Original Article

Respiratory symptoms and pulmonary function impairment among textile industry workers in Alexandria, Egypt

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Abstract. Occupational exposure to cotton dust is still an important cause of respiratory problems in textile workers particularly in less developed countries like Egypt. Evaluate respiratory symptoms and diseases, and pulmonary function pattern among Egyptian textile workers. Cross sectional comparative study was conducted from December 2019 to September 2020 in a textile factory in Egypt; 364 male workers (184 cotton dust exposed workers, and 180 unexposed workers) were included. Participants were subjected to an interviewing questionnaire, British Medical Research Council questionnaire, anthropometric measurements, pulmonary function tests, and byssinosis grading format. Descriptive and analytic statistics were conducted. Chronic cough, phlegm production, and shortness of breath grade I, II and III were more reported in cotton dust exposed workers than unexposed workers ($P<0.01$, $P<0.01$, and $P=0.02$, respectively). Prevalence of chronic bronchitis was significantly higher among cotton dust exposed workers (12%) than unexposed workers (3.9%) ($P<0.01$). The mean percent predicted values of lung function indices reflecting large-1irway function (VC, FVC, FEV_1, FEV_1%, PEFR, and FEF_{75}) were significantly lower in cotton dust exposed workers ($P<0.01$). Prevalence of byssinosis was 22.8%. Workers with byssinosis had significantly higher prevalence of respiratory symptoms, chronic bronchitis, cross-shift reduction in PEFR and significant decrease in mean percent predicted values of FVC, FEV_1, PEFR, FEF_{75}, and FEF_{50} than workers without byssinosis. This study revealed a substantial association between cotton dust exposure at work and respiratory symptoms and morbidity. Regular measurement of cross shift change in PEFR is recommended among exposed workers for early diagnosis of byssinosis.

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Introduction

Occupational exposure to cotton dust is still an important cause of respiratory problems in textile workers particularly in countries undergoing rapid economic transformation (1,2). In seeking cheaper labor and operations, textile industry has moved from the developed countries in the early 1900s to Mexico, Asian countries and Egypt (3). This movement together with applying strict air quality standards have led to decrease in the prevalence and pattern of respiratory problems among textile workers in the developed counties between 1979 and 2014 (2,4).

On the contrary, textile workers in the developing countries started to show adverse health effects due to cotton dust exposure in 1980s and 1990s (5), similar to those reported in the developed countries in the 1950s and 1960s (6). High rates of byssinosis have been observed in developing countries (7,8) and Egypt (9). Recent studies in Benin (10), Pakistan (11), Ethiopia (12,13), India (14), and Nigeria (15) have shown an increased prevalence of respiratory disorders among textile workers. In Egypt, a recent cross-sectional study revealed high respiratory morbidity among textile workers (16).

Textile workers, as a result of prolonged inhalation of cotton dust during the manufacturing process of textiles, could develop respiratory symptoms as nasal irritation, cough, phlegm production, shortness of breath, and work related wheeze (10-14,17). In addition, they might be predisposed to respiratory diseases mostly chronic bronchitis and byssinosis. The biggest clue to byssinosis is the characteristic work-related asthma-like symptoms that usually occur at the beginning of the work week and improves as the work week progress or dust exposure stops, however, prolonged exposure may cause irreversible airway obstruction (3).

Epidemiological studies on textile workers have shown several changes in pulmonary function after prolonged exposure to cotton dust, principally, a cross-shift change (fall) in the forced expired volume in one second (FEV_1) during consecutive days of workplace exposure starting from the first day of the working week. The change in FEV_1 has a particular pattern where the largest fall occurs in the first day of the working week. This loss in FEV_1 recover after weekend or long rest period (18). In addition, a change in the peak expiratory flow rate (PEFR) could occur and should be considered when trying to observe cross shift fall in LFIs (19). Furthermore, annual decline in FEV_1 and forced vital capacity (FVC) has been reported and suggests a greater cumulative decrease and worse prognosis (chronic impairment) (20).

