

Received: 2013.08.16  
Accepted: 2013.10.09  
Published: 2013.12.18

# Longitudinal pulmonary functional loss in cotton textile workers: A 5-year follow-up study

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**Background:** Occupational exposure to cotton dust causes several diseases affecting the lungs, but only limited information is available on effects of long-term exposure. In this study, we aimed to evaluate longitudinal changes in selected parameters of pulmonary function in textile workers.





**Material/Methods:** This prospective cohort study began with 196 textile workers in 2006 and was completed in 2011 with 49 workers. We used standardized tests for pulmonary function on participants on the first day of the workweek in June of 2006 and 2011. Environmental samples of cotton dust were gathered with a vertical elutriator. Loss of pulmonary function was assessed based on gender and smoking status.

**Results:** The mean number of years participants worked in the textile factory was  $7.61 \pm 1.83$  years, and the mean age was  $35.3 \pm 5.8$  years. The annual FEV1 loss of all workers was 53.2 ml, giving a ratio of annual FEV1 loss to baseline FEV1 of 1.4%. Pulmonary function parameters of all participants in 2011 were significantly lower than those in 2006 (for all,  $p < 0.05$ ). In both surveys, pulmonary function in current smokers was lower, but this difference was not significant ( $p > 0.05$ ).

**Conclusions:** This study provides the first data on pulmonary functional loss in Turkish textile workers and supports the findings of other cohort studies that workers with long-term exposure to cotton dust may lose some pulmonary function. The ratio of annual FEV1 loss to baseline FEV1 appears to be a more accurate and comparable method than annual FEV1 loss for evaluating pulmonary functional loss.

**Key words:** textile • occupational health • respiratory • organic dusts • pulmonary function

**Full-text PDF:** <http://www.medscimonit.com/download/index/idArt/889681>

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## Background

Epidemiologic studies show that cotton dust exposure is associated with several diseases, most of which are related to the lungs. The relationship between pulmonary functional loss and exposure to cotton dust has been a topic of interest for occupational health. The main model of cotton dust-related disease is considered to be acute airway responses, known as “Monday mill fever”, which is characterized by chest tightness, cross-shift drops in forced expiratory volume in 1 second (FEV1), and airway hyperresponsiveness. These acute airway responses can be observed even with short-term cotton dust exposure [1,2]. Byssinosis is the classic cotton dust-related disease and is defined as an acute airway response characterized by chest tightness and shortness of breath, most typically manifested on the first day of the workweek (Monday accentuation). The disease may progress to include other days in the advanced stages [1] and is rarely seen in persons exposed to cotton dust for less than 10 years [3]. Long-term exposure to cotton dust may lead to increased loss of pulmonary functions [4]. Length of the exposure period, cumulative or mean dust concentration, past exposure levels, grade of cotton, and extent of colonization with Gram-negative microorganisms have all been determined to affect functional loss [5,6]. Exposure to cotton dust has also been reported to be related to chronic bronchitis, cough, and dyspnea, which are nonspecific respiratory symptoms [6,7].

Several experimental and observational studies have suggested that bacterial endotoxins in cotton dust may be the main causative agents contributing to airway inflammation and obstruction [2,8]. Endotoxins are a component of the outer membrane of Gram-negative bacteria and are generally released from bacteria by lysis; they diffuse everywhere in the airborne environment. High airborne levels have been detected in industrial environments, such as cotton mills, waste collection sites, and grain handling equipment areas [9]. Christiani et al. determined that endotoxin levels from environmental exposure were not markedly different among cotton mills and were moderately correlated with cotton dust levels [8].

Historically, research on the adverse effects of exposure to cotton dust has been largely restricted to acute respiratory responses and the prevalence of respiratory symptoms. A limited number of longitudinal studies have evaluated the relation between long-term exposure to cotton dust and chronic changes in pulmonary function. In the present study, we evaluated the 5-year longitudinal changes of 3 parameters – FEV1, forced vital capacity (FVC), and peak expiratory flow (PEF) – in Turkish cotton textile workers.

