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Epidemiology of respiratory diseases and associated factors among female textile workers in Pakistan

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Objective. The study aimed to estimate the prevalence of byssinosis and other respiratory symptoms among women textile workers and the associated risk factors in 18 spinning mills of Faisalabad and Lahore districts of Punjab, Pakistan. *Method*. In this case–control study of 1054 female workers, we used the dose–response function to measure the association between dust level and respiratory disorders in cotton textile workers. *Results*. Working overtime and long working hours per week are significantly associated with self-reported symptoms of byssinosis. Women's age, marital status and wages were significantly associated with mitigating actions (seeing the doctor), while the education of the women was significantly associated with averting action (use of a mask). *Conclusion*. Regulating working hours and ensuring employees' compliance with the safety standards are expected to mitigate the health problems of female workers.

Keywords: textile sector; female labor force; occupational health; sickness absence

1. Introduction

The textile sector is highly labor-intensive in many developing countries. It employs approximately 60 million workers globally [1]. Women are the leading suppliers of labor for the textile industry, where working conditions are generally harsh and labor rights are often missing [2]. The textile sector is now trademarked as an Asian industry. Asia alone accounts for 58.4% of world clothing and textile exports [3]. China has taken the lead in textile manufacturing, followed by other Asian countries, including India, Pakistan, Bangladesh, Vietnam, Cambodia and Indonesia. The rapid expansion of the textile industry in Asian countries is attributed to cheap labor (mainly women), lax labor standards and active government support [4].

The textile sector in Pakistan contributes 9.5% to the gross domestic product (GDP) and employs about 15 million people [5]. Pakistan is the fourth largest producer of cotton with the third largest spinning capacity in Asia after China and India, and contributes 5% to the global spinning capacity [6]. Like other textile exporting countries, it is also one of the few sectors that provide paid employment to women in Pakistan [7]. The data show that women's labor force participation in the textile sector is more than double that of the national manufacturing sector labor force [8]. However, women are almost always underpaid [7].

Apart from employing millions of workers, the textile industry can also be highly polluting and contributes significantly to indoor air and water pollution [9–12]. The earliest steps of textile processing release a more significant amount of dust into the air, and long-term exposure can leave workers with respiratory disorders. Research has identified high levels of endotoxin in the earlier stages of the textile process, which is generally considered the leading cause of byssinosis and respiratory diseases [13–16]. Endotoxin is a biologically active lipopolysaccharide, which is a component of the outer membrane of Gram-negative bacteria.

Byssinosis is a disabling lung disease primarily associated with exposure to cotton dust in textile mills [17–20]. Workers' prolonged exposure to pollutant materials in spinning units over months and years results in several respiratory diseases, such as chest tightness, shortness of breath, increased cough and phlegm, wheezing, asthma, tuberculosis, lung-function loss, eyesight problems and skin diseases, and may even cause mortality [10,21].

Although the relationship between cotton dust and respiratory diseases has repeatedly been explored, little attention has been paid to the illness-related functional limitations as reflected by loss of workdays and reduced productivity, increases in the number of visits to doctors and hospitals, and the resulting loss of wages and income. From the policy perspective, these estimates are very important for setting the standards of cotton dust pollution and allocating resources for workers' welfare and social security. Therefore, this study estimates the prevalence of byssinosis and other respiratory symptoms among women textile workers and associated functional limitations.

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2. Theoretical model

This study used a household health production function to estimate the economic burden of illness due to dust pollution in the textile industry. The health production function relates exogenous variables (such as pollution) and choice variables (such as preventive medicine and treatment costs) to some measure of health status. Health production function, initially formulated by Grossman [22], optimally chooses the input and output levels to minimize the cost of production for any level of health. Harrington and Portney [23] extended the model further. Freeman III and Herriges [24] then simplified this model.

Let health be measured as the number of sick days in any given period denoted by s. One of the determinants of health status is the quantity of pollution or dose. A dose is represented by the scalar variable d, which depends on the concentration of pollution c and the amount of an averting activity a undertaken to avoid or reduce exposure to pollution. There is also a set of mitigating activities or treatments to reduce the health impact of any given exposure to pollution, represented by b [24]. The health production function for an individual is thus defined as:

$$s = s(d, b), \quad (1)$$

$$d = d(c, a). \quad (2)$$

By substituting Equation (2) into Equation (1):

$$s = s(c, a, b), \quad (3)$$

where:

$$\frac{\partial s}{\partial c} > 0, \ \frac{\partial s}{\partial a} < 0, \ \frac{\partial s}{\partial b} < 0 \ .$$

After controlling for other physical and socioeconomic/demographic indicators, such as age, gender, smoking, income and education, the production function is then written as:

$$s = s(c, a, b, g), \quad (4)$$

where g is the vector of other characteristics affecting the health of the individual.

The individual enjoys utility from the consumption of a numeraire good z, normalized with a price of 1, and leisure f. However, illness results in disutility; thus, an individual's utility function can be specified as:

$$\mu = \mu(z, f, s), \quad (5)$$

where s = number of sick days

$$\frac{\partial \mu}{\partial z} > 0, \ \frac{\partial \mu}{\partial f} > 0, \ \frac{\partial \mu}{\partial s} < 0.$$

The individual chooses z, f, a and b to maximize utility subject to the budget constraint, i.e.,

$$I + p_w(T - f - s) = z + p_a a + p_b b, \quad (6)$$

where I = non-wage income; p_w = wage rate; T = total available time; f = leisure; s = number of sick days; z = consumption of a numeraire good; p_a = price of averting activities; a = averting activity; p_b = price of mitigating activities; b = exposure to pollution. The individual selects a, b, z and f to maximize her utility subject to the budget constraint. Solving this utility-maximization problem yields the demand functions for mitigating activities (b) and averting activities (a):

$$b = I, p_w, p_a, p_b, c, \quad (7)$$

$$a = I, p_w, p_a, p_b, c. \quad (8)$$

These functions give the optimal quantities of averting activities (a) and mitigating activities (b) as functions of income, prices and pollution [24].

A detailed framework that relates an environmental agent (i.e., cotton dust) in textile mills to a specific illness requires the collection of physical data on factory conditions (i.e., suspended cotton dust) and medical examination of workers' health status. These data can then be used to associate an illness with a specific agent (so-called dose–response relationship).

