FINAL PERFORMANCE REPORT

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Significant Findings

The purpose of the study was to evaluate the relationship between long-term exposure to cotton dust and associated gram-negative bacterial endotoxin on lung function. The current study consisted of an eleven-year prospective study of cotton textile workers in Shanghai, China with workers at a nearby silk-thread manufacturing mill used as a referent population. Significant findings included the following:

(1) Cotton workers had a larger loss of lung function as measured by FEV_1 during the first five years of the study as compared with the second six years. The average decline among silk workers was slightly higher in the first period but was more consistent, and these differences could not be explained by worker selection or drop-out. The net effect was that over the entire eleven-year period, cotton and silk workers exhibited a similar crude loss in lung function.

(2) When cumulative exposure to dust and endotoxin were estimated and retired workers included in testing, cumulative dust but not endotoxin was associated with an eleven-year loss of FEV_1 after adjustment for appropriate confounders.

(3) There was no evidence for interaction between smoking and cumulative dust or cumulative endotoxin exposure in these models.

(4) Results suggest that cotton dust is a relatively potent cause of chronic airflow limitation independent of associated endotoxins.

(5) Further work is needed to clarify the potential reversibility of cessation of exposure, and relative contributions of dust, endotoxin, and tobacco use to chronic respiratory impairment in cotton and other vegetable dust-exposed workers.

Usefulness of Findings

These findings have public health significance both in and out of the textile industry. Within the textile industry airborne endotoxins appear to explain much of the byssinosis syndrome seen in cotton and other textile workers. However, there is no information to date that suggest that endotoxin is associated with chronic loss of lung function among these workers, sometimes referred to as chronic byssinosis, or more appropriately, chronic obstructive lung disease among textile workers. This study suggests that other components of cotton dust are more important than endotoxin in producing chronic airflow limitation. Outside of the textile industry these findings have as much or even more relevance. There are many work-places where gram-negative bacterial endotoxin is associated with vegetable-dust exposure such as grain-processing, wood-chip manufacturing, sewage treatment plants, animal confinement buildings, small animal laboratories, biotechnology industries and certain indoor environments contaminated with bacteria, to name a few. Since cotton dust is particularly rich in endotoxins, it would be important not only to delineate the acute responses to such exposures but to define potential chronic lung impairment as a sequela to such exposures. This work continues to evolve and will eventually be important in any standard-setting activity for endotoxin and generically for vegetable and other organic dust (e.g., animal confinement in agriculture) standards.

Abstract

To evaluate the relationship between long-term exposure to cotton dust and gram-negative bacterial endotoxin on lung function, we conducted an 11-year follow-up study of cotton textile workers in Shanghai, China. Workers at a nearby silk-thread manufacturing mill were used as a referent population. Ninety percent of the original cohort of 445 cotton and 467 silk textile workers — both active and retired — were identified for testing at the eleventh year. Questionnaires and spirometric testing were performed, as well as cotton dust and endotoxin sampling at three points over the 11-year follow-up period. After excluding deaths and subjects on sick-leave, 84 percent of the original cohort had complete health and environmental data.

Cotton workers had a larger loss of FEV_1 during the first 5 years of study (-40 mls/yr) as compared with the second 6 years of follow-up (-18 mls/yr). The average decline among silk workers was slightly higher in the first period, but was more consistent (-30 mls/yr versus -27 mls/yr) and these differences could not be explained by worker selection or dropout. The net effect over the entire 11-year period was that cotton and silk workers exhibited similar crude losses (-27 mls/yr versus -28 mls/yr respectively). When cumulative exposure to dust and endotoxin were estimated and used in a multivariate model for FEV_1 loss, cumulative dust, but not endotoxin, was associated with 11-year loss in FEV_1 after adjustments for confounders. There was no evidence for interactions between smoking and cumulative dust or endotoxin exposure in these models. Our results suggest that cotton dust is a relatively potent cause of chronic airflow limitation independent of associated endotoxins. Further work is needed to clarify potential reversibility after cessation of exposure, and the relative contributions of dust, endotoxin and tobacco to chronic respiratory impairment in cotton and other vegetable-exposed workers.