## Material and Methods

### Subjects and examination protocol

This prospective cohort study was approved by the Institutional Review Board of Kahramanmaraş Sutcu Imam University. The study subjects were recruited from workers in the garment and denim preparation areas of a state-owned cotton textile factory located in Malatya, Turkey. All participants gave informed consent.

The first measurements were taken on a Monday morning in June 2006. All workers had been working in the factory for at least 1 year and had no history of respiratory disease before they were hired. The initial study included 196 workers, which represented 61% of all workers in the cotton textile factory. This baseline cross-sectional study was also published [10]. The follow-up survey was carried out on a Monday morning in June 2011 and considered just the 49 workers who were still working in the same cotton textile factory; the follow-up rate was 25%. Other workers had left their jobs before our follow-up survey. In Turkey, many textile workers are young and consider their job to be temporary, probably because of low pay and annoyingly dusty environmental conditions [11].

### Exposure assessment

In 2006 and 2011, stationary measurements of airborne cotton dust were taken with a vertical elutriator (General Electric Corp. NY, USA) from the same 5 work areas of the cotton textile factory where garment and denim were prepared. In 2006, levels of respirable dust in the 5 work areas were compared to pulmonary function levels, but no significant difference was determined [10]. Therefore, in the present study respirable dust levels are given as general information.

Pulmonary functional tests (PFTs) were performed by a pulmonary disease specialist using a MicroLoop portable spirometer (Micro Medical Ltd, Rochester, UK) in accordance with the recommendations of the American Thoracic Society [12]. There were no differences in measurement equipment, techniques, and conditions between 2006 and 2011. A minimum of 3 acceptable tests were performed on each worker in a sitting position; a nose fastener was used to close the worker's nose. A test was defined as acceptable if the worker showed no sign of hesitation at the start of the maneuver, did not cough or hesitate during the maneuver, air did not leak from the mouthpiece, and if the exhalation lasted at least 6 seconds. The highest level of FEV1 measured in any of the 3 tests was selected. FEV1 was defined as the maximal volume of air exhaled in the first second of a forced expiration from a position of full inspiration. PEF was defined as peak flow measured during expiration. FVC was defined as the forced expiration volume of the total inspired lung.

Smoking status was defined according to the classifications of the World Health Organization. Current smokers were defined as smoking at the time of the interview, including daily smokers and nondaily smokers (also known as occasional smokers). Smoking status was determined from the response to the question: "At the present time do you smoke cigarettes daily, occasionally, or not at all?" Former smokers were defined as not smoking at the time of the interview; however, subjects in this category answered "Yes" to the question: "Have you ever smoked cigarettes at all?". Never smokers were defined as not smoking at the time of the interview and answered "No" to the same question [13]. In our study, workers were classified as current smokers, never smokers, and former smokers.

### Statistical analyses

The statistical analyses were performed using SPSS for Windows software (SPSS Inc. Release 15.0, Chicago, IL, USA). The paired samples t test was used to compare declines in FEV1, FVC, and PEF parameters. For the correlation analysis, Spearman's rho correlation was performed for parametric variables. Multivariate linear regression analysis was performed for evaluating the factors affecting the 5-year FEV1 loss. For analysis of 5-year FEV1 loss according to smoking factor, Wilcoxon and Mann-Whitney U tests were used. In these analyses, the significance level was assumed  $p < 0.05$ .

## Results

### Characteristics of the participants

In our cohort study of 49 cotton textile workers, 37 were male and 12 were female. At the end of the study, the average age of workers was  $35.3 \pm 5.8$  years for males and  $35.0 \pm 5.4$  years for females. The mean working period for the male and female workers was  $7.6 \pm 1.8$  (6–13) years and  $7.5 \pm 1.7$  (6–11) years, respectively. The mean concentration of dust was  $0.17 \text{ mg/m}^3$  in 2006 (beginning of the study) and  $0.29 \text{ mg/m}^3$  in 2011 (end of the study). Over the 5-year period, the body mass index (BMI) of workers did not change significantly ( $p > 0.05$ ). Workers are not allowed to work if any concurrent pulmonary disease (e.g. asthma or COPD) was detected. Hypertension was detected in 3 male workers. Demographic characteristics of the subjects are shown in Table 1.

