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Original Article

Dose-response of Cotton Dust Exposure with Lung Function among Textile Workers: MultiTex Study in Karachi, Pakistan

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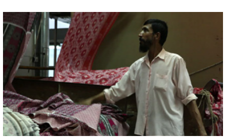

Abstract

Background: Cotton dust exposure among textile mill workers lead to impaired lung function. However, only few studies have investigated the dose-response relationship between cotton dust and lung function.

Objective: To determine the dose-response relationship between cotton dust exposure and lung function among textile workers.

Methods: This cross-sectional survey was conducted from January to March 2016 and included 303 adult male textile workers from spinning and weaving sections of 5 mills in Karachi, Pakistan. We collected data through a translated version of the American Thoracic Society respiratory questionnaire (ATS-DLD-78A) and using spirometry. Mill-level airborne cotton dust was measured over an 8–12-hour shift through UCB-PATS (University of California, Berkeley-Particle, and Temperature Monitoring System). Multiple linear regression was used to determine the association between cotton dust exposure and lung function assessed through the 3 indices: forced expiratory volume in the first second (FEV_1), forced vital capacity (FVC), and their ratio (FEV_1/FVC).

Results: The mean age of the workers was 32.5 (SD 10.5) years. The mean spirometry indices expressed in percent predicted values were FEV_1 82.6 (SD 14.0); FVC 90.3 (14.7), and FEV_1/FVC 94.9 (10.5). The median cotton dust concentration was 0.61 (IQR 0.2 to 1.3) mg/m^3. The frequency of respiratory symptoms was 15% for cough, 20% for phlegm, and 20% for wheezing. After adjustment for covariates, every mg/m^3 increase in dust concentration was associated with 5.4% decline in FEV_1.

Conclusion: This study quantifies the exposure-dependent relationship between cotton dust and lung function; which has implications for regulations and standards in the textile industry in Pakistan and similar cotton-processing countries.

Keywords: Cotton fiber; Occupational exposure; Respiratory function tests; Spirometry; Pakistan; Byssinosis

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Introduction

Workers are exposed to various hazards in textile industry. Those include organic and inorganic dust, chemicals, and physical agents.

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Exposure to cotton dust is among the most important concerns in textile mills.[1] Exposure to cotton dust is associated with respiratory diseases and impaired lung function.[2,3] The dust particles include particulate matter (PM) with different sizes that impacts health with varying severity. $PM_{2.5}$, with an ability to penetrate deep into the minor airways in lungs, is more noxious than others.[4]

Respiratory illnesses with symptoms end up in a progressive decline in the lung function, which is clearly evident from available literature on the health of textile workers. Studies from the UK report a prevalence of byssinosis of 0.3% among textile workers;[5] the prevalence reported from China and Pakistan are 32% and 10%, respectively.[2,6] High dust concentration in the cotton-ginning mills in India, ranging from 1–6 mg/m^3, was found to be associated with decrements in lung function among workers.[7] Similar situation persists in cotton growing and processing countries globally, where large number of workers are affected by respiratory illness due to improper occupational health and safety measures.[6]

Studies conducted in Sweden and the US found a dose-response relationship between the lung function and the airborne dust.[8-9] A study conducted in two Shanghai factories, on the other hand, found no such relationship.[10] These findings are inconclusive. These studies are old and conducted in economically developed countries. Therefore, we clearly need to assess the situation based on the current standards and regulations globally. Since the high burden of respiratory diseases in turn results in high worker turnover,[11] there are important regulatory and policy implications for several countries where textile and garments industry plays a significant role in the national economy. This study was therefore conducted to determine the dose-response relationship between cotton dust exposure and lung function among textile workers.