Body of Report

Background and Significance

The increase in morbidity and mortality attributable to chronic obstructive pulmonary disease (COPD) has focused attention on the environmental and host factors causally associated with the clinical entities encompassed by the term COPD. Despite the biologic plausibility of workplace exposures being causally implicated, only the role of tobacco smoke has been accepted beyond doubt. In addition to cohort mortality and pathologic studies, longitudinal studies have symptoms and lung function which are needed. Longitudinal studies of respiratory disease will enhance the signal of interest, namely the effects of occupational exposures, and diminish the noise due to intra-individual differences.

It has been known for many years that persons exposed to dust from cotton, flax or soft hemp may develop a characteristic acute symptom complex of chest-tightness on the first day back at work after a break of one, and more typically two days. The chest tightness is often, but not always, accompanied by impairment of lung function, demonstrable by an across-shift drop in the forced expiratory volume in one second (FEV_1). This symptomatic reaction has been defined clinically and epidemiologically as byssinosis and has been related to cotton dust exposures. This relationship has been used in some countries as a criterion to guide environmental control in cotton textile mills and as justification for workers' compensation programs.

Investigations of cotton dust exposures, however, have also suggested that non-specific measures of dust particles may not best explain these relationships or other aspects of respiratory illness in such exposure environments. Cross-sectional population studies on workers exposed to cotton dust indicate that other reactions are present which cannot fit the classical description of byssinosis. For example, in cotton mills many workers experience an acute fever with an influenza-like syndrome in the afternoon or evening after the first exposure to cotton dust ("mill fever"). These same symptoms occur in various environments where vegetable or other organic dusts are found such as grain dust or swine-confinement buildings, and as been termed by some as "organic dust toxic syndrome", or "inhalation fever". Recent work suggests that endotoxin may explain both mill fever and the acute chest-tightness/shortness of breath which Schilling described as byssinosis.

Approximately thirty years ago Pernis and co-workers described the similarity of mill fever to that produced by inhalation of gram-negative bacterial endotoxin. Cotton dust consists of inhalable and respirable particules composed of a variety of constituents of the cotton plant and its associated microbial flora. Recent evidence suggests that there is enough endotoxin in cotton dust to cause not only mill fever but also the chest-tightness and acute loss of ventilatory function typical of byssinosis. This evidence is from model cardroom studies and evidence from actual mill environments are still lacking.

In the last decade several cross-sectional epidemiologic studies of cotton textile workers have indirectly supported a role for endotoxin by studying the association of gram-negative bacteria and the production of at least some of the symptoms in acute lung function changes occurring in these workers.

Based on these studies, model cardroom clinical studies are undertaken by NIOSH. The most extensive of these reveal that endotoxin exposure predicted acute pulmonary function loss better than dust, particularly at lower levels of exposure (less than 0.6 mg/m^3). Swedish workers use shorter challenge periods with naive subjects and cotton textile workers, neither pre-selected for cotton dust responses. Their results showed, as expected, a higher threshold effect of endotoxin, but similarly found a clearer exposure-response relationship with endotoxin than with inhalable cotton dust alone. Further studies necessary to describe the exposure response relationship for endotoxin and both acute and chronic responses in unselected cotton textile workers.

The purpose of the current study has been as follows: (1) To determine a long-term incidence and remission of byssinosis and non-specific respiratory symptoms among cotton textile workers using silk workers for comparison and relate these findings to various estimates of current and historical work exposures, accounting for the usual confounders. (2) To determine the rate of annual decline in pulmonary function among both cotton and silk workers and relate these findings to various estimates of current and historical work exposures, adjusting for standard confounders. (3) To explore the relative contributions of cotton dust in airborne gram-negative endotoxin exposure in the development and progression of pulmonary function changes. (4) To explore the significance of cross-shift change in FEV_1 and longitudinal loss in lung function and to explore the relationship between across-shift drops and respiratory symptoms.