### Effects of gender and age on pulmonary function

Table 2 shows the changes in pulmonary functional parameters during the 5-year study period. Our results show a significant loss of pulmonary function ( $p < 0.05$ ). In male workers, losses in FVC and PEF were significantly higher ( $p = 0.004$  and

**Table 1.** The demographical characteristic of the workers.

Features	Survey 2011 (n=49)
Male, n (%)	37 (75.5%)
Female, n (%)	12 (24.5%)
Age (mean±SD)	35.3±5.8
Age (years old)	
≤30	9 (18.4%)
31–35	19 (38.7%)
36–40	11 (22.5%)
≥41	10 (20.4%)
Mean working period (year)	7.61±1.83
Working period (year)	
6	14 (28.6%)
7–8	23 (46.9%)
>9	12 (24.5%)
Mean height (min–max)	170.4 (153–190)
Male	173.6 (165–190)
Female	160.5 (153–170)
BMI (kg/m <sup>2</sup> ) (mean ±SD)	
BMI in 2006	23.71±4.11
BMI in 2011	24.81±4.22
Cumulative dust exposure (mg/m <sup>3</sup> /yr)	1.75±0.42

$p = 0.001$ , respectively) and loss in FEV1 was higher, but not significantly ( $p > 0.05$ ), compared to female workers. Table 3 shows the mean annual 5-year loss of pulmonary functions. Figures 1 and 2 show 5-year loss of FEV1 in both genders.

### Effects of smoking on pulmonary function

In 2006, the percentage of smokers (among 196 workers) was 46.9% for the male workers and 33.3% for the female workers. In 2011 (among 49 workers) this percentage was 37.8% for males and 33.3% females. Although the majority of workers were male in both investigations, female workers composed of 33.7% of the study group in 2006 and 24.5% in 2011.

Values of FEV1, FVC, FEV1/FVC, and PEF were lower for current smokers than for never smokers and former smokers in 2006 and 2011, but the difference was not significant ( $p > 0.05$ ). The 5-year loss of pulmonary functions (FEV1, FVC, and PEF) in current smokers was not statistically different from that of never

**Table 2.** Pulmonary function parameters of textile workers in 2006 and 2011 and five-year functional deterioration.

	2006 (mean ±SD)	2011 (mean ±SD)	Difference	p-value
<b>Parameters (all) (n=49)</b>				
FEV1 (ml)	3794.48±735.4	3531.42±711.6	263.06±145.84	p=0.000
FVC (ml)	4605.71±873.1	4261.02±850.2	344.69±244.4	p=0.000
FEV1/FVC (%)	82.97±4.6	82.96±4.5		p=0.94
PEF (ml/s)	894.51±190.3	815.24±171.3	79.26±63.24	p=0.000
<b>Never smoker (n=24)</b>				
FEV1 (ml)	3863.33±774.5	3545±754.8	318.33±117.2	p<0.001
FVC (ml)	4585.83±934.1	4232.08±916.7	353.75±193.8	p<0.001
FEV1/FVC (%)	83.83±4.3	83.88±4.2		p=0.68
PEF (ml/s)	884.04±185.2	802.79±160.7	81.25±54.6	p<0.001
<b>Current smoker (n=18)</b>				
FEV1 (ml)	3710.55±790.9	3477.22±738.7	233.33±162.48	p<0.001
FVC (ml)	4555.55±920.2	4243.33±844.8	312.22±313.9	p=0.001
FEV1/FVC (%)	81.72±4.9	81.89±4.8		p=0.47
PEF (ml/s)	874.16±219.4	798.5±189.2	75.66±74.66	p<0.001
<b>Former smoker (n=7)</b>				
FEV1 (ml)	3774.28±462.8	3624.28±549.2	150±113.7	p=0.013
FVC (ml)	4802.85±548.2	4405.71±714.3	397.14±219.3	p=0.003
FEV1/FVC (%)	83.28±4.9	82.57±4.6		p=0.318
PEF (ml/s)	982.71±105.3	901±155.6	81.71±68.6	p=0.02
<b>Female (n=12)</b>				
FEV1 (ml)	2992.50±430.90	2755.83±429.30	237.5±126.94	p=0.002
FVC (ml)	3494.16±395.96	3255.83±390.06	242.5±143.02	p=0.002
FEV1/FVC (%)	84.58±5.4	84.39±5.5		p=0.041
PEF (ml/s)	628.91±108.93	590.16±113.77	33.75±39.83	p=0.002
<b>Male (n=37)</b>				
FEV1 (ml)	4054.59±616.80	3782.97±594.49	275.67±147.33	p=0.000
FVC (ml)	4966.21±650.56	4587.02±686.51	369.72±199.31	p=0.000
FEV1/FVC (%)	82.45±4.2	82.5±4.1		p=0.8
PEF (ml/s)	980.64±116.36	888.24±113.18	78.86±79.76	p=0.000

