

Risk Factors of Pulmonary Obstruction Among Textile Industry Workers

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ABSTRACT

Chronic exposure to cotton dust in the textile manufacturing industry has been a possible risk factor for pulmonary obstruction. Not many studies, however, have investigated its impact in combination with personal variables like age, gender, and length of service, particularly in developing countries. The present study investigated the impact of cotton dust exposure, age, gender, and length of service on the incidence of pulmonary obstruction among textile workers in Surakarta, Indonesia. Observational analytic study using cross-sectional design was done on 88 eligible workers. Quantitation of exposure to cotton dust was done with a High-Volume Air Sampler and lung function ascertained using spirometry. Data analysis was done through simple and multiple binary logistic regression at a significance level of 0.05. The incidence of pulmonary obstruction was 56.8%. Being exposed to cotton dust levels exceeding the threshold limit value (TLV) of 0.2 mg/m³ significantly increased the risk of pulmonary obstruction (OR: 4.18; 95% CI: 1.51–11.63; p=0.006). Employment duration was also significantly associated with pulmonary obstruction (OR: 1.21 per year; 95% CI: 1.03–1.44; p=0.023), while age and gender were not significant predictors. The accuracy of the final model was 75%, which is considered to be acceptable in occupational health studies in predictive modeling. The current research reaffirms that long-term exposure to cotton dust and extended working hours are critical risk factors for pulmonary obstruction in textile industry workers. Therefore, it is recommended to long-working-hour employees to have proper control of the exposure and continuous lung function monitoring.

Key Messages:

- Long-term exposure to cotton dust is a significant risk factor for pulmonary obstruction among textile workers, indicating the need for strict dust control in the work environment.
- Length of Employment is an important predictor of decline in lung function, and it suggests the need for regular evaluation of lung health, particularly for employees with long durations.

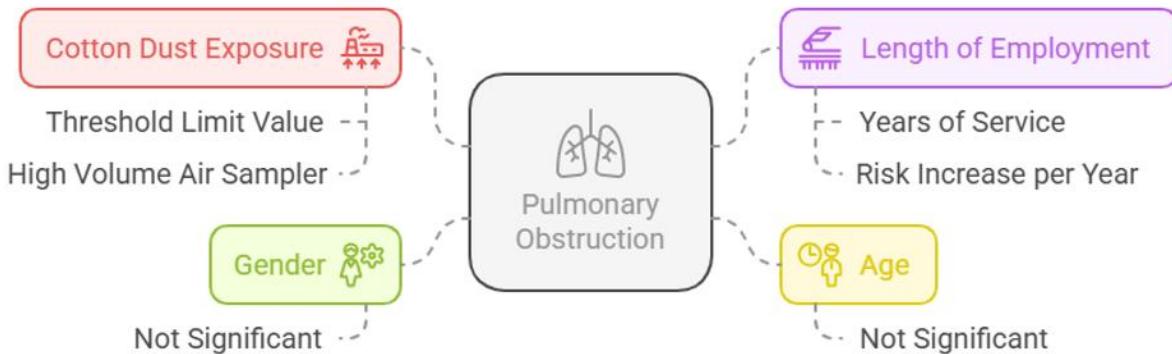
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GRAPHICAL ABSTRACT

Risk Factors for Pulmonary Obstruction in Textile Workers



INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is one of the leading causes of morbidity and mortality across the globe, with more than 3.2 million deaths annually (1). COPD is not only a large health burden in developed countries but also increasingly among developing nations due to harmful workplace exposures (2,3). In various occupational groups, textile workers are one of the most susceptible to developing byssinosis (35%), asthma (20%), and chronic bronchitis (10%), particularly those with prolonged exposure to cotton dust (4–6).

Cotton dust generated in spinning and weaving processes contains fine, respirable particles that can penetrate the lower respiratory tract (7,8), resulting in chronic inflammation, airway irritation, and reduced lung function (9,10). Previous studies have also repeatedly linked cotton dust exposure to impaired pulmonary function among textile workers (11,12). Textile workers have also been reported to have a greater annual decline in forced expiratory volume in one second (FEV_1) than control populations, indicating progressive ventilatory impairment (13). A study in India reported a 24% prevalence of byssinosis and a positive association between work years and FEV_1 and forced vital capacity (FVC) decrements in cotton spinners (14). Furthermore, research in China has shown that long-term cotton dust exposure causes structural changes in the lung and an elevated risk of chronic obstructive pulmonary disease (COPD) (15). Research findings from Greek textile factories revealed that textile workers showed reduced lung function than controls (16).