The prevalence of respiratory symptoms and diseases among textile workers in the developing countries is expected to be on the rise, since these countries consider occupational health and safety measures as unaffordable luxury (21). In Egypt, more than one third of the workforce is employed in the textile industry (22). Recently, awareness to occupational health problems has increased and policymakers in Egypt are willing to improve the general health of the employees. Therefore, this study was conducted to estimate the frequency of respiratory symptoms (cough, phlegm production, and shortness of breath) and respiratory diseases (chronic bronchitis and bronchial asthma), and reveal pulmonary function pattern among Egyptian textile workers.

Materials and methods

Research design and setting. A cross sectional comparative study was conducted from December 2019 to September 2020 in a textile factory located in Alexandria city, Egypt. The factory uses cotton as a raw material to produce clothing and fabric. The factory is divided into administrative section and production section which comprises five departments: bale opening, carding, spinning, weaving and final fabrication departments. Workers at production section alternate in three 8-h shifts per day to maintain a 24-h continuous production.

Participants. Target population were male textile workers exposed to cotton dust in the studied factory. They were recruited from bale opening, carding, spinning, and weaving departments. The inclusion criteria set for enrolment were male gender, and exposure to cotton dust in the current job for at least two years. While exclusion criteria were current or past occupational history of exposure to respiratory hazards other than cotton dust or having a systematic disease that may affect the respiratory system. Accordingly, 219 workers from the above-mentioned departments were interviewed; among them, 35 workers were excepted. A comparison group included male workers from the same factory not exposed to respiratory hazards or suffering any systematic disease that may affect the respiratory system.

Sampling. Sample size was calculated using the Open-Epi online calculator (23). To detect the least difference in the prevalence of respiratory symptoms between cotton dust exposed workers and unexposed workers of 19% (13), with prevalence ratio of 1.9 at a power of 85% and confidence level of 0.95 (α=0.05), the minimum required sample size was 216. In this study, only eligible workers who agreed to participate were enrolled, accordingly, 364 male workers were included in the study and distributed into two groups: 184 workers exposed to cotton dust, and 180 workers not exposed to cotton dust or any respiratory hazard (served as a comparison group).

Research tools. All participants were subjected to the following data collection tools:

Interviewing questionnaire. A self-structured interviewing questionnaire was designed to obtain personal data (age and education); and occupational data [occupation, department, job duration, and use of personal protective equipment (PPE)].

British medical research council questionnaire. It has been tested and proved to be an accurate way of collecting information about respiratory symptoms and diseases (24,25). It included questions on symptoms as cough, phlegm production, breathlessness (grade I, II, or III), wheezing and attacks of asthma. In addition, it included questions on diseases of lungs and chest wall (such as bronchitis, bronchial asthma, pneumonia, pleurisy, pulmonary tuberculosis, heart troubles, previous injuries or chest operations) aimed at finding a cause for breathlessness and reveal whether it is due to a pulmonary or cardiac cause. Chronic bronchitis was diagnosed when the worker fulfilled the criteria of cough with sputum production on most days of the week during at least three consecutive months for at least two or more consecutive years.

The questionnaire included questions on smoking habit (age when regular smoking was initiated, and amount of tobacco consumption). Workers were classified into 'current smoker' (an adult who has smoked 100 cigarettes in his lifetime and who currently smokes cigarettes; and 'never smoker' (an adult who has never smoked, or who has smoked less than 100 cigarettes in his lifetime) (26).

Anthropometric measurements. Weight was obtained in kilograms using a standard balance and procedure; and height was recorded to the nearest centimeter using a vertical measurement scale (27).

Pulmonary function test. Spirometry was done during working hours on working days, using a portable spirometer ST-95 version 1.1A manufactured by Fukuda Sangyo Co., ltd. Japan in 1998. The equipment used and the maneuver met the recommended standardization cited by the American Thoracic Society and European Respiratory Society (28). The maintenance, calibration and quality control were considered to ensure clinically useful results and efficient testing.

First, the forced expiratory maneuver was explained to worker. Each worker performed at least 3 test maneuvers. If the performance was unsatisfactory, the worker was asked to repeat it again with maximum number of maneuvers of seven times. Then, the best three traces were selected provided there was good reproducibility between the best three trials (the variability between them was less than 5% for the FVC and FEV_1 indices and 10% for the PEFR index). Finally, the highest of the three trials for each index was recorded as the final measured value (28).

Results of the spirometry were given as two values for each LFI; the measured value and expected value (according to age, weight, height, and room temperature). Mean percent predicted values of the following LFIs were recorded for each worker: vital capacity (VC); FVC; FEV_1; forced expiratory volume in one second percent of FVC ($FEV1_{\%}$); PEFR; FEF_{75}: forced expiratory flows at 75, 50, and 25% of FVC (FEF_{70}, FEF_{50}, and FEF_{25}), and maximum voluntary ventilation (MVV).

In addition, PEFR was measured for cotton dust exposed workers (n=184) at their workplace within 20 min before and after the shift. PEFR was measured in a standing position using a portable handheld Omron peak flow meter (29).

Byssinosis diagnosis format. Byssinosis was diagnosed according to the Schilling criteria (Grade 0, $C_{1/2}$, C_1 C_2, and C_3) (30).

Statistical analysis. The SPSS v.22 (IBM Corp. Released 2011. IBM SPSS Statistics for Mac, Armonk, NY, USA) was used for data analysis. Qualitative data were described using frequencies and percentages, while quantitative data were described using mean and standard deviation. Analytic statistics were done, firstly to reveal any significant difference between cotton dust exposed workers and unexposed workers regarding sociodemographic, occupational, and medial data (respiratory symptoms and diseases, and LFIs). Then, among cotton dust exposed workers, a comparison was done between workers with byssinosis and workers without byssinosis regarding the above-mentioned data to determine factors significantly associated with byssinosis. The parametric and non-parametric tests used in this study were Student t-test and Mann Whitney test for quantitative variables; and Chi-square test, Fisher's exact test, and Monte Carlo test for qualitative variables. The Pearson correlation was done to study the relation between job duration and mean values and mean percent predicted values of FEV_1 and PEFR among cotton dust exposed workers. In this study, significance of all obtained results was judged at the 5% level (α=0.05).

Ethical considerations. The study received ethical approval from the Research Ethics Committee at the Faculty of Medicine affiliated with Alexandria University in Egypt (serial number: 0105532; IRB NO: 00007555; FWA NO: 00018699). The confidentiality of the collected data was ensured throughout all stages of the study.

Results

Characteristics of the studied workers (n=364). No significant difference was found between cotton dust exposed workers and unexposed workers regarding their mean age, marital status, education, weight, height, smoking habit, and service duration. Workers in both groups had a mean job duration of about 14.5 years at the selected factory. Cotton dust exposed workers were selected from the weaving department (25.5%), spinning department (25%), carding department (26.1%) and bale opening department (23.4%). The work environment in the above-mentioned departments was in the form of semi-closed wards; natural ventilation systems were used (doors and windows); there were no mechanical ventilation systems. High percentage of cotton dust exposed workers reported non-use (87.5%) or occasional use (7.6%) of PPE. (Table I).

Respiratory symptoms and diseases derived by BMRC questionnaire (n=364). Chronic cough and/or phlegm production in early morning, or diurnal and/or nocturnal cough and/or phlegm production were significantly more prevalent among cotton dust exposed workers (P<0.01). In addition, shortness of breath grade I, II and III was more reported in cotton dust exposed workers (6, 7.1 and 1.1% respectively) than unexposed workers (3.9, 2.2 and 0.6% respectively) (P=0.02). Although, cotton dust exposed workers reported attacks of wheeze (during the last 12 months) more than the unexposed workers, yet, this increase was statistically insignificant (P=0.11).

The prevalence of chronic bronchitis was significantly higher among cotton dust exposed workers (12%) than unexposed workers (3.9%) (P<0.01). Nevertheless, no difference between both groups regarding reporting physician-diagnosed bronchial asthma. (Table II).

Pulmonary function testing (n=364). The mean percent predicted values of the measured LFIs reflecting large-airway function (VC, FVC, FEV_1, PEFR and FEF_{75}) were significantly lower in cotton dust exposed workers than unexposed workers. While, no difference was detected between both groups regarding LFIs reflecting medium and small-airway function (FEF_{50} and FEF_{25}). (Table III).

Byssinosis among cotton dust exposed workers (n=184). Byssinosis was diagnosed in 42 workers exposed to cotton dust (22.8%). According to Schilling's clinical grading of byssinosis, 12 workers (6.5%) were grade C½, 23 workers (12.5%) were grade C_1, 5 workers (2.7%) were grade C_2, and 2 workers (1.0%) were grade C_3. The prevalence of byssinosis was highest at carding department (38.0%), followed by spinning (30.9%), weaving (19.0%) and bale opening (11.9%) departments.

Among cotton dust exposed workers, no difference was realized between workers with byssinosis and without byssinosis regarding personal and occupational characteristics except for smoking intensity, and job duration. Among current smokers, the mean smoking index was significantly higher among workers with byssinosis (527.1±245.2) compared with workers without byssinosis (369.6±158.6) (P=0.03). Moreover, more than one third of workers with byssinosis (35.7%) had a long job duration (20-30 years) at the selected factory compared with 22% of workers without byssinosis (P=0.04). (Table IV).

Cough, phlegm production, and chronic bronchitis were more encountered among cotton dust exposed workers with byssinosis compared with cotton dust exposed workers without byssinosis. (Table V).

As for LFIs among cotton dust exposed workers (n=184), a negative correlation was found between job duration and mean percent predicted values of FEV_1 and PEFR. (Table VI). The mean percent predicted values of FVC, FEV_1, PEFR, FEF_{75}, and FEF_{50} were significantly lower among workers with byssinosis compared with those without byssinosis. (Table VII). The mean cross-shift change in PEFR (%) was significantly higher in workers with byssinosis (8.10±4.97) compared with workers without byssinosis (1.44±0.68) (P<0.01). (Table VIII).

Discussion

This study revealed a significant association between occupational exposure to cotton dust and cough, phlegm production,

Table I. Personal and occupational characteristics of the studied textile workers (n=364).

	Cotton dust exposed workers (n=184)		Unexposed workers (n=180)		
Characteristics	No.	%	No.	%	P-value
Age (years)					0.56[b]
30-	45	24.5	52	28.9	
40-	93	50.5	82	45.6	
50-60	46	25.7	46	25.6	
Mean ± SD (Min-Max)	44.28±6.74 (30-59)		43.88±7.19 (30-59)		0.58[c]
Level of education					0.49[a]
Illiterate	31	16.8	25	13.9	
Read and write	91	49.5	78	43.3	
Basic	45	24.5	53	29.4	
Technical	15	8.2	21	11.7	
University	2	1.1	3	1.7	
Weight (Kg)					
Mean ± SD (Min-Max)	86.67±15.43 (50-130)		85.48±14.38 (50-125)		0.44[c]
Height (m)					
Mean ± SD (Min-Max)	1.73±07 (1.60-1.95)		1.74±.06 (1.60-1.93)		0.16[c]
Smoking status					0.44[b]
Never smoker	144	76.1	143	79.4	
Current smoker	44	23.9	37	20.6	
Smoking index^					0.13[b]
Light	6	13.6	9	24.3	
Moderate	11	25	13	35.1	
Heavy	27	61.4	15	40.5	
Mean ± SD (Min-Max)	419.77±201.66 (50-1200)		354.45±238.57 (40-1000)		0.07[d]
Job duration					0.02[b*]
<10	37	20.1	28	15.6	
10-	101	54.9	123	68.3	
20-30	46	25	29	16.1	
Mean ± SD (Min-Max)	14.71±5.55 (5-30)		14.57±4.70 (5-27)		0.80[c]
PPE usage					<0.01[d**]
No	161	87.5	180	100.0	
Yes, occasionally	14	7.6	0	0.0	
Yes, all the time	9	4.8	0	0.0	

SD, standard deviation; PPE, personal protective equipment. ^among smokers in exposed workers (n=44), and unexposed workers (n=37). Smoking index (SI) was calculated by multiplying number of cigarettes smoked per day by number of smoking years, and categorized into light (<200), moderate (200-400), and heavy (>400); [a]Monte Carlo test; [b] Chi square test; [c] Student's t-test; [d] