respiratory health effects is affected by smoking status.

Few occupational epidemiologic studies in the cotton textile industry have focused on chronic lung function changes after work cessation. One study showed no significant difference in lung function parameters between cotton textile workers and a comparison group after retirement (11). After 15 years of follow-up of the Shanghai Textile Workers Study, a prospective cohort analysis, we found a significant correlation between retirement and the prevalence of chronic cough, chronic bronchitis, and dyspnea in cotton workers and found no similar improvement in silk workers (3). The 20-year follow-up study of this population indicated a nonsignificant negative association between years since work cessation and FEV_1 (12). However, only half of the workers were retired at the 20-year follow-up, and many had been retired for only a few years.

Here, we report results from the 25-year survey of textile workers, focusing on changes in lung function over the 25-year period and the impact of years since cessation of cotton textile work on longitudinal change in FEV_1 and the prevalence of chronic respiratory symptoms. In 2006, virtually all of the study subjects had retired, providing additional statistical power. Approximately 50% of the male retirees were smokers, allowing us to assess the effect of smoking status on these associations.

(*Received in original form March 3, 2009; accepted in final form March 24, 2010*)

Supported by NIOSH grant R01 OH02421 and NIH grant ES00002.

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This article has an online supplement, which is accessible from this issue's table of contents at www.atsjournals.org

Am J Respir Crit Care Med Vol 182. pp 200–206, 2010
Originally Published in Press as DOI: 10.1164/rccm.200903-0329OC on March 25, 2010
Internet address: www.atsjournals.org

METHODS

Study Population

Detailed information on the study population and design has been reported previously (13, 14). The prospective cohort study was initiated in 1981, with 447 cotton workers exposed to cotton dust and endotoxin and 472 unexposed silk workers enrolled at baseline. Follow-up surveys were performed approximately every 5 years, most recently in 2006. Retention rates for subjects at the 25-year follow-up were 70.9% (n = 316) and 67.4% (n = 318) for cotton workers and silk workers, respectively. The Institutional Review Boards of the Harvard School of Public Health, the Putuo District People's Hospital, and the Human Resources Administration, China, approved the study.

Exposure Assessment

Work area measurements of airborne cotton dust were measured with a Vertical Elutriator during the first four surveys, and gram-negative bacteria endotoxins were analyzed and quantified from the dust samples using the chromogenic Limulus amoebocyte lysate assay as previously described (15, 16). The cotton mills incorporated synthetic fibers as blends in 1996, reducing cotton dust and endotoxin exposures by half relative to preblend levels (*see* the online supplement for details). Airborne endotoxin concentration estimated from samples collected in the silk mills approximated ambient levels.

Outcome Assessment

Spirograms were performed by trained technicians consistent with methods from previous surveys and according to American Thoracic Society criteria (2, 13). The 5-year change in FEV_1 was calculated by subtracting prework shift FEV_1 of the previous survey from prework FEV_1 at each subsequent survey.

Respiratory Questionnaire

A modified American Thoracic Society standardized respiratory symptom questionnaire (17) that was translated into Chinese and back-translated into English was used to collect information on work and medical and smoking history. We extracted the following respiratory symptoms variables for analysis: chronic bronchitis, chronic cough, dyspnea, and byssinosis, as defined previously (3). We examined prevalence of byssinosis only for actively working cotton workers and at the survey that immediately followed the date of cessation.

Statistical Analysis

Generalized estimating equations (GEEs) (18) were used to account for repeated measures in generalized linear models for lung function change and prevalence of respiratory symptoms. A preliminary analysis was used to select the working correlation structure by fitting linear mixed models for FEV_1 change with biologically plausible structures, including the compound symmetric and first-order autoregressive structures (1). The Akaike's information criterion statistic indicated that the compound symmetric structure yielded the better fit; thus, the exchangeable correlation structure was used as the working covariance structure in the GEE models for all outcomes. We used an identity link function for 5-year change in FEV_1 and a logit link function for binomially distributed respiratory symptoms, including chronic bronchitis, chronic cough, dyspnea, and byssinosis.

All variables, except sex and height (an average of the first three surveys), were treated as time-dependent factors. Years since cessation of textile work was defined as years from the date last worked in a job exposed to cotton dust (for cotton workers) or date last worked in a silk textile processing job (for silk workers). We evaluated alternative methods for treating continuous measures of cumulative exposure to endotoxin (EU/m^3-yr) as a discrete variable but focused on the 75th percentile of the cumulative exposure at each survey to define high and low exposure. Dichotomous covariates were defined for sex (male = 0), cotton dust exposure (silk = 0), smoking status (never = 0), and endotoxin exposure (<75th percentile = 0). Female subjects were virtually never smokers in this study, so pack-years smoked was fit into the adjusted model rather than smoking status. Models were subsequently stratified by sex and smoking status (only for male subjects; *see* Table E1 in the online supplement). Effect modification by smoking status was evaluated in retired cotton and retired silk workers, in separate models, where smoking status was considered fixed rather than time varying. Few workers (9 cotton and 10 silk) stopped smoking after retirement, and change in smoking status after retirement was not associated with FEV_1 level or years since cessation of textile work.

Data analysis was performed by SAS software (version 9.1.3) (SAS institute, Cary, NC).

RESULTS

Consistent with the baseline and previous surveys on this cohort, there were no significant differences in age, height, and sex between the cotton and silk groups in the most recent survey (Table 1). Among the female subjects, 14 (6.0%) cotton

TABLE 1. DEMOGRAPHIC DATA OF COTTON AND SILK WORKERS AT BASELINE AND THE LAST SURVEY

	Cotton Workers		Silk Workers	
	Baseline (1981)	Last Survey (2006)	Baseline (1981)	Last Survey (2006)
Subjects, n (%)	447 (100)	316 (70.7)	472 (100)	318 (67.4)
Age, yr	37.8 ± 10.6	60.8 ± 10.0	36.6 ± 10.7	61.0 ± 10.0
Height, cm	163.9 ± 7.5	162.9 ± 7.7	162.5 ± 7.3	161.8 ± 7.4
Males, n (%)	213 (47.7)	143 (45.1)	199 (42.2)	128 (40.3)
Smoker, n (%)	163 (36.5)	111 (35.0)	124 (26.3)	90 (28.3)
Pack-years*	8.5 ± 9.8	27.2 ± 17.9	9.2 ± 10.0	27.4 ± 17.4
Baseline FEV_1, ml	2,920 ± 838	2,960 ± 708	2,868 ± 792	2,887 ± 673
Cessation/retired, n (%)	0	280 (88.3)	0	290 (91.2)
Years since cessation of textile work†		12.8 ± 5.2		13.4 ± 4.2
Annualized changes in FEV_1 over 25 yr, ml/yr		25.6 ± 14.5‡		−22.5 ± 12.5
Respiratory symptoms				
Chronic bronchitis, n (%)	96 (21.5)	17 (5.4)	36 (7.6)	19 (6.0)
Chronic cough, n (%)	87 (19.5)	6 (1.9)	33 (7.0)	10 (3.1)
Dyspnea,§ n (%)	67 (15.0)	64 (20.2)	18 (3.8)	44 (13.8)
Byssinosis, n (%)	34 (8.0)	5 (1.6)	0	0

Data are presented as means ± SD unless otherwise stated.
* Calculated among ever-smokers only.
† Calculated among retired workers only ($P < 0.0001$).
‡ $P = 0.02$ when compared with silk workers.
§ Reaching ⩾2 on a scale of 1–5, where 1 = no dyspnea, 2 = having to walk slower than a person of the same age at an ordinary pace on level ground because of breathlessness, and 5 = dyspnea at rest.

workers and 4 (1.5%) silk workers were smokers. Although by 2006 silk workers had been retired longer on average than cotton workers, cotton workers had accrued more years since cessation since the 1996 survey. Consistent with previous surveys, cotton workers had a higher frequency of chronic bronchitis, chronic cough, and dyspnea compared with silk workers, although a higher proportion of silk workers reported chronic bronchitis and chronic cough in the last survey. Although cotton workers experienced significantly greater decline in annual FEV_1 than silk workers at each survey, the rate of decline decreased over the follow-up period. Ror cotton workers the annual declines were −32.9 ml/yr, −29.2 ml/yr, and −25.6 ml/yr; for silk workers the annual declines were −28.9 ml/yr, −25.0 ml/yr, and –22.5 ml/yr at the 15, 20, and 25-year follow-up surveys, respectively. Mean percent predicted FEV_1 for cotton workers and silk workers was 99.3 ± 15.3% and 100.0 ± 14.9%, respectively, at the time of their retirement and 106.3 ± 19.2% and 109.8 ± 19.3%, respectively, at the last survey. Forty cotton workers (9.0%) and 31 silk workers (6.5%) died before the end of follow-up.

Approximately 30% of the cotton workers were lost to follow-up at the last survey. Compared with participating cotton workers, nonparticipants at the last survey were more likely to be male, older, and nonsmokers and to have significantly lower annualized changes in FEV_1 over 20 years. No significant difference in cumulative endotoxin exposure was observed at the last survey between participating and nonparticipating cotton workers.

We also evaluated whether cotton workers with reduced FEV_1 at any survey were less likely to participate in the subsequent survey. We found no association between reduced FEV_1 defined as less than 80% of predicted FEV_1 (relative to silk workers at baseline, adjusted for age, height, sex, and pack years) and participation in the subsequent survey. A sensitivity analysis using different cut-offs to define reduced FEV_1 did not change these results. Similarly, no differences were observed between participating and nonparticipating silk workers, except that nonparticipants were more likely to be female and to have more years since retirement at the 2001 survey.

The adjusted average 5-year change in FEV_1, stratified by exposure status and years since cessation of textile work, is presented in Figure 1. Cotton workers lost more FEV_1 than did silk workers during the 5-year period immediately after work cessation, similar to the magnitude of loss when actively exposed. However, the subsequent reversibility of 5-year FEV_1 decline was much greater for cotton workers than silk workers 10 to 15 years after cessation. The improvement in adjusted mean FEV_1 loss was greatest among cotton workers with high lifetime exposure to endotoxin. Cotton workers with high lifetime exposure to endotoxin lost the most FEV_1 during every prior 5-year period but improved most rapidly after work cessation, particularly during the first 10 years. Although improvement leveled off for cotton workers after 15 years, silk workers continued to improve over the entire period of follow-up after work cessation. Cotton workers with low lifetime exposure to endotoxin improved to nearly the same level as silk workers during the first 10 to 15 years after work cessation, but their lung function declined thereafter. The data also suggest a quadratic relationship between years since cessation of textile work and change in FEV_1 among cotton workers and a linear relationship for silk workers.

The models for average change in FEV_1 in the 5-year period are summarized in Table 2. The log likelihood was calculated to compare the goodness of fit between models with and without quadratic terms for years since cessation of exposure in cotton and silk groups. There was a positive linear association for cotton and silk workers between cessation of textile work and 5-year change in FEV_1; however, the rate of improvement was almost twice as great for cotton workers (11.6 vs. 5.6 ml/yr in the two groups, respectively). A significant quadratic effect was also observed for cotton workers ($P < 0.05$), wherein the initial rate of improvement was followed by a plateau. The inverse effect of pack-years was more pronounced in cotton workers than in silk workers.

When the models for average 5-year change in FEV_1 were stratified by sex and smoking status (Table 3), cotton workers improved more than silk workers in all subgroups. In cotton workers, male smokers gained more FEV_1 per year since cessation of textile work compared with male nonsmokers. When restricting the analysis to only retired male cotton workers, the P value for the interaction term between years since cessation of textile work and smoking status was statistically significant ($P = 0.02$; data not shown). Among silk workers, improvement in FEV_1 for every year after cessation was similar for male smokers and nonsmokers. We could not assess the pattern in female workers because so few smoked. However, the female nonsmoking cotton workers gained more FEV_1 in a 5-years period (14.6 ml/yr since cessation; $P < 0.0001$) than male nonsmokers or male

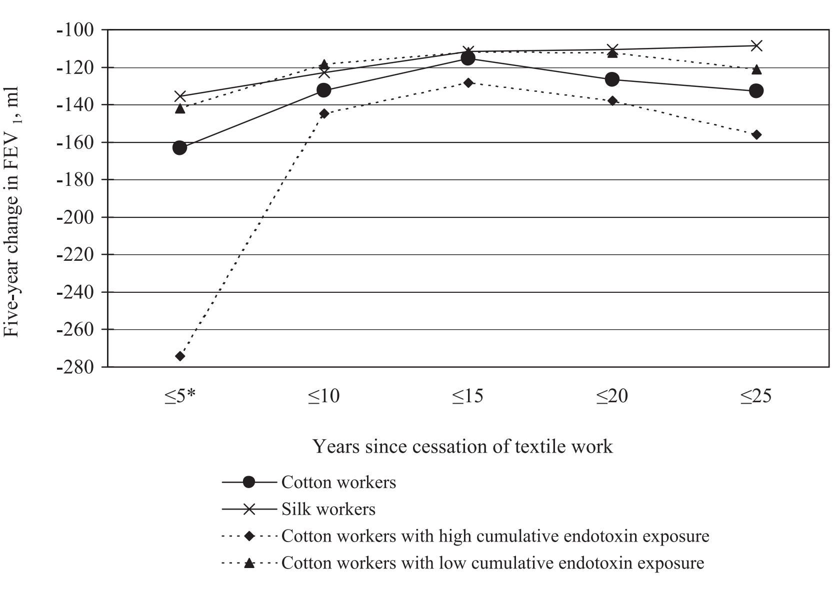

Figure 1. Average 5-year changes in FEV_1 after cessation of textile work by years since cessation among retired cotton workers, silk workers, cotton workers with high-level endotoxin exposure, and cotton workers with low-level endotoxin exposure after adjustment by age, height, sex, smoking, and cumulative endotoxin exposure (for all cotton workers). *Each data point for years since cessation of textile work overlaps another such that the interval for each point begins at greater than 0 (i.e., active employment); thus, workers actively employed are not included in this figure.

TABLE 2. DETERMINANTS OF CHANGES IN FEV_1 IN COTTON AND SILK TEXTILE WORKERS*

	All workers		Cotton workers only		Silk workers only	
	Estimate ± SE	*P* Value	Estimate ± SE	*P* Value	Estimate ± SE	*P* Value
Age, yr	−1.6 ± 0.4	<0.0001	−2.0 ± 0.7	<0.01	−1.6 ± 0.4	<0.001
Height, cm	−2.0 ± 0.5	<0.0001	−2.2 ± 0.8	<0.01	−1.7 ± 0.6	<0.01
Male	−32.8 ± 8.2	<0.0001	−56.9 ± 12.2	<0.0001	−38.5 ± 10.9	<0.001
Pack-years	−1.2 ± 0.4	<0.001	−1.7 ± 0.6	<0.01	−0.6 ± 0.4	0.13
Years since cessation of textile work	9.7 ± 1.5	<0.0001	11.6 ± 2.4	<0.0001	5.6 ± 0.9	<0.0001
(Years since cessation of textile work)^{2†}	−0.3 ± 0.1	<0.01	−0.4 ± 0.2	<0.05		
Exposed to cotton	−8.7 ± 4.9	0.07				
Cumulative endotoxin, 1,000 EU/m^3			0.2 ± 0.1	0.15		

Data are presented as estimates ± SE unless otherwise stated.

* The data are estimates of the coefficients for a 5-yr change in FEV_1 in ml based on a generalized estimating equations model. All available data from 447 cotton and 472 silk workers were used, estimated from generalized estimating equation models, with all variables but sex and height as time-dependent variables.

† Square of years since cessation of textile work.

smokers in the cotton group. Nonsmoking female silk workers demonstrated a similar estimated 5-year change in FEV_1 for every year since cessation similar to that of male silk workers.

Because virtually all of the female subjects in this study were nonsmokers, our comparison of adjusted annual change in FEV_1 by smoking status was restricted to male subjects (Figure 2). Cotton workers who were smokers had the largest annual FEV_1 decline (−44.0 ml/yr) compared with other subgroups. Among nonsmokers, the annual rate of decline in FEV_1 was slightly steeper for cotton workers compared with silk workers.

We also explored the relationship between the prevalence of respiratory symptoms and years since cessation of textile work at each 5-year survey. Compared with silk workers, cotton workers reported significantly more respiratory symptoms (chronic bronchitis, chronic cough, dyspnea, and byssinosis) over 25 years (odds ratio [OR], 1.54; 95% confidence interval [CI], 1.26–1.86; $P < 0.0001$), and years since cessation of textile work had a protective effect on symptom prevalence (OR, 0.98; 95% CI, 0.96–0.99; $P < 0.05$). Examined by subgroups, the prevalence of respiratory symptoms was greater for active cotton workers (OR, 2.10; 95% CI, 1.60–2.77; $P < 0.0001$) than for retired cotton workers (OR, 1.63; 95% CI, 1.21–2.20; $P < 0.01$), comparing each to silk workers.

The adjusted ORs of respiratory symptom prevalence as a function of employment status and years since work cessation are summarized in Table 4. Retired status was significantly inversely associated with chronic bronchitis, dyspnea, chronic cough, and byssinosis in cotton workers and with chronic bronchitis and chronic cough in silk workers. Compared with silk workers, the reduction in the prevalence of symptoms was greater in cotton workers after work cessation. For cotton workers, years since work cessation was significantly associated with lower odds of chronic bronchitis, byssinosis, and chronic cough. Protective effect of years since cessation of work on chronic bronchitis and chronic cough were observed in silk workers as well. We also observed a protective effect of work cessation on dyspnea in cotton workers, although this finding was not statistically significant.

Adjusted ORs for respiratory symptom prevalence and years since cessation of textile work were estimated in subgroups defined by smoking status and sex (data not shown). Smokers improved more than nonsmokers, with a greater reduction in ORs per year after cessation of work for chronic cough (OR, 0.93 vs. 0.95 in all cotton workers; OR, 0.94 vs. 0.99 in all male cotton workers) and byssinosis (OR, 0.84 vs. 0.90 in all cotton workers; OR, 0.87 vs. 0.99 in male cotton workers). For silk workers, years since work cessation was associated with lower risk of chronic bronchitis and chronic cough in smokers and in male subjects.

DISCUSSION

We report here that textile workers have improved FEV_1 and fewer chronic respiratory symptoms after leaving work and that

TABLE 3. CHANGES IN FEV_1 ASSOCIATED WITH YEARS SINCE CESSATION OF TEXTILE WORK AFTER STRATIFICATION BY EXPOSURE AND SMOKING STATUS*

	Cotton Workers		Silk Workers	
	Nonsmokers	Smokers	Nonsmokers	Smokers
All workers				
n	238	153	252	131
Years since cessation of textile work	5.2 ± 5.3	25.4 ± 6.6†	5.4 ± 1.7†	6.7 ± 2.1†
Male workers				
n	43	139	39	128
Years since cessation of textile work	−6.8 ± 13.9	29.6 ± 7.4†	1.6 ± 5.7	6.6 ± 2.1†
Female workers				
n	195	14	213	3
Years since cessation of textile work	10.9 ± 5.6†	—‡	5.7 ± 1.9†	—‡

Data are presented as estimates ± SE unless otherwise stated.

* The data are estimates of the coefficients for a 5-yr change in FEV_1 in ml based on a generalized estimated equations model. The generalized estimating equation models used all available data over 25 yr, adjusted for age, sex, mean height of first three surveys, square years since cessation of textile work, lifetime cumulative endotoxin exposure and pack-years in cotton subgroups and age, sex, mean height of first three surveys, and pack-years in silk subgroups.

† Statistically significant estimates.

‡ A generalized estimated equations model could not be run because few subjects were available for analysis.

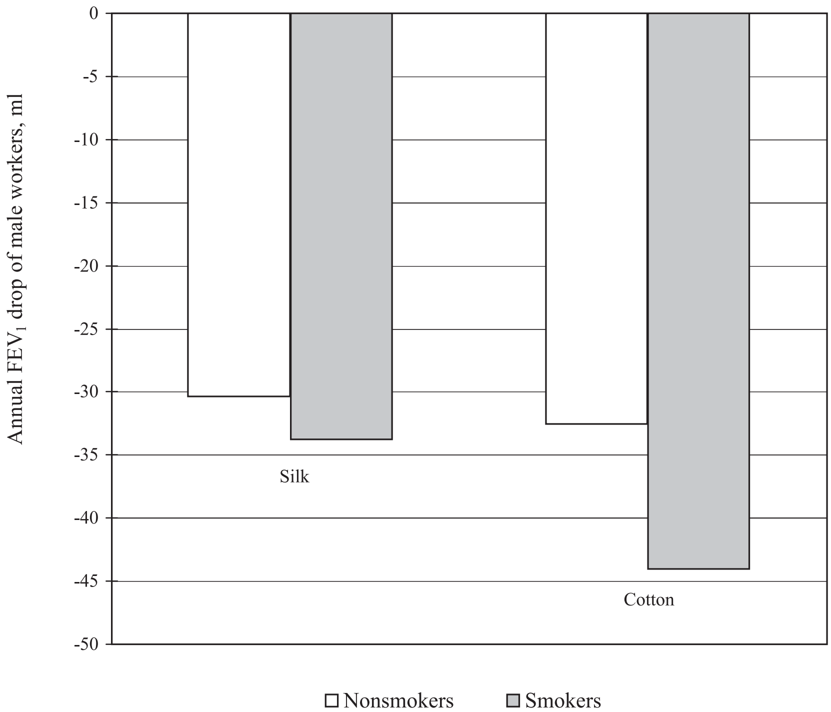

Figure 2. Annual FEV_1 changes in male workers over the 25-year period, adjusted by age, height, sex, years since cessation of textile work, and cumulative endotoxin exposure (for cotton workers).

the changes are more pronounced for cotton than silk workers. The improvements are positively correlated with the amount of time since cessation of work. We also provide more evidence that cigarette smoking modifies the effects of endotoxin exposure: Smokers had greater FEV_1 decline when actively exposed and faster improvement after work cessation than nonsmokers. A similar pattern was observed in the reduction in prevalence of chronic cough and byssinosis between smoking and nonsmoking cotton workers.

Previous studies have focused on the long-term effect of time since cessation of exposure on FEV_1 improvement in cotton textile workers (2, 3, 12, 19–22). This 25-year follow-up survey is the longest prospective follow-up study of cotton workers to date. Although this study was initially a study of active workers, the follow-up period was long enough to cover most subjects well into retirement, offering an unusual opportunity to examine work cessation and improvement of chronic lung function loss with greater precision. Our previous 20-year follow-up study showed a positive effect only when the analysis was restricted to cotton workers (12). Other studies showed positive effects (23, 24), but none of them was statistically significant. We observed a significant 11.6 ml/yr FEV_1 gain after retirement in cotton workers even after adjusting for years since cessation of work. Although cotton workers gained more FEV_1 than silk workers, their FEV_1 did not improve to the same level as silk workers. The protective effect of stopping work reduced the magnitude of 5-year FEV_1 decline from −163.1 ml/5 yr when they were actively exposed to cotton dust to −115.3 ml/5 yr after about 10 years after cessation of work. For cotton workers with low lifetime endotoxin exposure, average 5-year FEV_1 change improved to a level similar to the silk workers' 5-year FEV_1 decline (about −118.6 ml/5 yr). However, because the lung function of cotton workers on average did not reach the same level as silk workers after retirement, such improvement should be considered partial. In contrast, the reduction in prevalence of chronic bronchitis and chronic cough was similar in the two groups: 5.4 versus 6.0% for chronic bronchitis and 1.9 versus 3.1% for chronic cough, for cotton and silk workers, respectively. Time since cessation of textile work was also inversely associated with dyspnea, although the prevalence

TABLE 4. CHANGES IN RESPIRATORY SYMPTOM PREVALENCE IN ASSOCIATION WITH YEARS SINCE CESSATION OF TEXTILE WORK*

	Cotton Workers		Silk Workers	
	Retired	Years since Cessation of Textile Work	Retired	Years since Cessation of Textile Work
Chronic bronchitis	0.38 (0.26–0.56)†	0.95 (0.8–0.99)‡	0.61 (0.36–1.02)‡	0.95 (0.90–1.00)
Chronic cough	0.53 (0.32–0.88)†	0.93 (0.88–0.98)†	0.70 (0.50–0.98)†	0.94 (0.88–0.99)†
Dyspnea (+2)§	0.54 (0.39–0.74)†	0.98 (0.94–1.01)	0.76 (0.46–1.26)	1.01 (0.98–1.04)
Byssinosis	0.53 (0.32–0.87)†	0.88 (0.83–0.92)†	—‖	—‖

Data are presented as estimate (95% confidence interval) unless otherwise stated.

* The Generalized estimating equation (GEE) models analysis was performed using all available data of 447 cotton and 472 silk workers over 25 yr. The data are odds ratios adjusted by age, mean height of first three surveys, sex, pack years, and lifetime cumulative endotoxin exposure levels (high and low for cotton workers) in GEE models. All variables but height and sex are time-dependent variables.

† Statistically significant odds ratios.

‡ Marginal significance ($P = 0.06$).

§ Reaching ⩾2 on a scale of 1–5, where 1 = no dyspnea, 2 = having to walk slower than a person of the same age at an ordinary pace on level ground because of breathlessness, and 5 = dyspnea at rest.

‖ There were no byssinosis cases observed in silk workers.

TABLE 5. COMPARISON OF DEMOGRAPHIC DATA BETWEEN PARTICIPANTS WITH AND WITHOUT FEV_1 VALUE IN THE LAST SURVEY

	Cotton Workers		Silk Workers	
	With FEV_1	Without FEV_1	With FEV_1	Without FEV_1
Subjects, n	317	30	318	44
Male, n (%)	119 (37.5)	21 (70.0)	108 (34.0)	15 (34.1)
Age, yr	59.7 ± 9.3	71.9 ± 9.2	60.5 ± 9.6	64.1 ± 11.7
Height, cm	163.8 ± 7.4	163.5 ± 7.7	162.20 ± 7.2	161.7 ± 7.5
Smokers, n (%)	279 (88.0)	25 (83.3)	259 (81.5)	37 (84.1)
Pack-years*	10.3 ± 17.2	17.3 ± 20.4	8.7 ± 16.1	7.6 ± 16.3
Years since cessation of textile work	12.4 ± 5.1	15.9 ± 5.7	13.7 ± 4.4	14.5 ± 4.4
Baseline FEV_1, ml	2,979 ± 718	2,766 ± 632	2,890 ± 672	2,864 ± 686
Annual FEV_1 decline,† ml/yr	−30.7 ± 45.0	−56.7 ± 41.2	−22.41 ± 30.6	−31.02 ± 25.7

Data are presented as means ± SD unless otherwise stated.
* Calculated in smokers only.
† Annual FEV_1 decline is relative to the difference between FEV_1 measured at the baseline (1981) and previous (2001) surveys.

was higher among cotton workers than among silk workers in our last survey. The collective findings suggest that respiratory symptoms may revert to the level observed in silk workers after a sufficient time since cessation of textile work.

Previous studies have indicated that the relationship between years since cessation of work and FEV_1 is linear (11, 12, 23, 24). However, we observed a significant nonlinear effect for cotton workers, whereby FEV_1 increased with years after cessation of textile work until reaching a plateau. The peak in improvement for cotton workers appeared to occur about 15 years into retirement (Figure 1). The associations were similar for silk workers but were weaker, with no significant nonlinear effect.

The reason for the observed improvement in lung function loss observed in silk workers after cessation of work is not clear. The operations and production in the silk mills were similar to those of the cotton mills, but no cotton dust was present, and airborne endotoxin concentrations approximated ambient levels. If some silk workers had improved in lung function as a result of removal from some unmeasured exposure, this would result in the underestimation of the effect of cotton dust/endotoxin exposure on lung function loss. This may also result in an underestimation of the observed difference in improvement in cotton workers, relative to silk workers, after cessation of textile work.

Exposure to cotton dust and smoking status have been associated with the development of chronic obstructive lung disease (3, 25). Glindmeyer and colleagues, in a 5-year longitudinal study, found the largest annual declines observed in cotton yarn workers who smoked (10). Hasday and colleagues have also reported significant quantities of endotoxin in cigarette smoke (26, 27). In our study, lung function improved more for smokers than nonsmokers after cessation of cotton textile work. When we restricted analysis to male cotton workers, pack-years were associated with more FEV_1 loss during employment and more annual improvement in the rate of lung function loss since cessation of textile work. No differences were observed between male and female silk workers or between smokers and nonsmokers among silk workers after retirement. Because of the small number of female smokers, it is unclear whether a similar pattern for smoking exists among female cotton workers. Finally, few workers (9 cotton and 10 silk) stopped smoking after retirement. When we introduced a binary smoking post-retirement variable (0 if continue smoking, 1 if stop smoking after retirement) into the GEE models (*see* Table 2), no significant associations were observed for this binary term independent of adjustment for pack-years.

There were several potential biases in our cohort study. We did not collect personal air samples of airborne cotton dust and endotoxin. Although a reasonable correlation between personal and work area measures of airborne endotoxin was observed in the Shanghai cotton textile industry (26), the lack of personal air sampling data may be a possible source of exposure misclassification for this study. Furthermore, air sampling of dust and bacterial endotoxin was not performed throughout the follow-up period; they were measured at 5-year intervals for 3 to 6 months. Thus, the estimated personal cumulative exposure might not accurately reflect the actual cumulative level of individual exposure.

Selection bias may result from loss to follow-up, lack of participation, unacceptable pulmonary function testing (PFT), and healthy worker survivor effect. This study population appeared to be healthy. The mean percent predicted FEV_1 at time of retirement was 99.3% for cotton workers and 100.0% for silk workers. Workers who were less healthy may have been lost to follow-up before participating after retirement. A preliminary analysis of our study showed that less-healthy workers (<80% of predicted FEV_1) were less likely to participate in the next survey or to retire by the next survey ($P < 0.05$ and $P < 0.01$, respectively). If less healthy workers were lost to follow-up before retirement or followed only briefly into retirement and were more likely to have improved lung function only after a longer time, then our estimated effects of years since cessation of textile work may have been biased toward the null.

Participation in the questionnaire surveys was high during the 25-year follow-up. Some workers, however, took part in the surveys but did not have an acceptable FEV_1 value, especially in last survey. In the 2006 survey, participants without PFT were less healthy than those with PFT (Table 5); cotton and silk workers who were without an acceptable FEV_1 were older, had a lower baseline FEV_1, and had larger annual FEV_1 decline than those with PFT (28). However, no significant difference in loss to follow-up was seen between cotton workers and silk workers over the 25 years of follow-up. In the pooled population, nonparticipation was not associated with reduced FEV_1 in the previous survey ($P = 0.92$) or exposure status ($P = 0.15$). There was little transfer between jobs, but if less healthy cotton workers were more likely to retire, the healthy worker survivor effect may have biased our findings toward the null. However, most of the cotton workers (74.7%) had the same level of exposure over the five surveys, and no association was found between change of endotoxin exposure level and loss of FEV_1.

In conclusion, the present findings from the 25-year follow-up study of cotton textile workers suggest that after long-term cotton dust exposure, lung function loss partially improves and respiratory symptoms improve in the years after cessation of work. The improvement appears to occur most rapidly during the first 10 to 15 years after cessation of work, followed by a plateau. For silk workers, however, the linear improvement in lung function loss was maintained over the entire period after retirement. Finally, improvements in lung function loss and reduction in respiratory symptoms after cessation of work appear to be greater in smokers than in nonsmokers.

Conflict of Interest Statement: None of the authors has a financial relationship with a commercial entity that has an interest in the subject of this manuscript.

Acknowledgment: The authors thank the members of the Shanghai field team, the workers and staff of the First and Second Textile Mills and the First Silk Mill, and Janna Frelich and Marcia Chertok for data management and research assistance.

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