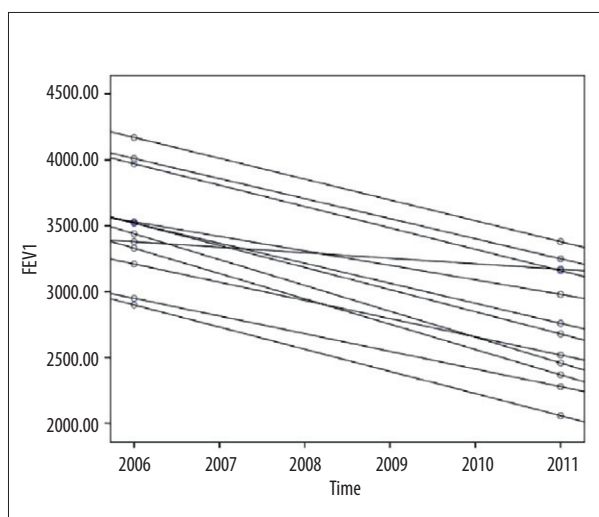
and former smokers ( $p>0.05$ ), but in former smokers 5-year loss in FEV1 is higher than in never smokers ( $p=0.02$ ).

Five-year losses in pulmonary function were assessed to determine correlations among age, height, cumulative dust

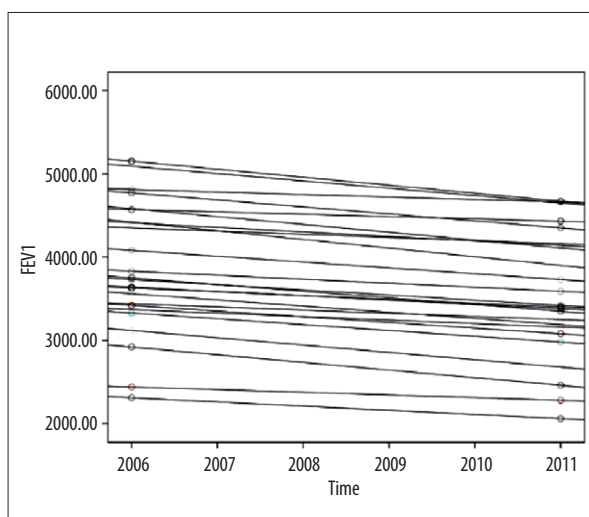
exposure, pack-years of smoking, and 5-year change in BMI, but no significant correlations were found (Table 4). Regression analysis showed that only smoking and weight are independent variables, affecting the 5-year FEV1 loss by 23.7% ( $p<0.05$ ).

**Table 3.** Annualized 5-year loss of pulmonary function tests in different situations.

Features (n)	FEV1 (ml/y)	FVC (ml/y)	PEF (ml/s per y)
Total (49)	53.2±28.4	68.9±48.8	79.2±63.2
Male (37)	55.1± 29.4	75.8±52.2	18.4±13.0
Female (12)	47.5± 25.3	47.6±29.1	7.7±6.9
Current smokers (18)	47.0±32.3	62.4±62.7	15.1±14.9
Non-current smokers (21)	56.9±25.7	72.7±39.3	16.2±11.3
BMI increased (31)	60.7±27.3	71.9±50.5	16.7±14.1
BMI non-increased (18)	40.4±26.3	63.7±46.9	14.3±9.6



**Figure 1.** 5-year loss in FEV1 value in female gender.



**Figure 2.** 5-year loss in FEV1 value in male gender.

**Table 4.** The correlations between 5-year changes in FEV1 with other factors.

	5-year changes in FEV1 (ml/yr)
Cumulative dust exposure, mg/m <sup>3</sup> /yr	r=0.05, p=0.73
Pack-years*	r=-0.19, p=0.17
5-year changes in BMI	r=0.25, p=0.081

\* Calculated among current smokers only.

## Discussion

The exact pathogenesis of airway disease caused by cotton and other organic dusts remains to be described. However, increasing evidence indicates that chronic pulmonary functional loss observed in cotton textile workers possibly results from continuous exposure, repeated acute airway responses, or both [14]. Epidemiologic studies have also shown that

a Gram-negative bacterial endotoxin is a possible causative agent of respiratory symptoms and pulmonary functional loss among cotton workers [15,16]. Previous analyses of this cohort of cotton workers also showed that the FEV1 loss was more associated with a higher cumulative endotoxin exposure than with cotton dust [15,17]. However, Christiani et al. determined that exposed environmental endotoxin levels were moderately correlated with cotton dust levels in all study periods [18]. In our study, respirable environmental dust concentrations were measured, but we did not measure the endotoxin levels, for 2 reasons. First, our opinion was that the endotoxin levels would not provide a meaningful contribution to the study because endotoxin level is suspected to be lower in drier climates, such as in the city of Malatya [2]. Second, the endotoxin level could not be measured due to technical and financial limits. In our previous study in 2006, we did not find any correlation between dust concentration and functional loss because different kinds of textile procedures were being performed in the same fabric area [10]. Hence, in the present study, we did not investigate the correlation between dust concentration and pulmonary functional loss.

The nature of lung function over the life span is still under discussion. During childhood and adolescence, there is clearly a rise in lung function [4]. A plateau phase then occurs in early adulthood during which there is little or no change in FEV1. After this plateau, lung functions start to decrease at around 20 years of age. In a large study, the decline in FEV1 was assessed longitudinally in 20-year-olds and was found to be 29 ml/year in men and 25 ml/year in women [19]. Workers exposed to cotton dust were expected to lose more pulmonary functions. Hang et al. [20], in a 20-year follow-up study of cotton dust exposure in China, found 0.2–1.6 mg/m<sup>3</sup> respirable dust concentrations, 2894 ml mean baseline FEV1, and 31.4 ml annual FEV1 loss. A 5-year follow-up study in China reported a mean baseline FEV1 of 2915 ml and a mean annual decline in FEV1 of 39.5 ml among cotton workers [21]. In England, respirable dust concentrations between 0.11 and 1.4 mg/m<sup>3</sup> and annual FEV1 loss at 54 ml were documented [22]. In a 5-year follow-up study, Glindmeyer et al. investigated yarn manufacturing shift workers in the United States and determined annual declines in FEV1 of 11.2, 34.6, and 35.4 ml/year, according to the shift worked [23]. In our study, we found exposed dust concentrations to be between 0.1 and 0.38 mg/m<sup>3</sup> and mean baseline FEV1 and mean annual FEV1 loss to be 3794 ml and 53.2 ml, respectively. Annual FEV1 losses among different studies, mostly from China, ranged from 31.4 to 54 ml. However, a study in the Netherlands that included 12 years of follow-up of healthy 20-year-olds found annual FEV1 loss to be 35 ml/year [24], and this annual loss in the general population was higher than in workers exposed to cotton dust in China [20]. It is known that pulmonary function parameters are affected significantly by personal factors, such as height and weight [8]. We assumed that the ratio of annual FEV1 loss to baseline FEV1 would be more accurate and more logical for determining pulmonary functional deterioration than the annual FEV1 loss. Hence, we examined the results of Christiani's study in which the mean working period was 15.8 years and the mean annual decline in FEV1 was 39.5 ml [21]. In our study, the mean number of years worked in the textile factory was 7.6 years and the mean annual decline in FEV1 was 53.2 ml; our calculated ratio of annual FEV1 loss to baseline FEV1 was 1.4%. The ratio in Christiani's study was 1.36%, which is comparable to our results. Wang et al. revealed that annual FEV1 loss in pulmonary function decreases with increasing number of years of occupational exposure. In their study, the mean baseline FEV1 was 2915 ml and the annual FEV1 loss was 32.9 ml over 15 years and 29.2 ml over 20 years [25]. Our calculated ratio of annual FEV1 loss to baseline FEV1 for that study was 1.12% (15 years) and 1.0% (20 years). Our result of 1.4% in the present study is higher than previously mentioned studies because our exposure period was shorter. These findings indicate that the ratio of FEV1 loss to baseline FEV1 is more useful for evaluating annual pulmonary functional loss.