Physical evidence of the work-related health problems is not collected partly because of resource constraints and non-cooperation of sample textile mills in the study area. The existing literature on byssinosis can reasonably solve this problem. The literature has shown that a dose–response relationship has repeatedly been established between byssinosis in cotton textile workers and levels of dust in cotton mills. Most of the recent studies, based on the literature of the dose–response relationship, focused only on the prevalence of the disease in textile mills [25,26].[1] Following the aforementioned practice, this study collects self-reported data from the target respondents concerning the prevalence of byssinosis and other respiratory diseases.

It must be noted that, over the last six decades, studies have been using self-reported data from textile workers about symptoms of byssinosis using standard questionnaires of Schilling's grading methodology for diagnosing the disease [28]. The self-reported data are often followed by medical examinations (spirometry or pulmonary function test [PFT]) of the workers. The use of spirometry provides the additional advantage of diagnosing impaired lung function among those who do not have apparent symptoms, and it may not be possible to capture such impairment by the use of questionnaires alone [29–31].

In a recent study, Jamali and Nafees [31] compared the results of spirometry and byssinosis questionnaires in identifying byssinosis and respiratory diseases. The results illustrated that self-reported respiratory symptoms identified by the questionnaire could be good predictors of impaired lung function, and the questionnaire could be used as a validated tool to estimate the burden of respiratory symptoms among the working population. Similar findings have been reported in previous studies [29,30]. Therefore, both the PFT and standard byssinosis questionnaires are an acceptable diagnostic criterion for byssinosis.

This is the reason why a few studies used the PFT for diagnosing byssinosis [13,32], whereas the majority of the studies only applied Schilling's grading methodology [10,33,34].

The first point of comparison could then be whether the health status of the textile workers differs from the control with respect to the burden of pulmonary diseases. Most of the prevalence studies have incorporated comparison groups (or control groups), which often come from non-textile sectors [25,35,36]. The difference in health status between textile workers and the control group for pulmonary diseases may itself indicate an occupational cause.

3. Research methods

3.1. Development of the survey questionnaire

This study collected information about the personal and socioeconomic characteristics of women workers, workplace conditions, job status and wage data. Moreover, the study also collected information about occupational injuries and health symptoms, certain abatement technologies available at the workplace and data on overall health costs. A fully structured questionnaire was developed to collect relevant data in line with the standard questionnaires used in byssinosis and health cost studies [37]. A pilot survey was undertaken in two textile factories before final data collection. The questionnaire was modified and improved based on field experiences and reviewers' comments.

3.2. Data and survey design

We carried out a case–control study in 18 textile mills of Faisalabad and Lahore districts. The study group (cases) consists of 541 women textile workers and the control group consists of 513 women non-textile workers, either working in a different industry/office or staying at home. The controls were chosen with no history of occupational cotton dust exposure, which causes byssinosis and respiratory diseases.

However, the concern may arise that there are several workplaces in which similar factors may be present that cause respiratory diseases. For example, bacterial endotoxin, which is associated with byssinosis and respiratory diseases, may also be present in other industrial settings such as the food industry, the recycling industry and garbage workers [13,14]. Therefore, an analysis of the workplace (job type) of controls is essential. Nearly 86% of the women in the control group in our sample stay at home ($N = 440$). On the other hand, only 14% of women in the control group ($N = 73$) are working in various settings except the food industry, recycling industry and waste disposal facilities. Figure 1 shows the distribution of job types for the women in the control group.

The workplace distribution of the women in the control group reveals that occupational factors that may cause respiratory diseases are not present in the control group, and hence are not likely to bias the results of this study. We collected data on various respiratory symptoms from both the control and treatment groups, such as byssinosis, asthma, blood phlegm, bronchitis, cough, phlegm, tuberculosis and wheezing. Table 1 presents the epidemiology of the respiratory symptoms analyzed for this study, according to the World Health Organization (WHO) Classification of Diseases ICD-11 [38].

Further, the controls were selected from the same households and were of similar age (immediately older or younger than the respondent) so that workers and controls can be matched for socioeconomic and demographic attributes. The survey was administered from April to June 2015. Every worker was given details about the nature of the research and the information required before the interview. The workers were also informed about the confidentiality of the information, and informed consent was received from each worker.

4. Estimation strategy

We estimated the dose–response function, the health production function and the demand functions for mitigating and averting activities using limited dependent-variable regression models.

4.1. Estimations of the dose–response function

According to Equation (2), the dose–response function measures the relationship between the respiratory illnesses in cotton textile workers and levels of dust in textile mills. In this model, the dependent variables are diseases, e.g., byssinosis, phlegm, blood phlegm, chronic cough and wheezing. While some studies use health conditions such as cough, phlegm, wheezing, dyspnea, chest pain and breathlessness as a dichotomous variable, byssinosis corresponds to multiple stages. Therefore, in the case of byssinosis, the dependent variable is defined as the categorical variable (0, 1, 2, 3), i.e., 0 = *no byssinosis*, 1 = *occasional chest tightness on Monday*, 2 = *frequent chest tightness on Monday only* and 3 = *chest tightness on Monday and other days*.

As the byssinosis categories are in ordered form, we used the ordered probit model to analyze the correlates of byssinosis. All other dependent variables are dichotomous and are split into 0 and 1, where 0 indicates the absence of the respiratory disease during the reference period in the respondent and 1 indicates the presence of the disease.

The explanatory variables are about personal characteristics, household characteristics and workplace characteristics. The personal characteristics include the age of the worker, defined in years. The household characteristics include three separate dummy variables for a separate

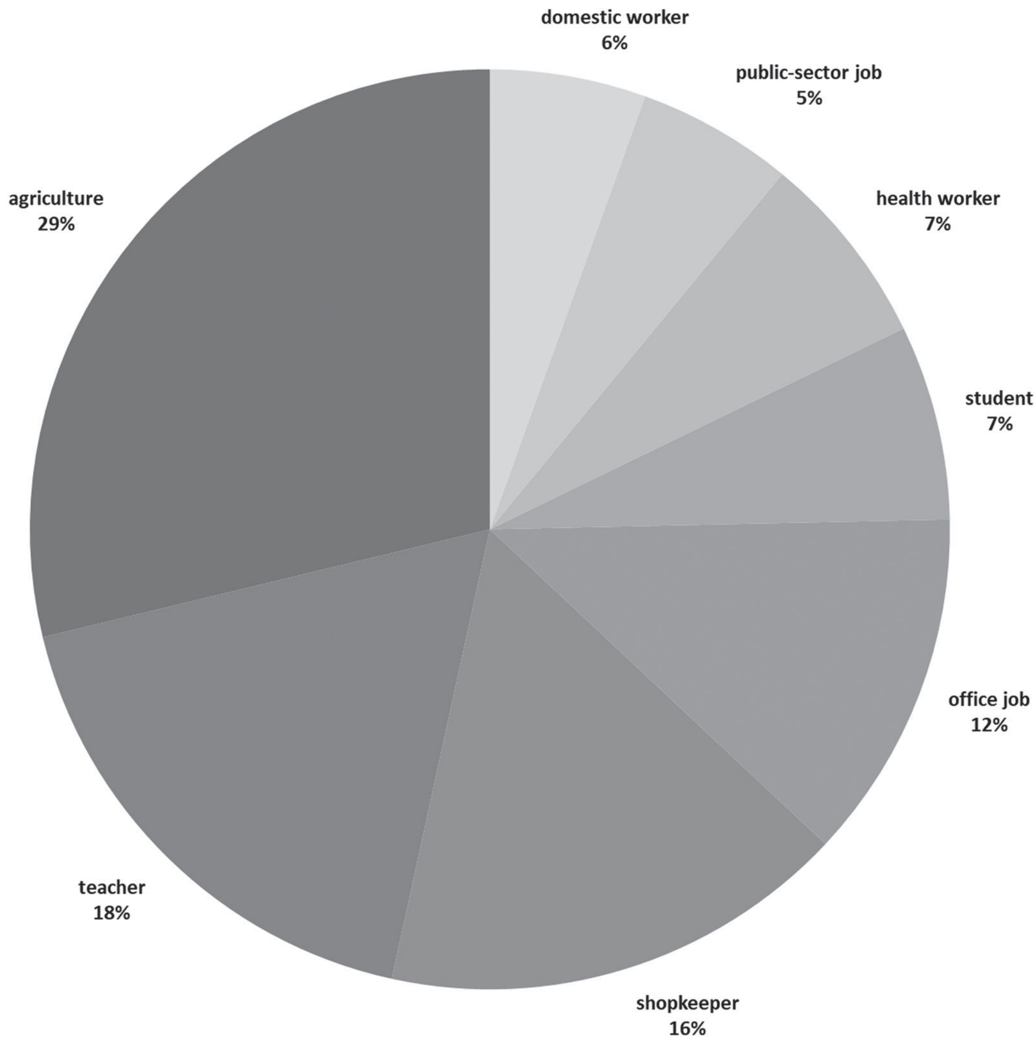

Figure 1. Women's work type (control group).

kitchen, use of firewood for cooking and use of a kerosene oil stove for cooking. The workplace characteristics include working overtime and working hours/week. Working hours/week is taken as a continuous variable. Overtime work is a binary variable, i.e., 1 for working overtime and 0 otherwise.

The empirical specification of the models is given as follows:

$$d_i^* = X_i\beta + e_i, \tag{9}$$

where d_i^* = latent variable; X_i = vector of independent variables; β = vector of parameters; e_i = independent of X_i with $e \mid x \sim$ Normal (0, 1).

4.2. *Estimation of the household health production function*

Regarding Equation (4), the dependent variable is sickness absence, which is a function of working hours/week, working overtime, averting activities (i.e., use of a mask), mitigating activities (i.e., visiting the doctor) and a vector of personal attributes, i.e., age and employment status. All of the variables are already defined except for a visit to the doctor and employment status. Both of these variables (i.e., visit to the doctor and employment status) are specified as a binary, where 1 refers to a visit to the doctor and permanent employment, respectively. Moreover, sickness absence is also specified as a binary variable. If a workday is missed due to dust-induced illness in a given 15-day period, the respondent is assigned 1; otherwise 0. A probit model is used for estimation of the workers' health production function:

$$S_i^* = X_i\alpha + e_i, \tag{10}$$

where S_i^* = latent variable; X_i = vector of independent variables; α = vector of parameters; e_i = error term with $e \mid x \sim$ Normal (0, 1).

Table 1. Epidemiology of respiratory symptoms.

Pathology (ICD-11 code)	Epidemiology
Byssinosis (SF85)	Byssinosis is a respiratory symptom caused by exposure to raw non-synthetic textiles during the manufacturing process [39]. It is also called cotton worker's lung disease, brown lung disease, Monday fever or mill fever. It has the features of chronic obstructive pulmonary disease (COPD) [40,41]. Additionally, byssinosis is caused by exposure to hazardous particles in the jute, hemp and flex industries [39]. Counter to what is ordinarily believed, cotton dust is not the only risk factor for byssinosis. The endotoxin–heat-stable lipopolysaccharide–protein complexes contained in the cell wall of Gram-negative bacteria could also cause byssinosis [42]. As cotton industries constitute the sizable part of the industrial sector of India, Pakistan, Nepal, Sri Lanka and Bangladesh, byssinosis in these countries is common. Heavy smoking in these countries exacerbates byssinosis symptoms further. Even if much better working conditions exist today compared with the past thanks to technological innovations, byssinosis is still prevalent in Pakistan, India, Turkey and Indonesia in Asia, and Sudan and Ethiopia in Africa [39].
Asthma (CA23.0Z)	Work-related asthma is the most prevalent occupational lung disease. A thorough occupational history is critical for identifying patients. Although asthma can arise at any stage, approximately 17% of all cases of asthma in adulthood (called adult-onset asthma) are related to occupational exposures, including the textile industry. Work-related asthma is associated with a higher frequency of asthma attacks and a larger number of visits to emergency rooms, as compared to the case of other adult asthma patients. Some of the ethnic groups more likely to suffer from work-related asthma are black individuals, American Indian individuals or those individuals of multiple race [43].
Blood phlegm (hemoptysis) (MD22)	Hemoptysis is a medical condition in which the patient expectorates blood or blood-stained mucus not necessarily because of bleeding in the upper respiratory tract or associated with gastrointestinal bleeding [44]. Hemoptysis accounts for 10–15% of all pulmonology consultations and may be associated with life-threatening medical conditions such as lung cancer [45].
Bronchitis (CA20)	Bronchitis is inflammation of the main air passages to the lungs. About 5% of the population reports an episode of acute bronchitis in 1 year [46]. Bronchitis is likely to occur in autumn and winter when flu is more common. Smoking, exposure to pollution, crowding and history of asthma are common risk factors for bronchitis. Allergens like vapors, pollen and perfumes may also trigger bronchitis [47].
Cough (MD12)	Chronic cough is one of the most common symptoms of chronic diseases [48], with nearly 12% of the global population having symptoms of chronic cough on a daily or weekly basis. Chronic cough is associated with both physical conditions (e.g., incontinence) and psychological conditions (e.g., social isolation and impaired quality of life). Factors associated with a chronic cough could be divided into two broad categories: (a) those which cause asthma-like conditions characterized by eosinophilic infiltration of the airways; (b) those which cause esophageal disease such as weakly acid reflux. A failure in timely diagnosis of these causes has a high socioeconomic cost, which may include a higher number of lost jobs, increased burden on the health system and higher incidence and prevalence of psychosocial morbidity [49,50].
Phlegm (esophageal phlegmon) (DA24.00)	Phlegm is the formation of suppurative/purulent exudate or pus in the esophageal wall caused mainly by acute inflammation due to bacterial infection. Chronic phlegm is an essential indicator of respiratory diseases [51]. Phlegm is associated with a decline in lung functions [52]. Tobacco smoking [53] and exposure to biomass fuels [54] are important risk factors associated with chronic phlegm. Chronic respiratory diseases account for 7% of all deaths in India [55].
Tuberculosis (of the respiratory system) (1B10)	Tuberculosis is a chronic disease that results from an infection caused by the bacterium *Mycobacterium tuberculosis* or *M. tuberculosis* complex. Although it is a global health condition, developing countries share a higher proportion of the burden of this disease. Use of immunosuppressive agents such as long-term corticosteroid therapy, a monoclonal antibody targeting the inflammatory cytokine, tumor necrosis factor-alpha (TNF-α) and drugs used for the treatment of inflammatory disorders is associated with increased risk of tuberculosis [56].
Wheezing (SA81)	Wheezing is associated with multiple pathologies of the lung and respiratory system. The high concentration of endotoxins is considered the significant risk factor of wheezing [57]. A study found that around 61% of workers exposed to a high concentration of endotoxins suffered from wheezing [58]. Workers in textile industries are at a significantly higher risk of suffering from wheezing [59]. Wheezing shows no income gradient in terms of its incidence. It is found in developed countries such as the USA [60] and Great Britain [16], as well as in developing countries such as Pakistan, Ethiopia, India, Nigeria and Egypt [18,59,61–63].