Materials and Methods

This study was conducted as part of the larger MultiTex research study (Multifaceted intervention package for respiratory health of Textile workers), which aims at determining the effectiveness of an intervention package for improvement of respiratory health among textile workers. The baseline survey was conducted from January to March, 2016 among adult male textile workers of Karachi, Pakistan. We included data from five textile mills, selected from main industrial areas in Karachi—Korangi/Landhi Industrial Area, Sindh Industrial Trading Estate (SITE), and SITE Super Highway. A site from the suburbs of Karachi (Nooriabad) was also included. Karachi is the capital of Sindh province and is the largest city in Pakistan with multi-ethnic population of more than 17 million.[12] Karachi is the economic center of the country and contributes significantly to the state economy, hosting main industries, including an estimated 794 textile mills.[6]

For more information on respiratory symptoms and lung function among Greek cotton industry workers see http://www.theijoem.com/ijoem/index.php/ijoem/article/view/888

We included five mills, where the administration agreed to be part of the study. We recruited 310 workers out of the total of 4413 eligible workers in the five textile mills using a non-probability purposive sampling method. A minimum sample size of 303 textile workers was required to achieve a power of 80% to detect a difference of 1% with anticipated correlation coefficient ranging between 0.5 and 0.6 and a level of significance of 0.05. NCSS-PASS software (ver 2008) was used for the calculation.

The eligible participants included adult (≥18 years) male textile mill workers, working for at least one year in weaving or spinning sections of textile mills. All workers who were willing to participate and were available at the time of the visit of the study team and those who provided written informed consent were recruited. Those reporting myocardial infarction within the past three months, any chest or abdominal surgery within past six months, any skeletal deformity, currently using tuberculosis medicine, and those unable to perform spirometry due to certain medical conditions like oral sub-mucous fibrosis, were excluded from the study. Workers were recruited on working days and during working hours (includes morning and evening shifts).

Spirometry

Lung function was measured with a Vitalograph In2itive (Vitalograph, UK) spirometer by trained technician in a selected area within the mill provided by administrative staff. Workers were asked to abstain from smoking for at least one hour prior to spirometry. All spirometry measurements were performed according to the American Thoracic Society standards.[13] Interpretations of spirometry were done through comparing the absolute values of lung function indices (FEV_1, FVC, and FEV_1/FVC) with predicted values, and reviewing the spirogram. The best of the three readings was used for further analysis. Moreover, all spirograms were reviewed by a consultant pulmonologist for quality assurance purpose.

TAKE-HOME MESSAGE

- This study quantifies the exposure-dependent relationship of cotton dust with lung function.
- The most common respiratory symptoms reported by cotton workers were phlegm (20%) and wheezing (20%).
- Our findings supported the role of multiple factors in relation to lung function among studied workers. After adjustment for different covariates, every mg/m^3 increase in dust exposure led to 5.4% decline in FEV_1.

Questionnaire

The American Thoracic Society respiratory questionnaire (ATS-DLD-78A) was used to assess the current and past respiratory illness and symptoms, family history of asthma or other lung diseases, and smoking history. Sections related to socio-demographic, type of fuel used, and exposure to occupational respiratory hazards were also included. Textile workers were also asked about their previous occupations, such as farming, welding, and construction, which might be associated with higher risk of lung function abnormalities. Exposure to solid fuel was defined as the use of firewood, cow dung, charcoal, and coal or crop residues for cooking or heating purpose, for one or more year in the lifetime. Pack-years of smoking was calculated as an average number of cigarettes per day multiplied by years of smoking divided by 20. The structured questionnaire was translated into Urdu and pre-tested before use in the study. Trained data collectors conducted the interviews.

Dust Monitoring

We used UCB-PATS (University of California, Berkeley-Particle, and Temperature Monitoring System) for area monitoring of particulate matter ($PM_{2.5}$). It is a simple, portable, data logging optical particle monitor device that carries a photoelectric detector and has been validated in different countries.[14] The area monitoring was done by the data collector in all subsections of spinning and weaving sections at each of the selected mills on working days. The device was placed at a height of around 1.5 meters above the floor (approximate standing height of a worker) in selected places. Zeroing of the device was done approximately 1–2 hours before and after the monitoring according to the manufacturer guidelines. The device recorded $PM_{2.5}$ concentration for every minute. We measured $PM_{2.5}$ concentration as an average per shift exposure expressed in mg/m^3. Cumulative dust exposure, defined as the sum of the duration of employment in a specific section in textile mills, was calculated as years of exposure multiplied by the concentration of the cotton dust in the studied department or section. The average daily dust exposure was calculated by dividing the calculated cumulative dust exposure by the total number of days of employment in the textile mill and was termed "cotton dust exposure."

Ethics

This study was approved by the Ethics Review Committee of Aga Khan University, Karachi (ERC No. 3949-CHS-ERC-15). Written informed consent was taken from all the study participants. Confidentiality of data was maintained.