Methodology

Baseline data were collected on 447 cotton textile workers and 465 silk textile workers in Shanghai, China, beginning in 1981. These data included full spirometry before and after the shift on the first day of the work-week on all subjects. Pulmonary function was performed on spirometers which meet ATS criteria and use strict ATS performance recommendations. These subjects also responded to an modified ATS questionnaire survey of respiratory symptoms, disease history and tobacco-smoking habits. The questionnaire had been translated into Chinese and back into English. Finally, each subject's full job history was recorded including absences for illness, military service, etc. Importantly, we were able to contact and examine retirees and those who have left because of illness over the eleven-year period of follow-up. This is unique to studies in occupational health including prospective studies which usually are only able to focus on current workers throughout the study. Similar information on before-and-after-shift pulmonary function, etc., were available on silk workers as well. All spirometry tracings were hand-read according to ATS recommendations and the questionnaire pulmonary function test key-entered, data-checked, and cleaned.

Exposure assessing consisted of cotton dust and gram-negative bacterial endotoxin measurements using methods previously described. All samples were aero-samplers using vertical elutriators in the various yarn-preparation areas. A total of 730 samples were collected over three surveys during the eleven years in the yarn-preparation areas of the cotton mills. A limited number of samples were also taken in the silk mills to ensure the absence of contaminating endotoxin.

At Year 05 approximately 90 percent of the original 912 cohort members were identified. Of those, 87 percent were tested. At Year 11 again about 90 percent of the original cohort was accounted for, and after excluding deaths, subjects on sick-leave, and subjects who left the area, 84 percent of the original cohort was retested at Year 11. Demographic and pulmonary function results are shown in Table 1.

Each of the specific aims originally planned during the project were addressed in our analyses and can be summarized as follows: (1) To determine long-term incidence and remission of byssinosis and non-specific symptoms among cotton workers using silk workers for comparison. This is addressed in a publication entitled *Variability and Symptom Reporting, Across-shift Drop and* FEV_1 *in Longitudinal Change in Pulmonary Function in Cotton Textile Workers*. Specific aims (2) and (3) are, with emphasis on the eleven-year follow-up, discussed below.

Specific aim 4 is addressed in the paper entitled *Cotton Dust Exposure, Cross-shift Change in* FEV_1*, and Longitudinal Change in Lung Function*, published in the American Review of Respiratory Disease (see below).

Discussion of the Results Addressing the Remainder of the Specific Aims:

Statistical Analysis

We examined lung function (FEV_1) change over 11 years using the S-plus statistical package in models constructed to examine percent change in FEV_1 over the entire period of follow-up and between each survey with adjustments for appropriate covariates. In these models, $\%\Delta FEV_1$ was regressed on exposure status (0=silk, 1=cotton), period (0 = 1981-86; 1 = 1986-1992), age, smoking habit and symptoms. Interactions were also examined. Because there were so few ex-smokers (n=18), they were excluded from these models. We also examined mean absolute change in FEV_1 adjusted for exposure status and period.

We examined the data for possible exposure-response relationships in the following ways. We developed a cumulative index of exposure for each subject defined as the geometric mean levels of dust (or endotoxin exposure) from the three surveys multiplied by years of work in each specific work area. The first survey's measurements were used to estimate exposures prior to the initial survey. Surveys 2 and 3 sampling data were used to calculate interval exposures, which were added to the pre-1981 values for a total cumulative exposure for dust and endotoxin. The cumulative exposures were then entered as independent variables in a regression model for 11-year change in FEV_1 among cotton workers.

Results

Study Population

All 912 members of the initial cohort residing in the Shanghai area who were still employed or retired were eligible and identified for testing. A total of 90% of the original cohort was accounted for. After excluding deaths, subjects on sick-leave too ill to be tested and subjects who left the area (total = 145), we re-tested 84% of the original cohort at year 11: 378 cotton and 389 silk workers. Acceptable spirometric curves were obtained on 349 cotton and 319 silk workers in both 1981 and 1992 and results for these subjects were used in the subsequent analyses.