ICD-11 = World Health Organization Classification of Diseases.

4.3. Estimation of the mitigating activities function

The mitigating activities function represents the relationship between medical treatment undertaken by individuals and non-wage income (I), wage income (p_w), working hours/week, working overtime and other characteristics, e.g., education level, age and employment status. Here, income is a continuous variable and specified as the monthly household expenditure minus the wage income in Pakistani Rupees (PKR);[2] the wage is also a continuous variable and defined in thousands of rupees. Education level is defined as several years of education and is a continuous variable. The dependent variable 'visit to the doctor' is again a binary variable split into 1 and 0, indicating a visit to the doctor and no visit to the doctor, respectively. The probit model for estimating this relationship is specified as:

$$b_i^* = X_i\theta + e_i, \tag{11}$$

where b_i^* = latent variable; X_i = vector of independent variables; θ = vector of parameters; e_i = error term with $e \mid x \sim$ Normal (0, 1).

4.4. *Estimation of the averting activities function*

Regarding Equation (8), the averting activities function represents the relationship between averting activities (use of a mask) and income, wage, price of masks, price of mitigating activities (treatment cost), working hours/week, working overtime and other characteristics such as education level, age and employment status. The price of the mask variable is excluded from the analysis due to a data availability problem. The use of a mask is a binary variable. Hence, the probit model is specified as:

$$a_i^* = X_i\gamma + e_i, \tag{12}$$

where a_i^* = latent variable; X_i = vector of independent variables; γ = vector of parameters; e_i = independently and identically distributed error term with mean 0 and variance 1.

5. Results

5.1. *Descriptive analysis*

5.1.1. *Workers' demographic and socioeconomic characteristics*

Our sample data show that the age of the female workers ranges from 12 to 52 years, with an average age of 26.23 years. The age of the control group females ranges from 13 to 55 years, averaging approximately 30 years. Since the minimum age of the workers in this sample is 12 years, this is indicative of the presence of under-age workers in the sample. The national and provincial laws consider an individual a 'child' for employment purposes until he or she reaches 15 years old [64]. This may create bias in the study because the under-age workers may be more vulnerable to workplace hazards than adult workers. However, the bias may not be significant because there are only eight respondents in the sample who are younger than 15 years old.

The data showed that more than half of the workers (56%) are illiterate. Compared to textile workers, the education levels of the control group are generally higher (see Figure 2). The lower education level of textile workers is understandable because most of the women are employed for manual work in the textile sector, which requires either no or little education.

5.2. *Household characteristics and living conditions*

The household characteristics and living conditions are stable indicators of the well-being of the household members in terms of their economic and health outcomes. Poor housing quality is associated with an array of infectious and respiratory diseases. A contaminated water supply and unhygienic waste disposal spread infectious diseases, while use of biomass and fossil fuels contributes to respiratory diseases. Cramped places also have health costs. Our sample shows that 55.5% of the workers lived in two-room houses, while a sizable fraction lived in a single-room house (20.5%) and a three-room house (19.6%). Only a small fraction of workers lived in a four-room house (4.6%) and a five-room house (0.4%).

Furthermore, 91% of workers reported separate bathrooms, 73% had a separate kitchen and 62% had a kitchen with a window in the house. Half of the households used natural gas for cooking. However, a significant fraction of respondents used firewood (39%) and animal dung (29%) or a combination of both. About 16% used kerosene oil in the kitchen.

5.3. *Wages and employment status*

Wages and employment status are crucial indicators of the labor market dynamics. The analysis of female worker's wages indicates that wages ranged from PKR 4000 to 20,000 while the average wage of a worker was PKR 9857. The average monthly household expenditure was PKR 19,196. The wages of 48% of respondents did not even meet the minimum wage standards of PKR 12,000 in the country. The working hour data showed that the mean duration of work is 54 h per week in the current sample, which is, on average, 6 h higher than the regular working hours (i.e., 48 h per week).

The data on the employment status of sample workers in textile mills indicated that only 9.2% workers were permanent employees with fixed wages, while 19% were casual paid workers (i.e., the workers with no job security, no sickness and parental leave entitlement, and can be terminated without prior notice). The rest (71.8%) were daily wage earners (number of working days × per day wage). The data show that women did not benefit from the employment expansion in textile mills. Women worked for higher than average working hours and lower than minimum wages. Further, 63% of the women in the sample did not have formal social security and labor benefits.

5.4. *Workplace and safety information*

5.4.1. *Averting behavior*

When textile workers enter the work sections, they are exposed to cotton dust and noise. The exposure to dust and noise can lead to an array of health effects, depending on the quantity absorbed. However, the health effects

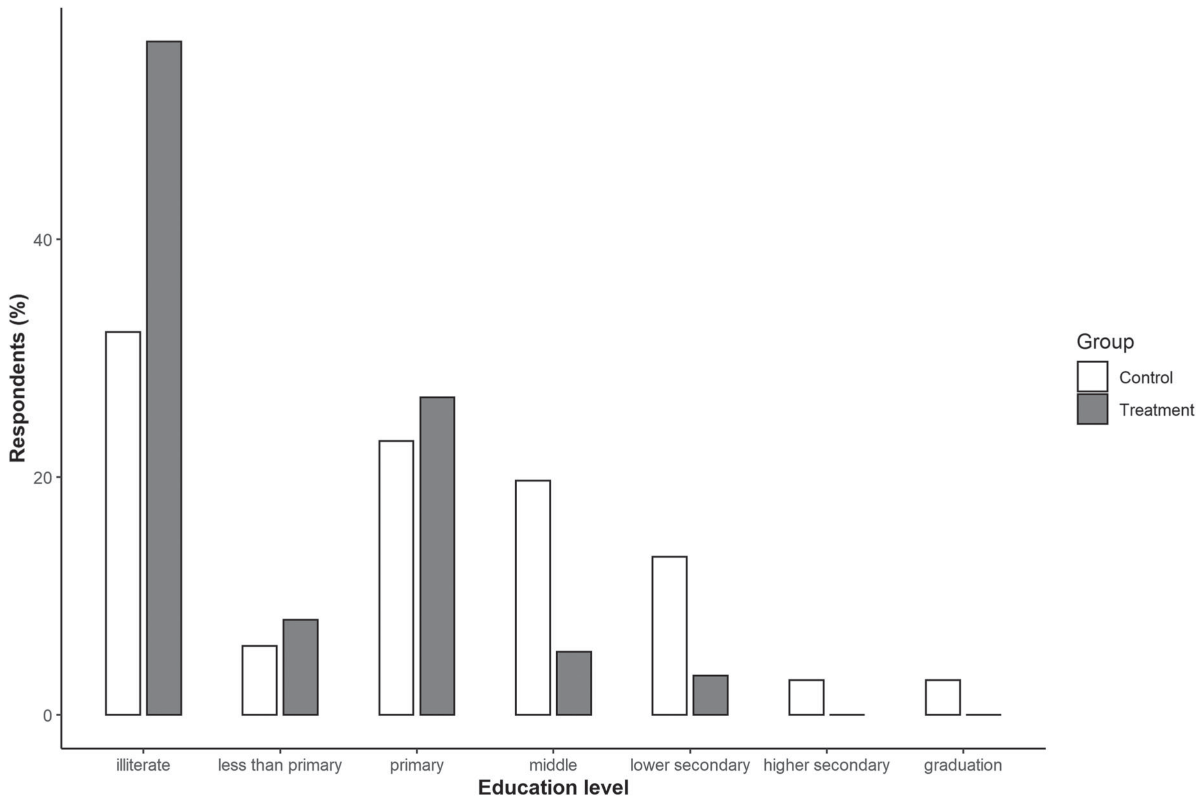

Figure 2. Education level of respondents.

can often be reduced significantly by averting behavior (i.e., exercising precaution, which usually includes wearing masks and earplugs). In our survey, the majority of the workers (70.5%) said that they put on face masks during work, and about 87% openly admitted that they never used earplugs while working. These statistics are very much akin to previous studies in Pakistan and other developing countries that report less use of protective masks among textile workers [65,66].

5.4.2. *Health effects*

A comparison of the control and treatment groups concerning the health conditions showed that most of the respiratory symptoms were higher in the treatment group than in the control group (Figure 3). The difference between the treatment group and the control group was highest in terms of the incidence of cough and asthma. Figure 3 also shows that more than 21% of workers experienced cough during the reported period of 15 days compared to just over 8% of the control group. Up to 9.3% of workers reported asthma compared to 4.1% by the control group.

5.4.3. *Prevalence of byssinosis*

Byssinosis is a lung disease caused by prolonged exposure to cotton dust. Schilling categorized it concerning the severity of the disease [28]. Grade 0 corresponds to no symptoms of chest tightness or breathlessness on the first day of the week (Monday). Grade 1/2 corresponds to occasional chest tightness or breathing difficulty on the first day of the working week. Grade 1 corresponds to chest tightness and/or breathlessness on Monday only. Grade 2 corresponds to chest tightness and/or breathlessness on Monday and other weekdays. Grade 3 corresponds to Grade 2 symptoms accompanied by evidence of permanent impairment in capacity from reduced ventilator defect.

Around 16.8% of the textile workers in our sample reported byssinosis. In terms of severity of byssinosis, about 12.5% experienced byssinosis symptoms of Grade 1 and 3.5% experienced byssinosis symptoms of Grade 2. Moreover, about 0.8% have reported the experience of grade 1/2 byssinosis. Most of the studies in Pakistan have reported similar results. For example, Farooque et al. [33] estimated that 19% of workers in cotton spinning mills in Karachi suffered from byssinosis, while Khan [67] reported that 22.3% of workers in the textile sector suffered from byssinosis in Faisalabad. However, some studies have reported a higher incidence of byssinosis. For instance, Memon et al. [10] found a 35% prevalence of byssinosis in Karachi. Similar results can also be seen in other countries in the region. For example, Saoji et al. [35] found a 12% incidence of byssinosis in India, and Wang et al. [25] found a 24% incidence of byssinosis in China.

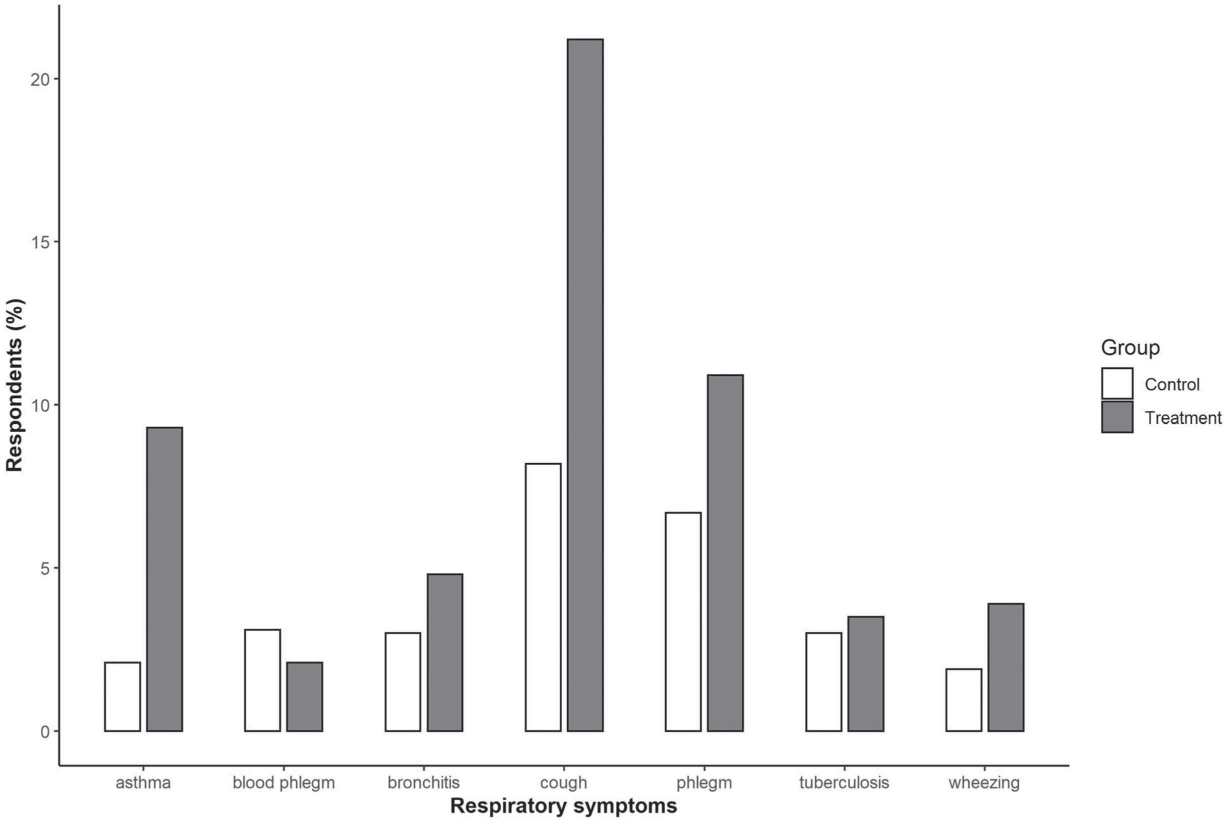

Figure 3. Respiratory symptoms experienced by workers.

5.5. *Multivariate probit model*

5.5.1. *Dose–response function*

We estimated an ordered probit model for byssinosis in Model 1 and four probit models for phlegm, blood phlegm, chronic cough and wheezing in Models 2–5, respectively. The results of the regression analysis for the incidence of diseases and their relationship with explanatory variables are reported in Table 2.

Results show that the probability of developing byssinosis is significantly higher for individuals who worked overtime and worked more hours per week. Women working overtime were 44% more likely to suffer from byssinosis compared with the women who did not work overtime. Similarly, a positive relationship holds between working hours per week and the incidence of byssinosis. These findings are consistent with the findings of previous studies [68].

Working overtime is also significantly associated with the symptoms of phlegm and blood phlegm. Working overtime is the only consistent and significant factor associated with most of the respiratory diseases, suggesting that working overtime increased the likelihood of respiratory diseases among women textile workers. More working hours per week and overtime work mean extended exposure to cotton dust and resultant health symptoms. Working hours per week and overtime work are also positively associated with chronic cough and wheezing; however, this relationship is not significant. Extended working hours and overtime work in textile mills significantly affected women workers' health.

The analysis of house characteristics indicates that a separate kitchen and use of firewood were significantly associated with byssinosis. The results for a separate kitchen showed negative relationships with byssinosis, and the use of firewood instead of natural gas for cooking yields positive relationships with byssinosis.

Among personal characteristics, age is positively linked with byssinosis. The significant effect of age suggests that the effect of dust is cumulative, which means that the long-term exposure to cotton dust in textile mills results in the development of byssinosis and other health symptoms among workers. Mishra et al. [69] and Ajeet et al. [70] noted that workers over 40 years of age in cotton textile mills were significantly more likely to suffer from respiratory morbidities than workers younger than 40 years of age.

5.6. *Health production function*

The health production function is estimated using the probit regression model, and the results are presented in Table 3. The personal characteristics show a positive but

Table 2. Regression analysis of the incidence of diseases.

Predictor	Coefficient				
	Model 1: byssinosis	Model 2: phlegm	Model 3: blood phlegm	Model 4: chronic cough	Model 5: wheezing
Personal characteristics					
Age (years)	0.0253***	0.0152	0.0331**	0.0081	−0.0067
	(0.008)	(0.010)	(0.016)	(0.009)	(0.016)
Marital status (1 = married, 0 = others)	00028	0.1942**	0.1513	−0.2114*	−0.0297
	(0.0736)	(0.094)	(0.148)	(0.115)	(0.156)
House characteristics					
Separate kitchen (1 = yes, no = 0)	−0.4242***	0.5136**	0.1366	0.7716***	0.4187
	(0.1381)	(0.219)	(0.361)	(0.882)	(0.305)
Use of firewood dummy	0.7176***	−0.0004	0.3502	0.2144	−0.3068
	(0.1332)	(0.191)	(0.248)	(0.133)	(0.245)
Use of kerosene dummy	−0.2122	0.2758	−0.6220	0.0310	0.3484
	(0.1660)	(0.210)	(0.495)	(0.1880)	(0.289)
Workplace characteristics					
Working overtime (1 = yes, no = 0)	0.4472***	0.8520***	1.285***	2645	−0.3808
	(0.1901)	(0.215)	(0.295)	(0.202)	(0.460)
Working hours/week	0.0346**	−0.0012	0.0016	0.0147	0.0376
	(0.0159)	(0.011)	(0.019)	(0.010)	(0.020)
Dust level	−0.0403	0.0055	−0.1279	−0.0095	0.0074
	(0.9709)	(0.121)	(0.192)	(0.009)	(0.167)
Constant (Cut 1)	2.789	−2.45***	−3.355**	−1.799***	−3.947***
	(0.821)				
Cut 2	2.789	(0.792)	(1.309)	(0.714)	(1.365)
	(0.822)				
Cut 3	3.423	–	–	–	–
	(0.827)				
Observations	541	541	541	541	541
Likelihood Ratio $\chi^2(11)$	51.72***	29.39***	32.89***	39.98***	8.98
Log likelihood	−435.76	−171.70	−62.507	−259.89	−77.805
Pseudo R^2	0.063	0.078	0.208	0.071	0.054

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.
Note: *SE* in parentheses.

insignificant relationship with the probability of being absent from work because of sickness (workdays lost). The household characteristics, on the other hand, are significantly associated with lost days because of sickness. While a separate kitchen protected against sickness leave, the use of kerosene oil for cooking increased the risk of sick leave. Counter to our expectation, the use of firewood, considered a hazardous cooking fuel type, protected against lost workdays.