Nevertheless, the literature on this subject still presents contradictory findings. Although some studies indicate that short-term or low-level cotton dust exposure is not necessarily linked with quantifiable pulmonary function reduction (17,18). Other study have reported that even low-level cotton dust exposure exposure can be harmful if the exposure is long-term (19). These differences are due to exposure time variability, use of personal protective equipment, quality of the production process, and individual characteristics such as age, gender, and length of employment. There is, therefore, an urgent need for a study that accounts for exposure to cotton dust along with these individual-level factors.

In Indonesia, the textile industry remains a labor-intensive industry with millions of workers. To date, very few local studies have investigated the relationship between cotton dust levels and pulmonary obstruction risk, after adjusting for individual factors. This leaves a serious knowledge gap that needs to be filled to support more evidence-based risk control. The aim of the present study is to investigate how cotton dust, age, gender, and length of employment affect the prevalence of pulmonary obstruction in textile industry workers.

METHODS

This study employed an observational analytic approach using a cross-sectional design to

determine the relation between cotton dust level, gender, age, years of working experience, and pulmonary obstruction in textile workers. This research was carried out in Surakarta, Central Java, Indonesia at a textile factory (approx. 850 workers) in November 2024. The exposed group was made up of production (weaving) personnel who had been employed for a period of one year or more and who were exposed to cotton dust beyond the threshold limit value (TLV) of 0.2 mg/m^3 , as stipulated in the Regulation of the Minister of Health of the Republic of Indonesia Number 70 of 2016 regarding Industrial Workplace Environmental Health Standards and Requirements (20). The comparison group that had exposure below the TLV comprised inspecting, folding, and warehouse personnel. The inclusion factors were: working experience of more than one year, above the age of 20 years, readiness to provide informed consent, and inconsistent or irregular use of respiratory masks. Exclusion factors were: having a previous history of pulmonary conditions such as COPD or asthma.

The sample in the present study was sampled according to a non-probability sampling technique, i.e., purposive sampling with a fixed sample size design. The fixed sample size design was employed due to time efficiency considerations and limited field access. Sample size was calculated using the formula $N = (10 \times k)/p$, where $k = 4$ variables and $p = 0.5$ (no prior reference data were available for comparison, so p was set at 0.5), which calculated a required sample of 80 workers. 10% was added to increase statistical power, so 88 workers were investigated. Data were gathered over two phases. First, a High Volume Air Sampler model TFIA-2F previously calibrated by the Ministry of Environment and Forestry Testing Laboratory No. LK-193-IDN with certificate no. K-211/KAL/PSIKLH/04/2022 was employed to measure the quantity of cotton dust within the workplace environment twice during each workday, 09.00-10.00 and 14.00-15.00, with the two readings' average being used to represent a day's exposure concentrations in each of the departments. Secondly, lung function was assessed with a Chest Graph HI-105 spirometer to establish FEV_1 and FVC values. The FEV_1 and FVC values were measured by a Ministry of Manpower-certified occupational health physician. Pulmonary obstruction was an FEV_1/FVC value of less than 0.70, according to the 2023 Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines (21).

Demographic data such as gender, age, and duration of work were retrieved from employee registration books that the company's human resource department maintained. The data were all kept confidential. The smoking status data in the current study were not numerated, which was a limitation. SPSS version 27 was utilized in data analysis. Data description was conducted through univariate analysis, while simple binary logistic regression was conducted for bivariate analysis. For multivariate analysis, multiple binary logistic regression was used to identify factors associated with pulmonary obstruction after adjusting for potential confounders. Statistical significance was at $\alpha = 0.05$.

CODE OF HEALTH ETHICS

The research protocol was reviewed and approved by Dr. Moewardi Hospital Surakarta's Health Research Ethics Committee with no. approval 932/IV/HREC/2024 dated April 6, 2024.