Demographic and pulmonary function results are shown in Table 1. Workers in the cotton and silk mills were comparable with respect to age, gender, and smoking status. Work duration was longer for silk versus cotton textile workers (26.7 years versus 24.9 years, $p<0.05$). There were only 8 female smokers and 18 ex-smokers. The unadjusted annual change in FEV_1 over 11 years was similar for cotton and silk workers: -27 ml/yr and -28 ml/yr respectively.

Environmental Data

The results of the area sampling for both respirable dust ($\leq 15\ \mu$) and endotoxin are shown in Tables 2 and 3. At the first survey, some of the filters were lost in shipping and were therefore not assayed for endotoxin. However, we assessed the importance of lost filters by recalculating the mean area dust concentrations based only on those filters which had both dust and endotoxin analysis. Comparison of these results with the original calculations showed no significant difference in any of the mean values (23), and thus were representative. For subsequent surveys in 1986 and 1992, endotoxin analysis was performed on all filters after weighing for dust.

Dust concentrations tended to decrease in both cotton mills over the 11 years of follow-up, although work-area rankings based on dust levels were similar. Geometric mean dust exposures ranged from a low of 0.2 mg/m^3 in spinning in mill 2 to highs of 1.6 mg/m^3 in the opening/cleaning/carding rooms of mills 1 and 2 and drawing in mill 2. The US standard for yarn preparation is 0.2 mg/m^3.

Airborne endotoxin levels differed in the two cotton mills; 4.3 EU/m^3 to 120.3 EU/m^3 in mill 1; 0.3 to 74.6 EU/m^3 in mill 2 (Table 3). There was a 400-fold difference in area geometric mean levels of endotoxin.

When individual cumulative exposure values were estimated, the median cumulative exposure for cotton dust was 15.45 mg/m^3 • years and for endotoxin 40.2 EU/m^3 • years.

Annual Change in FEV_1 : Cotton versus Silk Mills

Annual changes in FEV_1 and pre-shift FEV_1 among cotton and silk workers are shown in Table 4. The numbers of both cotton and silk workers tested at the third survey are higher because of improved capture of retirees during the third versus the second survey. When compared to subjects included in the third survey (1992), those workers tested in the second but not the third survey (n = 27) did not suffer a different loss of FEV_1 during the first 5 years of follow-up (-33 mls/yr versus -40 mls/yr respectively, p = 0.4).

Cotton workers showed a larger loss of function during the first 5 years (-40 mls/yr) as compared with the second 6 years (-18 mls/yr) of follow-up. The average decline among silk workers was also higher in the first 5 years of follow-up; however, the two periods were more consistent (-30 mls/yr for period 1 and -27 mls/yr for period 2). The net effect over the entire 11-year period was that cotton and silk workers exhibited similar crude losses (-27 mls/yr versus -28 mls/yr).

Regression Analysis

The associations were estimated between 0-5 and 6-11 year changes in FEV_1 and exposure, age, smoking respiratory symptoms and survey period using multiple linear regression analysis (Table 5). Each study individual contributed two possible data points to the analysis: change in FEV_1 during periods 1 and 2. Smoking, cotton exposure, age, wheeze with shortness of breath at first survey and an exposure-period interaction were significant predictors of 11-year change (Table 5). In this model, no other symptoms at time of first survey were significant predictors of longitudinal decline in FEV_1.

Dust and Endotoxin Exposure-Response Modeling

To estimate chronic effects of long-term dust and endotoxin exposure, we constructed cumulative dust and endotoxin variables for each subject in the two cotton mills. The variables represent the product of dust or endotoxin and years exposed. Exposure data from the first survey were used to calculate pre-1981 levels; data from 1981 and 1986 were used for that 5-year interval; and data from 1986 and 1992 for the second interval. A cumulative exposure index was calculated for each subject by the addition of the products of the years exposed in each work area by the geometric mean concentrations of dust and endotoxin over the periods described above. Age and years worked were highly correlated ($r = 0.89$, $p<0.01$) and since years worked provided a slightly better fit, the latter was used in the regression model. There was a strong correlation between cumulative dust and cumulative endotoxin exposure ($r=0.58$, $p<0.01$). To avoid unstable regression estimates due to collinearity, we examined cumulative dust and cumulative endotoxin separately. Our results reveal a significant association for adjusted 11-year decline in FEV_1 and cumulative dust, but not endotoxin exposure (Table 6). We examined potential interactions between smoking and cumulative dust or endotoxin exposures by adding product terms to the model, but found no evidence of different dose-response curves for smokers.

Discussion

Although the average annual 11-year FEV_1 loss was the same for cotton and silk workers, our results indicate that cumulative exposure to cotton dust, but not airborne endotoxin, is associated with long-term loss of lung function in cotton textile workers. Schilling first systematically described the relationship between cotton dust exposure and the byssinosis syndrome (1,2). His original observations have been reproduced in numerous cross-sectional studies from various countries. However, longitudinal studies have provided conflicting results regarding chronic respiratory effects from cotton dust exposure.

Berry et al. measured lung function in 595 cotton subjects and a comparison group of 81 workers from two synthetic fiber mills up to six times over a three-year period (4). Cotton workers had a mean annual FEV_1 loss of 54 ml, compared with 32 ml among workers from the two synthetic fiber mills. However, workers from the two synthetic mills differed substantially from each other : losses of 52 mls/yr versus 14 mls/yr. The study, though suggestive, did not make a persuasive case for an excess loss of FEV_1 related to cotton dust exposure. Moreover, the authors found that annual decline in FEV_1 was not significantly related to dust levels or to Monday cross-shift decline in FEV_1.

Fox and colleagues (3) studied 866 cleaning and card-room workers two years apart and found a 23 ml/yr loss of FEV_1, no greater than that expected due to age alone. Exposure levels ranged from 1.15 mg/m^3 to 4.8 mg/m^3 (excluding fly). This study was limited by the absence of a control group and the short follow-up interval.

Merchant and colleagues (4) studied 199 subjects in an investigation of cotton-steaming effects. The study had a short follow-up period — 10 months — in which annual FEV_1 declines were calculated. They estimated a mean loss in FEV_1 of 192 ml in 43 non-byssinotic early yarn preparation-area workers exposed to high levels of dust. Declines in FEV_1 were less (67 mls) in workers in the spinning and winding areas.

Kamat et al (5) studied Indian cotton textile workers longitudinally and found an accelerated loss of lung function. But, their controls also sustained great losses which were unexplainable, and methodologic problems (e.g., changing spirometers) may have influenced the results.

Beck et al. (6) have published the results from a community-based study of active and retired cotton textile workers in South Carolina. Both active and retired cotton workers had significantly greater annual losses in FEV_1 over years when compared with controls from Lebanon, Connecticut. This study suggested that in an older, largely retired group of cotton workers, additional loss of lung function occurred after removal from exposure. Although criticized for choice of controls and differences in recruitment between the two community surveys, this study raised serious concerns about adverse effects of exposure in both smokers and non-smokers years after leaving the cotton mills.

Zuskin et al. (7) recently published the results of a small longitudinal study of 66 cotton textile workers in a mill in Yugoslavia. The mean annual decline in FEV_1 was 59 ml/yr for female and 68 ml/yr for male workers with average respirable dust concentration of 0.97 mg/m^3. Initial survey across-shift changes in FEV_1 were significantly greater in the 50 workers lost to follow-up than in the 66 workers surveyed twice over the 10-year period. The association between across-shift change and 10-year loss was not reported.

Glindmeyer et al. (8) reported five-year annual declines in FEV_1, FVC and FEF_{25-75} which were steeper in cotton yarn-preparation workers than slashing and weaving. These declines were associated with cotton dust exposure in yarn preparation and occurred at levels even as low as 0.2 mg/m^3. However, their synthetic fiber control group exhibited greater ventilatory declines than did the cotton workers, findings not explained by smoking or work tenure.

Christiani et al. reported accelerated declines in FEV_1 for cotton workers compared with silk workers (the population studied here) at 5 years (9). Results at 5-years also demonstrated a strong relationship between cross-shift drop in FEV_1 and subsequent 5-year loss in pre-shift FEV_1. However, at the 5-year point, we were unable to demonstrate an exposure-response relationship for either cumulative dust or endotoxin.

Dust-Endotoxin Relationships with Chronic Loss of FEV_1

Results presented here are based on the longest and largest follow-up study of cotton textile workers to date. Moreover, our study is the only one to use knowledge which has incorporated measurements of airborne gram negative bacterial endotoxin over the length of the study.

Our data reveal that cumulative cotton dust, but not cumulative endotoxin, exposure predicts long-term loss of ventilatory function. Endotoxin exposure has been associated with acute airflow limitation in occupational studies of organic-dust exposed workers, including workers in the poultry industry (10) and swine confinement buildings (11). Experimental challenge studies with cotton dust have shown acute airflow limitation in exposed workers (12,13). One cross-sectional study on the current population revealed a significant exposure-response between endotoxin exposure and chronic bronchitis, but not with pre-shift FEV_1 (23); however, chronic loss of ventilatory function among textile workers had not been demonstrated.

A number of animal models support the epidemiologic findings of acute airflow limitation and airway inflammation following endotoxin inhalation. The species used include rabbits (14-16), hamsters (17), rats (18), mice (19), and guinea pigs (20-22). While the dose, time course of exposure, and endpoint as well as species varied among these studies, the conclusions are similar. Inhaled endotoxin is a potent inflammatory stimulus which causes acute airway obstruction and transient bronchial hyperresponsiveness after acute exposure. It remains unclear, however, even in animal models what the long-term airway effects of inhaled endotoxin are.

Epidemiologic studies which have examined the chronic effects of endotoxin exposure are lacking. In addition to our previous reports of this cohort (19,23), there is only one other reported study of the cumulative endotoxin effects on respiratory outcomes. In that cross-sectional study of animal feed workers, cumulative endotoxin exposure based on personal sampling and homogeneous exposure groupings was associated with significantly reduced FEV_1 and expiratory flow rates. The association with cumulative inhalable dust was weaker than that for endotoxin. Only one longitudinal study of lung function and endotoxin exposure has been published to date: our report of the 5-year follow-up in the population under study here.

Although we did report an association between endotoxin exposure and chronic bronchitis, at 5 years of follow-up, we did not detect cumulative endotoxin or dust effects on FEV_1.

From recent studies of byssinosis, it appears likely that the mechanism of the byssinosis syndrome involves stimulation of the same inflammatory receptors by endotoxin and cotton dust (13,23,24-27). However, there is now also evidence that other vegetable dust (grain) inhalation low in endotoxin induces similar physiologic effects in humans as endotoxin. For example, Clapp et al. (28) demonstrated that in spite of the same endotoxin levels, the effects of corn dust extract appear to have different biologic activity than either soybean dust extract or endotoxin, indicating that vegetable dust potency may not depend solely on its endotoxin content. Furthermore, it is biologically plausible that different constituents of cotton and other vegetable dusts are responsible for the acute (byssinosis) and chronic (chronic airflow limitation) effects.

The magnitude of the observed effect of cumulative dust on FEV_1 is substantial when compared with the effect of smoking in this population. Based on our prediction models, a cotton textile worker who has smoked throughout his or her working career, and attained 26 pack-years of smoking, can be expected to suffer an 18% loss in FEV_1 over that time (4 decades). By contrast, we would expect a non-smoking worker with cumulative cotton dust exposure equal to the median of 15.5 $mg/m^3 \cdot$ years suffers a 6% loss. It should be noted, however, that workers in the 95th percentile of cumulative exposure will experience a 16% decline in FEV_1.

Our data suggest, therefore, that cotton dust is a relatively potent inducer of chronic airway changes that are believed to lead to airway obstruction. Continued efforts to control dust exposure are appropriate in reducing the risk of chronic airways disease. Further epidemiologic work is needed to clarify the risk factors for chronic disease among newly-exposed workers and to clarify the relative contributions of chronic dust, endotoxin and tobacco smoking to chronic respiratory impairment.

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TABLE 1. Participant data on subjects with pulmonary function tests at least at beginning and end of 11-year period.

	COTTON	SILK
n*	349	319
% Male	47.3	43.6
% Current Smoker (1992)	34.7	29.5
Years Employed (SD)	24.9 (9.0)	26.7 (10.4)
% Pred ± SD		
-81	99.6 (12.8)	100.6 (11.7)
-92	100.0 (14.8)	100.2 (14.2)
Mean FEV_1 Annual Decline† ± SD		
1992-1981	-27 (23)	-28 (22)

* Actively working or retired with valid pulmonary function tests.
† Annual decline in ml/yr.

TABLE 2. Vertical Elutriated Cotton Dust Levels by Mill, Work Area and Survey

Area	Mill	1981	1986	1992
Open/Clean	1	1.6 (0.6-2.3)*	1.3 (0.8-2.4)	1.1 (0.7-1.6)
	2	1.2 (0.4-2.9)	1.6 (1.1-2.9)	0.9 (0.3-2.1)
Carding	1	1.1 (0.6-2.3)	1.5 (1.0-2.0)	0.8 (0.4-1.4)
	2	1.6 (0.5-2.5)	1.5 (0.7-2.6)	1.0 (0.5-1.6)
Drawing	1	0.5 (0.2-1.2)	1.0 (0.5-3.8)	0.3 (0.1-0.6)
	2	1.5 (0.5-2.2)	1.6 (1.1-2.3)	1.0 (0.6-1.4)
Combing	1	0.3 (0.2-0.5)	0.5 (0.1-1.1)	0.4 (0.2-0.7)
	2	0.6 (0.2-1.0)	0.3 (0.1-0.6)	0.3 (0.1-0.6)
Roving	1	0.4 (0.2-0.6)	0.3 (0.1-0.7)	0.3 (0.2-0.7)
	2	0.5 (0.4-0.6)	0.4 (0.3-0.7)	0.5 (0.3-0.7)
Spinning	2	0.5 (0.3-0.8)	0.2 (0.0-0.5)	0.2 (0.1-0.4)

* Geometric mean (range) in mg/m^3

TABLE 3. Vertical Elutriated Endotoxin Levels by Mill, Work Area and Survey

Area	Mill	1981	1986	1992
Open/Clean	1	25.8 (13.2-92.3)*	40.8 (20.1-79.6)	120.4 (42.6-503.1)
	2	9.6 (4.7-18.6)	44.5 (3.1-133.8)	27.5 (9.6-85.0)
Carding	1	51.4 (31.9-70.9)	47.1 (16.8-78.3)	100.4 (9.7-658.8)
	2	16.9 (4.4-55.4)	47.6 (25.1-169.7)	71.1 (33.4-339.3)
Drawing	1	7.4 (1.6-24.0)	59.8 (21.0-146.2)	26.9 (2.2-96.5)
	2	—	74.6 (52.0-120.2)	59.3 (14.8-172.4)
Combing	1	—	63.9 (27.0-152.5)	24.5 (5.9-119.1)
	2	6.9 (4.9-10.6)	6.7 (2.3-66.8)	14.7 (3.1-41.9)
Roving	1	17.2 (7.2-41.3)	8.6 (1.5-106.0)	8.4 (0.03-60.3)
	2	—	4.3 (2.0-11.2)	10.3 (4.0-38.3)
Spinning	2	0.3 (0.1-2.7)	0.4 (0.1-14.2)	1.2 (0.2-5.1)