Population-based studies have documented weight gain as a risk factor for pulmonary functional loss. As BMI increases (particularly in morbidly obese persons), there is evidence of reduced pulmonary functions, such as FEV1 and FVC [26,27]. In another study of weight gain in humans, reductions in FEV1 and FVC were detected, the FEV1 to FVC ratio did not change, and static lung volumes decreased. These findings suggest that reduction is due to the restriction type of pulmonary functional loss [26]. In our study, there was no significant increase in BMI during the 5-year period. We found that weight gain was an independent factor affecting the 5-year FEV1 loss, but no significant correlation was found between an increase in BMI and loss of FEV1. This suggests that the pulmonary functional loss found in our study cannot be attributed to an increase in BMI.

Exposure to cotton dust and smoking are associated with the development of chronic obstruction in pulmonary function. Cross-sectional and longitudinal studies indicate that the effects of cotton dust exposure and smoking on pulmonary functional loss appear to be additive [4,6,28]. In our study, we found no statistical difference among 5-year loss of pulmonary function in current, former, and never smokers. We also found no significant correlation in current smokers between pack-years and 5-year loss of FEV1. However, in both 2006 and 2011, all pulmonary functional parameters in current smokers were less than in never smokers and former smokers. This might have been because some "former or never smokers" concealed their actual smoking habit for fear of dismissal.

There are several limitations in our study. First, we could not measure endotoxin levels because of technical and financial inabilities. In addition, the city of Malatya has a dry climate, and we suspect endotoxin levels are lower, which could have affected our results since some authors suggest that endotoxin levels are moderately correlated with cotton dust concentrations. A second limitation was the absence of a control group. In addition, we had a limited number of workers in our study. Of the 196 workers selected at the outset, only 49 workers continued to work in the same factory by 2011. This might be because textile workers in Turkey are generally young and consider their job to be temporary.

## Conclusions

In conclusion, this study presents the first data on chronic pulmonary functional loss of Turkish textile workers exposed to cotton dust. Currently, annual FEV1 loss is generally used for evaluating the chronic pulmonary functional loss in cotton textile workers, but pulmonary function varies according to multiple factors, such as race, height, and weight. For this reason, values of FEV1 loss are not comparable among studies. Our

findings support the use of the annual FEV1 loss to baseline FEV1 ratio for evaluating pulmonary functional loss.

### Competing interests

The authors declare that they have no competing interests.

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### Acknowledgements

We especially thank the textile factory workers and Dr Osman Icel. The authors also thank to Dr. Murat Ozdemir, MD, from Sütçü İmam University, Faculty of Medicine, Department of Ophthalmology for English grammar control.