RESULTS

Table 1 shows the demographic characteristics of the textile industry workers according to cotton dust exposure, gender, age, length of employment, and lung function. The 88 workers made up the largest proportion exposed to cotton dust, with more than the threshold limit value (53.4%), were female (52.3%), had a mean age of 37.08 years, and had a mean of 10.18 years of employment. The largest proportion of the participants had pulmonary obstruction (56.8%).

Table 1. Demographic Characteristics of Textile Industry Workers (N=88)

Characteristic	n	%
Cotton Dust Exposure		
> TLV	47	53.4
< TLV	41	46.6
Gender		
Male	42	47.7
Female	46	52.3

Characteristic	n	%
Age (mean ± SD)	37.08 ± 8.6	-
Length of Employment (mean ± SD)	10.18 ± 5.6	-
Lung Function		
Normal	38	43.2
Obstruction	50	56.8

Table 2 demonstrates the prevalence of pulmonary obstruction based on textile worker characteristics. Pulmonary obstruction was highest among workers with exposure over the threshold limit value of cotton dust (74.5%), females (60.9%), above the average age (73.5%), and with the length of employment of ≥ 10 years (76%). The findings suggest that there may be an association between exposure to cotton dust, gender, age, and length of employment and an increased risk of pulmonary obstruction.

Table 2. Pulmonary Obstruction by Worker Characteristics (N=88)

Characteristic	Pulmonary Obstruction		Normal	
	n	%	n	%
Cotton Dust Exposure				
> TLV	35	74.5	15	25.5
< TLV	15	35.6	26	63.4
Gender				
Male	22	52.4	20	47.6
Female	28	60.9	18	39.1
Age				
Above average	36	73.5	13	26.5
Below average	14	35.9	25	64.1
Length of Employment				
Above average	38	76.0	12	24.0
Below average	12	31.6	26	68.4

Table 3 presents the result of the simple binary logistic regression analysis of the determinants of pulmonary obstruction. Cotton dust exposure significantly increases the risk of pulmonary obstruction ($p < 0.001$; OR = 5.05; 95% CI: 2.03–12.66). Workers with exposure levels greater than the TLV are five times more likely to have pulmonary obstruction compared to workers with exposure levels less than the TLV. Age ($p = 0.004$; OR = 1.08) and working duration ($p = 0.001$; OR = 1.18) are significantly associated with increased risk. However, gender was not significantly associated ($p = 0.423$; OR = 1.4).

Table 3. Results of Simple Binary Logistic Regression for Risk Factors of Pulmonary Obstruction

Variable	B	p-value	OR	95% C.I. for OR
Cotton Dust Exposure (Ref: < TLV)	-1.620	<0.001	5.05	2.03 to 12.66
Gender (Ref: Female)	0.347	0.423	1.4	0.30 to 3.29
Age (years)	-0.081	0.004	1.08	1.03 to 1.19
Length of Employment (years)	-0.165	0.001	1.18	1.07 to 1.29

Dependent variable: Pulmonary obstruction

Table 4 presents the findings of some binary logistic regression testing the impact of different variables on the incidence of pulmonary obstruction. Excessive exposure to cotton dust above the threshold limit remained an independent risk factor ($p = 0.006$; OR = 4.18; 95% CI: 1.51–11.63), as indicated by the odds ratio, which indicated that those with high exposure had more than four times the likelihood of having pulmonary obstruction after controlling for other variables. Length of service was also strongly related ($p = 0.023$; OR = 1.21; 95% CI: 1.03–1.44). Gender and age, however, were not significantly related in this model.

Table 4. Results of Multiple Binary Logistic Regression for Risk Factors of Pulmonary Obstruction

Variable	B	p-value	aOR	95% C.I. for aOR
Cotton Dust Exposure (Ref: < TLV)	-1.430	0.006	4.18	1.51 to 11.63
Gender (Ref: Female)	0.717	0.184	2.05	1.41 to 5.89
Age (years)	-0.027	0.623	1.03	0.89 to 1.08
Length of Employment (years)	-0.195	0.023	1.21	1.03 to 1.44
Constant	2.334			

Dependent variable: Pulmonary obstruction

Table 5 contains performance results from the binary logistic regression model, which determines textile industry worker pulmonary obstruction statuses. The results showed that the model achieved 75.0% accuracy while detecting pulmonary obstruction with 80.0% sensitivity alongside 68.4% specificity for normal readings.

Table 5. Classification Table of Logistic Regression Model Predictions for Pulmonary Obstruction Status among Textile Industry Workers

Observed / Predicted	Normal	Obstruction	% Correct
Actual Normal	26	12	68.4%
Actual Obstruction	10	40	80.0%
Overall			75.0%

DISCUSSION

Researchers studied how cotton dust levels in conjunction with worker age, length of service, and employee gender relate to obstructive pulmonary diseases within Surakarta textile factories. Pulmonary obstruction was significantly associated with cotton dust exposure and length of employment, but not with age or gender.

Cotton Dust Exposure and Pulmonary Obstruction

Exposure to cotton dust produces pulmonary obstructions as the primary study result. Pulmonary obstruction demonstrates a substantial connection to contact with cotton dust, which stands as the primary finding from this research. Workers who worked with cotton dust concentrations exceeding demonstrated a greater likelihood of developing pulmonary obstruction than workers with dust levels under TLV. The odds of pulmonary obstruction were elevated five times for workers exposed above the Threshold Limit Value (OR = 5.05, p < 0.001, binary logistic regression analysis). The finding is consistent with the literature, which has evidenced a link between cotton dust exposure and reduced lung function among workers in the textile sector (5,10–12). Increased concentrations of respirable dust in the textile work environment have been closely linked to decreased FEV1/FVC ratios and increased COPD prevalence, as demonstrated in earlier research (22). Respirable cotton dust can cause chronic airway inflammation and reduced lung function, which can ultimately progress to COPD over time (9). Although exposure to cotton dust is implicated in the risk of pulmonary obstruction, other factors, such as employment duration, are also involved in the disease. Exposure duration for over 10 years has been identified to have an independent role in increasing the risk of occupational lung diseases in workers in the cotton spinning industry (23). Therefore, occupational control of exposure to cotton dust is quite essential in order to reduce the risk of pulmonary illness in textile workers.

Age as a Risk Factor

From the current research, the simple binary logistic regression test (Table 3) revealed that age was significantly related to the incidence of pulmonary obstruction. That is, at an individual level, an increase in age is associated with an increased risk of pulmonary obstruction among textile workers. This finding agrees with research that states that physiological aging makes the lungs less flexible and increases the risk of COPD (24,25). Decline in lung function is also a natural consequence of degeneration and damage to alveolar structure, as well as elastic tissue depletion in the lungs with increasing age (26). However, the

result of the multiple binary logistic regression analysis (Table 4) showed that age was no longer significantly associated with pulmonary obstruction once other variables such as cotton dust exposure, employment duration, and gender were taken into account in the model. This suggests the existence of confounding effects of other variables, more precisely length of employment or cotton dust exposure, which are highly correlated with age. In an epidemiological context, if two variables are correlated and one is a direct cause and the other is not, the effect seen in bivariate analysis can disappear after adjustment for confounders in multivariate analysis (27,28). That is, older workers' risk of pulmonary obstruction was elevated not necessarily because of their chronological age, but most likely due to earlier cumulative exposure to cotton dust or longer length of Employment. Controlling for other effects of variables, therefore, age itself was not independently associated with pulmonary obstruction.

Length of Employment as a Risk Factor

The findings from the simple binary logistic regression (Table 3) indicated that employment duration had a significant correlation with pulmonary obstruction incidence. Additionally, more discussion is required as regards the accuracy and below average specificity (75% and 68.4%) achieved by the predictive model in this case. This is a corollary of additional validation and an enhancement of the model's specificity for predicting the risks of pulmonary obstruction.

In the multiple binary logistic regression analysis (Table 4), other variables like exposure to cotton dust, age, and gender were controlled for, but the relationship persisted as statistically significant. This, therefore, indicates that employment duration is an independent risk factor in pulmonary obstruction in textile workers. This result can be attributed to cumulative exposure to cotton dust throughout years of employment. The more years one spends being exposed to particulates within the work environment, the greater the chances of cumulative respiratory tract damage (5,7). Epidemiological data show that working duration in settings where there is exposure to cotton dust adds to low lung capacity, even at permissible amounts of exposure (9,13). Moreover, increased employment duration is also usually associated with recurrent exposure to organic dust irritants, whose chronic inflammation can lead to small airway fibrosis and additional obstructive disorders (29–31). Such an effect is progressive and irreversible unless intervened upon by appropriate preventive actions (32). Therefore, while day's exposure to cotton dust is the predominant factor, cumulative exposure duration over years is the most predictive factor of pulmonary obstruction. The findings are indicative of the importance of observing workplaces in terms of exposure-duration and of the periodic assessment of the lung function among the textile workers with histories of long service.