* Expressed as geometric mean (range), EU/m^3

TABLE 4. **Pulmonary Function Data on Textile Workers***

Mill	Annual FEV_1 Change (5, 6 and 11 yrs) 5-yr 81-86 (n)	6-yr 86-92 (n)	11-yr 81-92 (n)	Pre-Shift % Predicted 1981	1986	1992
Cotton						
1	-.033 (130)	-.018 (130)	-.023 (152)	96.8	96.6	98.5
2	-.045 (177)	-.018 (177)	-.030 (197)	101.7	98.8	101.2
Total =	-.040 (307)	-.018 (307)	-.027 (349)	99.6	97.8	100.0
Silk	-.030 (278)	-.027 (278)	-.028 (319)	100.6	99.8	100.2

*Includes subjects with valid pulmonary function studies at beginning and final surveys

TABLE 5. Regression coefficients for exposure, age, smoking, wheeze with SOB and period for % change in FEV_1 over 11 years in cotton and silk workers.

	β	SE	p
Intercept	0.009	0.0081	0.25
Exposure	-0.012	0.006	0.03
Period	0.008	0.006	0.15
Wheeze/SOB	-0.027	0.013	0.04
Age	-0.002	0.000	<0.01
Smoke	-0.021	0.004	<0.01
Exposure x Period	0.032	0.008	<0.01

General Model:

% Δ FEV_1 (ℓ, 1992-1981) = β_0 + β_1 (Exposed, 1 = cotton) + β_2 (Period = 0,1) + β_3 (Symptom, 1 = present) + β_4 (Age, yrs) + β_5 (Smoke, 1 = yes) + β_6 (Exp x Period), n = 653; $R^2 = 0.09$. Wheeze/SOB = wheezing with shortness of breath.

TABLE 6. Regression coefficients for percent change in FEV_1 over 11 years and cumulative exposure to dust and endotoxin for cotton workers*

Model with Cumulative Dust	β	SE	p	R^2
Cumulative Dust	-0.0009	.0004	<0.05	
Smoking (1 = smoker)	-0.040	.010	<0.01	
Age	-0.003	.0005	<0.01	0.22
Model with Cumulative Endotoxin				
Cumulative Endotoxin	-0.0001	.0008	0.87	
Smoking (1 = smoker)	-0.046	.009	<0.01	
Age	-0.003	.0004	<0.01	0.20

* Active and retired cotton textile workers with valid pulmonary function tests in 1981 and 1992 (n = 345). %Change in FEV_1 (ℓ) = [FEV_1 (1992)-FEV_1 (1981)] ÷ FEV_1 (1981)Christiani DC. Occupational Lung Disease in the Industrialized and Industrializing World — Commonalities and Contrasts: Measurement Tools in Research. Tubercle and Lung Dis 1992; 73:7-13.

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Planned Publications

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16. Abstract (Limit: 200 words) The relationship between long term exposure to cotton dust and associated gram negative bacterial endotoxin on lung function was investigated in an 11 year prospective study of cotton textile workers in Shanghai, China. Workers at a nearby silk thread manufacturing mill served as a referent population. The cotton workers had a larger loss of lung function as measured by forced expiratory volume in 1 second (FEV1) during the first 5 years of the study than in the second 6 years. The average decline among silk workers was slightly higher in the first period, but was more consistent. Cumulative dust but not endotoxin was associated with an 11 year loss of FEV1 after adjustment for appropriate confounders when cumulative exposure to dust and endotoxin were estimated and retired workers included in the testing. No evidence was found for interaction between smoking and cumulative dust or cumulative endotoxin exposure in these models. Results suggest that the cotton dust is a relatively potent cause of chronic airflow limitation independent of associated endotoxins.

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