Among workplace characteristics, the women working overtime were significantly more likely to remain absent from work because of sickness compared with the women who did not work overtime. Similarly, permanent workers were more likely to remain absent from work because of sickness compared with part-time or daily wage workers. One possible reason for this is that permanent workers are legally entitled to paid sick leave, while non-permanent workers do not have such entitlement, and, consequently, they show up at the workplace despite sickness.

5.6.1. *The demand function for mitigating and averting activities*

The demand function for mitigating activities is also estimated using the probit regression model, and the results are presented in Table 4. Older and married women were more likely to undertake mitigating actions (visiting doctors). The income and wage level of the workers had a significant impact on their choice of seeing the doctor.

As regards the averting actions, which included the use of masks, only education turned out to be a positive and significant factor. Wages again had an unexpected negative association with the use of a mask, but the absolute magnitude of the estimated coefficient is small (−0.000054). Workplace characteristics such as type of employment, working overtime and the dust level had a significant association with the averting actions.

Table 3. Probit regression of health production function.

Predictor	Sickness absence	
	Coefficient	*SE*
Personal characteristics		
Age (years)	0.011	(0.014)
Marital status (1 = married, 0 = others)	0.023	(0.114)
House characteristics		
Separate kitchen (1 = yes, no = 0)	−0.708***	(0.260)
Use of firewood dummy	−1.325***	(0.239)
Use of kerosene dummy	0.733***	(0.308)
Workplace characteristics		
Working overtime (1 = yes, no = 0)	1.823***	(0.445)
Working hours/week	−0.496	(0.450)
Dust level	−0.123	(0.197)
Permanent employee (1 = yes, no = 0)	0.644***	(0.225)
Averting and mitigating actions		
Use of a mask (1 = yes, no = 0)	0.508	(0.246)
Consultation with practitioner (1 = yes, no = 0)	0.859	(0.915)
Constant	−2.025	(1.312)
Observations	215.000	–
Likelihood Ratio $\chi^2(11)$	83.900	–
Log likelihood	−105.620	–
Pseudo R^2	0.284	–

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$

Table 4. Probit regression analysis of mitigating and averting activities.

Predictor	Mitigating actions (visit to doctors)		Averting actions (use of a mask)	
	Coefficient	*SE*	Coefficient	*SE*
Personal characteristics				
Age (years)	0.0236***	(0.008)	0.009	(0.009)
Marital status (1 = married, 0 = others)	0.204***	(0.083)	−0.090	(0.084)
Education	0.012	(0.019)	0.09289***	(0.019)
Income and wage				
Income	−0.000028***	(8.0E–6)	1.32E–7	(8.0E–6)
Wage	0.0000531*	(2.7E–5)	−0.000054*	(2.8E–5)
Workplace characteristics				
Permanent employee (1 = yes, 0 = otherwise)	−0.038	(0.096)	−0.073	(0.098)
Working overtime	0.225	(0.200)	0.179	(0.206)
Dust level	−0.409	(0.095)	0.059	(0.094)
Constant	−0.466	(0.570)	−0.224	(0.583)
Observations	540	–	541	–
Likelihood Ratio $\chi^2(11)$	52.65***	–	29.18***	–
Log likelihood	−336.693	–	−313.045	–
Pseudo R^2	0.073	–	0.045	–

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

6. Discussion

This study finds that female workers engaged in the textile sector in Pakistan are more likely to report symptoms such as byssinosis, chronic cough, phlegm, blood phlegm, asthma and wheezing compared with the women who either stay at home or work in other industrial sectors.

For the case of byssinosis, the symptoms occur on the first day back to work and improve with persistent exposure throughout the week, at least in the early disease stages. Most subjects reported more severe symptoms of byssinosis on the first day of the week and weekdays, and symptoms were less severe at weekends and holidays. This points toward a strong association between exposure to cotton dust in textile mills and respiratory symptoms. Some earlier studies, undertaken in India and Taiwan, also found that respiratory diseases among textile mills were significantly associated with cotton dust [68,71]. It may be added here that the experience of the workers who join the workplace after the weekend is not much different from the experience of the workers who join after an extended leave of absence because both groups reveal symptoms of byssinosis occasionally (Grade 1/2) or regularly (Grade 1) with an equal likelihood [72].

The risk of byssinosis and other respiratory diseases increases for workers who work overtime and for longer hours. Female workers are disproportionately employed in the initial phases of the manufacturing process, such as spinning and ginning, which are generally dustier and, consequently, more hazardous for human health. Many studies across a broad spectrum of economic development, such as Greece, Nepal and Great Britain, have pointed to higher levels of endotoxins in the early stages of textile spinning processes such as bale opening and carding sections than in weaving and stitching [13,15,16]. Endotoxins in the polluted textile sector are typically considered the principal reason for byssinosis [14]. Existing studies have also found that the severity of byssinosis increased with the duration of exposure [33,35].

The exposure of women to hazardous conditions has important implications for the policy of empowering women through increased participation in the labor force. Although female labor force participation in the textile industry has increased in recent times, women are more often engaged in manual jobs, which offer significantly lower wages. Lower wages in the industry induce women workers to work overtime in unhealthy conditions, which results in adverse health outcomes.

The relationships of the respiratory symptoms to non-occupational factors such as a separate kitchen, use of firewood and use of kerosene in the kitchen are, however, less clear. Previous studies in Pakistan and Nicaragua show that individuals using mostly biomass for cooking experience higher levels of respiratory health problems [73,74]. The protective effect of firewood against respiratory problems has already been highlighted in previous studies on air pollution epidemiology undertaken in China and Ethiopia [75,76]. Burning biomass fuels indoors for cooking is associated with high concentrations of particulate matter (PM) and carbon monoxide (CO), as found in some previous studies in Paraguay and India [77,78].

Besides, studies have identified higher levels of endotoxins in certain dwellings. For instance, a study in Singapore found that endotoxin activities within the range of 300–600 EU/m^3 were found in the kitchen and living rooms, whereas the samples collected in the kitchen in the residential setting were the highest among all other places inside the house [79].

The occurrence of byssinosis in workers belonging to houses with a separate kitchen was found to be significantly lower than among workers belonging to houses with no separate kitchen. The separate kitchen may reduce indoor air concentrations associated with biomass smoke. Therefore, workers having a separate kitchen are significantly less likely to develop the risk of aggravated byssinosis. However, these results do not hold for other diseases.

The relationship of the respiratory symptoms with non-occupational factors shows some interesting and unexpected patterns and may require some further explanation. A separate kitchen should ideally reduce lung-related symptoms, but counterintuitively it increased the chance of contracting phlegm and chronic cough. The use of firewood decreases the chance of byssinosis, but its impact on the other symptoms is insignificant. One possible reason for this is that the kitchen itself is not immune to hazardous particles, and, at times, a separate kitchen gives little advantage over no separate kitchen in congested residential settings. A study in Singapore found that endotoxin activities within the range of 300–600 EU/mg PM2.5 were found in the kitchen and living rooms, whereas a PM2.5 level of about 28 μg/m^3 was collected in the kitchen in the residential setting, which was the highest among all other places inside the house [79]. Park et al. [80] found that in residential settings in Boston, MA, USA, house dust containing endotoxins could be an essential determinant of asthma severity. There was a significant association between kitchen floor dust and bedroom airborne endotoxin [80]. The implication is that the existence of endotoxin within the kitchen increases the odds of lung-related symptoms.

As regards the personal characteristics, while age significantly increased the chance of contracting byssinosis and blood phlegm, its impact on other lung-related conditions is not statistically significant. Bouhuys and Van de Woestijne [81] found in their seminal study in Great Britain that the lack of association between lung symptoms and age can be explained by the fact that workers respond differently to the exposure to hazardous material in the workplace.

There is a significant positive association between marital status and phlegm but a negative association with chronic cough, whereas this association is insignificant in the case of other symptoms. There may not be any straightforward explanation for this except that married women, as shown by a study in Great Britain, are generally older than unmarried women, and older age is positively associated with phlegm [82]. Additionally, the marriage of a never-smoker woman with a current or former smoker is associated with different types of lung impairments, as shown by a study of American and French women [83].

The association of working overtime and a higher number of workdays lost because of sickness points to the vulnerabilities of the women workers in the textile sector. Workers generally sacrifice their leisure time and family time to work for additional hours to shore up their income, possibly because of pressing economic necessities. This pattern is observable in both developing economies like the USA [84] as well developing economies like Chile [85]. However, they work overtime at a cost. The positive influence of overtime work on income is partially offset because of days lost due to sickness.

Similarly, the probability of sickness absence is significantly higher for a permanent employee in the textile sector than a non-permanent worker. The permanent workers are legally entitled to paid sick leave, and, naturally, they are more likely to avail that facility compared to non-permanent workers who usually are not entitled to such leaves. For the non-permanent workers (which constitute 71% of the total labor force in the sample), sickness absence means loss of that day's wages. The overriding concern of these women is the wages. Health comes after wages. Therefore, they prefer to work rather than taking a rest. This situation points to the inequitable nature of female employment in Pakistan. A study in Finland also found that permanent workers are more likely to afford sick leave compared with temporary workers [86].

This study underscores the need to follow safety standards strictly. In order to protect workers during daily activities, preventive measures should be implemented. Personal protective equipment (PPE) is advised when exposure to high concentration dust cannot be avoided. PPE includes a mask, earplugs, gloves and specialized dress. Despite the free availability of face masks and earplugs in the mills, the use of protective masks and earplugs is limited. These results are very much similar to previous studies in Pakistan and other developing countries such as Ethiopia that explain less use of protective masks among textile workers as a risk factor of occupational health [65,66]. A positive association between education and the use of a face mask indicates the positive role of increasing awareness among the workers apart from the administrative measures for following safety standards.

This study has some limitations. In this study, only currently employed workers have been studied. There is a reason to believe that currently working women are in better health than those who have left the industry [87]. Furthermore, the assessment of respiratory health was based on self-reported information. Symptoms reported by questionnaire cannot entirely be interpreted as byssinosis clinically [14]. Therefore, self-reported health conditions may provide biased estimates. Nevertheless, the reported symptoms of byssinosis on the first day of the week and on weekdays, which were less severe at weekends and holidays, make it likely that reported symptoms are indeed linked to byssinosis. Further, the comparison of symptoms between workers and controls clearly establishes an association between exposure to cotton dust in textile mills and respiratory symptoms.

Another limitation is the presence of under-age child workers in the sample. The hazardous conditions in the textile sector and their consequences for child labor are analyzed in the existing literature as a potential source of bias. Forastieri [88] found that children's exposure to cotton, flax and linen in the mixing and card rooms of the textile sector is associated with byssinosis. Large amounts of fiber dust, accumulated on the ceilings or window ledges through different processes, could provoke respiratory diseases such as byssinosis and asbestosis among the children. However, our results are not likely to be biased because there are only eight respondents in the sample who are younger than 15 years old. The national and provincial laws consider an individual a 'child' for employment purposes until he or she reaches 15 years [64]. The youngest respondent in our sample is 12 years old.

7. Conclusion

The present study analyzed the epidemiology of dust-related respiratory diseases and associated factors among female textile workers in 18 spinning mills in Faisalabad and Lahore districts. The analysis provided evidence of a higher prevalence of byssinosis and other respiratory diseases among textile workers compared to the non-working women. The results indicated that overtime work, long working hours per week and the use of firewood in the kitchen appeared as important correlates of respiratory diseases among women workers in the textile sector. The respiratory diseases significantly contribute to absence from work because of sickness and a higher number of visits to the doctor.

The results of this study can be used for appropriate health interventions. Breathlessness and risk of respiratory symptoms estimates show considerable variation between the treatment and control groups. Therefore, the estimates of the risk of respiratory symptoms concerning dusty worksites could help set dust standards for the industry. The use of protective measures is very limited in the textile sector. Personal protection should be made mandatory through appropriate administrative measures. Further, health education programs should be developed to raise the awareness of the workers regarding the proper use of PPE in the textile industry.

8. Ethical statement

8.1. Compliance with ethical standards

This study complies with the ethical standards of the institutional research committee, the Departmental Academic Review Committee (DARC), as well as the national research standards of Pakistan.

8.2. Ethical approval

The approval of the DARC has been obtained regarding the ethical considerations of the research.

8.3. Informed consent

Informed consent was received from the respondents of the study.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Notes

1. It may be noted that it has been clinically confirmed that byssinosis is a cotton-specific disease (see, e.g., [17,27]).
2. EUR 100 = PKR 11,276.4; USD 100 = PKR 10,187.07.

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