Statistical Analysis

Data were entered on Epidata 3.1 and analyzed using STATA ver 12. The mean and SD were reported for continuous variables. Frequencies and percentages were reported for categorical variables. Normality of outcome variables was checked using the data distribution histogram. Using a stepwise model, multiple linear regression analysis was performed, adjusting for covariates. A p value <0.05 was considered statistically significant.

Results

Out of 310 workers studied, seven were excluded from the analysis due to unacceptable or missing spirometry data, leaving 303 workers for analysis. The mean age, height, and weight of the textile workers was 32.5 (SD 10.5) years, 169.6 (6.7) cm, and 61.3 (12.6) kg, respectively. Out of 303 textile workers, 101 (33.3%) worked in spinning section; the remaining 202 (66.7%) worked in weaving section. The median cotton dust concentration was 0.6 (IQR 0.2 to 1.3), 0.6 (0.5 to 0.9) in spinning and 0.6 (0.2 to 1.4) in weaving section, respectively (Table 1). The mean work experience was 2.2 (SD 1.1) years. The median work duration of previous occupations affecting lung function was 5 (IQR 2 to 10) years. Almost three-quarters (n=222) of

Table 1: Some characteristics of the studied textile workers, Karachi, Pakistan (n=303)

Characteristics	n (%)
Educational status	
Informal/not educated	205 (67.7)
Formal	98 (32.3)
Ethnicity of workers based on spoken language	
Urdu	62 (20.5)
Punjabi	82 (27.1)
Sindhi	38 (12.5)
Pashto	65 (21.5)
Saraiki, Hindko, Bengali, Rajputi, or Hazara	56 (18.5)
Monthly income of workers, PKR (US$)	
<15 000 (<124)	174 (57.4)
15 000–19 999 (124–165)	56 (18.5)
20 000–24 999 (165–206)	39 (12.9)
≥25 000 (≥206)	34 (11.2)
Status of house	
Own house	111 (36.6)
Rented house	192 (63.4)
Textile mill	
A	80 (26.4)
B	105 (34.7)
C	44 (14.5)
D	20 (6.6)
E	54 (17.8)

Table 2: Frequency of respiratory symptoms and spirometry patterns among textile workers, Karachi, Pakistan, (n=303)

Characteristics	n (%)
Respiratory symptoms and illness	
Cough	47 (15.5)
Phlegm	61 (20.1)
Wheezing	61 (20.1)
Chest tightness	36 (11.9)
History of asthma	28 (9.2)
History of allergies	61 (20.1)
Family history of asthma	35 (11.6)
Spirometry pattern	
Normal	180 (59.4)
Restrictive	38 (12.5)
Obstructive	82 (27.1)
Mixed	3 (1.0)

studied workers used solid fuels including firewood, cow dung, charcoal, coal, and crop residues. Of 303 workers, 161 (53.1%) were working more than eight hours a day. Residence of 165 (54.5%) of workers was less than 1.5 km away from factory. The workers who smoked had a median of 2.4 (IQR 0.6 to 6.7) pack-years of cigarette smoking. Other characteristics of the studied workers are presented in Table 1.

Wheezing (20%) and phlegm (20%) were the most commonly reported symptoms (Table 2). The mean percent predicted values for FEV_1, FVC, and FEV_1/FVC were 82.6% (SD 14.0%), 90.3% (14.7%), and 94.9% (10.5%), respectively. More than a quarter of workers had an obstructive pattern on spirometry (Table 2).

All independent variables were considered for their potential association with lung function indices in univariate analysis using simple linear regression for which unadjusted regression coefficients were calculated (Table 3). Multiple linear regression models were developed to examine the relationship between cotton dust exposure and lung function indices after adjusting for various variables. The final model showed that every mg/m^3 increase in cotton dust concentration led to more than 5% decline in FEV_1 and almost 3% decline in FEV_1/FVC ratio. No significant dose-response relationship was found between cotton dust exposure level and FVC (Table 4). The model showed that 20% of the variability observed in the mean FEV_1 level could be explained by the variation in the mean dust exposure level, pack-years of cigarette smoking, and previous history of asthma. Moreover, the mean dust exposure level, ethnicity of workers, and level of education were strong predictors in the model of FVC. Variability in the mean FEV_1/FVC levels could be explained by variation in the mean dust exposure level, solid fuel use, duration of previous job affecting lung function, and working for >8 hours a day (Table 4).

Discussion

We found that exposure to cotton dust was associated with lung function impairment in a dose-response manner among textile workers. There was an inverse dose-response relationship between the cotton dust exposure with FEV_1 and FEV_1/FVC. A study conducted in Sweden on 68 students and 39 cotton mill workers, participating in 23 card room experiments, revealed a similar dose-response relationship between the mean FEV_1 decline with the amount of airborne dust level.[8] Another five-year longitudinal study, which included 6037 workers from six cotton and three synthetic textile mills located in southeastern parts of the US, also found a significant dose-response relationship between annual declines in FEV_1, FVC, and Forced Expiratory Flow Rate (FEF_{25-75}) and the mean exposure level in a cotton

Table 3: Univariate analysis of factors associated with dependent variables, *ie*, FEV_1, FVC, and FEV_1/FVC among textile workers of Karachi, Pakistan (n=303)

	Regression coefficient (95% CI)		
Independent variables	**FEV_1**	**FVC**	**FEV_1/FVC**
Cotton dust exposures (mg/m^3)	0.6 (-2.0 to 3.3)	3.5 (0.7 to 6.3)	-2.1 (-4.1 to -0.2)
Pack-years of cigarette smoking	-0.5 (-0.8 to -0.1)	-0.2 (-0.5 to 0.1)	-0.3 (-0.6 to -0.1)
History of asthma	-5.0 (-10.4 to 0.5)	-4.7 (-10.5 to 0.9)	-1.1 (-5.2 to 2.9)
Working hours >8 hrs	-2.4 (-5.6 to 0.7)	0.1 (-3.4 to 3.2)	-2.7 (-5.0 to -0.3)
Solid fuel use	-3.4 (-6.9 to 0.2)	0.3 (-3.4 to 4.0)	-3.9 (-6.6 to -1.3)
Factory near home (≤1 km)	-0.1 (-3.2 to 3.1)	-0.4 (-3.8 to 2.8)	0.02 (-2.3 to 2.4)
Duration of previous job affecting lung function (yrs)	-0.2 (-0.4 to -0.03)	-0.1 (-0.3 to 0.2)	-0.2 (-0.4 to -0.1)
Ethnicity of workers			
Urdu (reference)			
Punjabi	2.0 (2.4 to 6.5)	2.6 (-2.1 to 7.3)	-1.8 (-5.3 to 1.6)
Sindhi	-6.5 (-12.1 to -1.1)	-5.5 (-11.2 to 0.3)	-3.2 (-7.4 to 1.1)
Pashto	7.2 (2.5 to 12.0)	7.5 (2.5 to 12.6)	-0.7 (-4.4 to 2.9)
Others	2.4 (-2.4 to 7.3)	0.9 (-4.3 to 6.1)	0.1 (-3.7 to 3.9)

yarn manufacturing industry.[9] However, in a study conducted in two Shanghai factories, which included 443 cotton workers and 439 control subjects from a silk mill, where vertical elutriator was used to measure dust and endotoxin concentration, no dose-response relationships was observed between dust concentration and any of lung function indices or frequency of symptoms.[10] The differences observed in the results of studies could be attributed to variation in methodology, sample size, or study population.

Our study did not find any association between cotton dust exposure and FVC. A possible reason might be the fact that FVC is primarily an indicator of restrictive pattern. Compared to FEV_1, FVC may not be a good indicator of obstructive pattern, which was more prevalent among the studied textile workers.[15]

This study provided support for the role of multiple factors in relation to lung function indices. Pack-years of cigarette smoking was also found to be an important factor for decrements observed in FEV_1 in our study, a finding which is similar to another study.[16] History of asthma was highly associated with the decline in FEV_1. It is evident that children with persistent asthma and reduced development of lung function are at greater risk for fixed airflow obstruction in early adulthood.[17] A previous study conducted in Karachi, Pakistan also showed that Sindhi ethnicity is an independent predictor for reduced lung function among textile workers,[6] as it was also reported in our study. A possible reason might be that workers belonging to Sindhi ethnicity have less knowledge regarding respiratory hazards at textile mills.[18] Some cultural practices or environmental factors could be the reasons for such a finding, however further assessment is needed

Table 4: Multivariable analysis of factors associated with dependent variables, *ie*, FEV_1, FVC, and FEV_1/FVC among textile workers of Karachi, Pakistan (n=303). All variables are mutually adjusted for each other.

	Regression coefficient (95% CI)		
Independent variables	**FEV_1**	**FVC**	**FEV_1/FVC**
Cotton dust exposures (mg/m^3)	-5.4 (-10.5 to -0.2)	3.7 (-0.9 to 6.4)	-2.7 (-4.7 to -0.7)
Pack-years of cigarette smoking	-0.5 (-0.8 to -0.2)	—	—
History of asthma	-18.5 (-30.9 to -6.1)	—	—
Working hours >8 hrs	—	—	-3.1 (-5.5 to -0.7)
Solid fuel use	—	—	-3.0 (-5.6 to -0.3)
Duration of previous job affecting lung function (yrs)	—	—	-0.2 (-0.4 to -0.04)
Informal/not educated	—	-4.0 (-7.5 to -0.5)	—
Ethnicity of workers	—		—
Urdu (reference)			
Sindhi		-7.8 (-13.6 to -1.9)	
Pashto		1.6 (-3.0 to 6.3)	
Punjabi		6.2 (-1.3 to 11.2)	
Others		-0.2 (-5.4 to 4.9)	

to elucidate this issue. Lack of education was also found to be a significant factor in our study. The finding was in line with the previous study.[6] The probable justification is that it might be associated with lack of awareness resulting in such behavior at work that makes them more exposed to cotton dust.[6]

Several epidemiological studies suggest a strong relationship between solid fuel use and development of respiratory diseases or decline in spirometry indices.[19-21] Our study also found a decline in the mean FEV_1/FVC ratio among workers who ever used solid fuels (firewood, cow dung, charcoal, and crop residue). Duration of the previous occupations affecting lung function including farming, welding, and construction working was also found to be a significant variable in our study. Similar finding was reported in previous studies.[22-24] FEV_1/FVC ratio was also found to be associated with work more than eight hours a day compared to those working less than eight hours. A study conducted in cotton mills in Punjab, Pakistan, showed that working hours per shift is a predictor for altered lung function.[25] A possible explanation would be that the long working hours may result in higher exposure to cotton dust. Literature also reported that prolonged exposure to cotton, flax, and fibers dust may cause permanent scarring of the airways and lung tissues that ends in lung diseases.[26]

To the best of our knowledge, this study was one of the few studies to determine the dose-response relationship between cotton dust exposure and lung function among textile mill workers. This study considered area monitoring of cotton dust levels along with an objective assessment of lung function through spirometry, giving a better assessment of exposure and outcome

For more information on the effect of exposure to cooking fumes on lung functional capacity see http://www.theijoem.com/ijoem/index.php/ijoem/article/view/1100

among textile workers as compared to previous studies. Moreover, all spirograms were reviewed and approved by a consultant pulmonologist for quality assurance purposes. In addition, a trained technician in the field conducted spirometry and operated UCB-PATS in order to avoid handling issues. Lastly, we included textile mills from major industrial zones in Karachi and suburbs. Therefore, we were able to capture diverse workers with different socioeconomic and ethnic groups from five variable-size industries with varying safety environments. Therefore, we believe that findings of this study are generalizable to similar textile workers in Pakistan and other developing countries.

Some limitations need to be considered for this study. This was a cross-sectional study, and thus could not predict causality; it could also not cater for workers who quitted their job due to their illness during their work at textile mills that gave rise to the healthy worker selection effect, which is an important limitation of this study.. In our study, variables like occupational history and previous respiratory illness were linked to the past events. Therefore, recall bias might limit the study. Moreover, individual monitoring and assessment of endotoxin levels were not possible due to time and budget constraints. We also did not include workers from the informal sector where they might be at a higher exposure with fewer safety mechanisms.

In conclusion, this study found an exposure-dependent relationship of cotton dust with the lung function among textile workers. Our findings provided empirical evidence regarding occupational health in the largest industrial sector of the country that called for the implementation of appropriate precautionary measures.

Conflicts of Interest: None declared.

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