Gender as a Risk Factor

Although to multivariate analysis gender was not significant ($p= 0.423$), the distribution pattern indicates relatively higher prevalence of pulmonary obstruction among female workers (60.9%) than among males (52.4%). It is possible for this finding to be influenced by two main factors. environmental and physiological. According to the environmental approach, female workers in the textile industry are usually allotted to the production departments (such as spinning or carding departments) with high quantities of dust exposure (33). Hence, female workers in the textile industries are exposed to a high amount of cotton dust particles in the air. Physiologically, females have diminished airway lumens and smaller total lung volume than males (34–36), are therefore more prone to deposition of inhaled particulates, and more damaged by obstructive pulmonary effects (37). Such job and biological variation mean female employees will be more likely to be prone to respiratory illnesses even if they are equally exposed. More advanced studies with more detailed designs may be needed to more clearly define the contribution of gender to COPD development in the textile industry.

Policy Implications and Preventive Actions

Workplace research data shows important rules to minimize hazardous dust exposure by focusing on both experienced workers as well as older employees. Nevertheless, PPE recommendations should specify the type of mask which is to be used, as per current trends such as N95 masks, and ventilation advice should report the addition of local exhaust ventilation in areas where cotton dust exceeds Threshold Limit Value (TLV). More so, dust monitoring apparatus have to be installed in high-risk manufacturing regions and that of rotation of workers should also be practiced in order to control extended working hours

in high dust zones. Focus on personal protective equipment (PPE) implementation should stand as a priority, while enhanced workplace ventilation and minimized dust exposure work in combination with standardized mask usage. Further monitoring must occur for workers who have spent long periods on the job, primarily within industries that expose them to high levels of dust. Widespread implementation of occupational health programs that feature systematic pulmonary function tests enables earlier diagnosis of textile worker pulmonary conditions.

Limitations of the Study

The shortcomings of the study have to be addressed. For instance, cross-sectional study cannot make causal inference. A tendency for selection bias can be introduced when a purposive sampling method is applied, and reporting of smoking history may result in over estimation of the cotton dust effect.

Policy Implications and Preventive Measures

The research data establishes a need for more rigorous workplace dust standards to protect older workers and those who remain in prolonged exposure conditions. Personal protective equipment (PPE) with standardized masks forms the cornerstone of preventive measures, while improved ventilation systems and reduced workplace dust remain essential for worker safety. Formulated control measures successfully decrease occupational dust exposure to preserve workers' pulmonary function. The research shows that worker surveillance needs to be ramped up during long-term employment periods, especially within industries prone to high dust exposure conditions. Laboratory screenings for lung efficiency form a vital component of essential occupational health management, which detects pulmonary conditions early in textile manufacturing environments.

CONCLUSION

This study shows independence of dust exposure with > Threshold Limit Value (TLV), work history ≥ 10 years as risk factors for pulmonary obstruction among textile factory workers. (OR 4.18-5.05). Although non-significant gender and age may be used to stimulate additional studies, which would aim at realising the cause behind the difference in the percentage of pulmonary obstruction between female workers (60.9%) and male workers (52.4%). Technical recommendations: 1) Local exhaust ventilation systems to be installed in dusty environments, 2) Routine spirometry screening, especially in employees who have worked for ≥ 10 years at dusty work surroundings, and 3) The use of standardized N95 respirators. These measures for control come with the Minister of Health Republic of Indonesia Regulation Number 70 of 2016 on Environmental Health Standards and Industrial Workplace Requirements to necessitate controlling the workplace exposure by physical and chemical hazards to ensure the health of the workers. Thus, future studies should be longitudinal and take into consideration control over other risk factors (including smoking) to validate evidence between cotton dust exposure and impaired pulmonary function.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest related to this study.

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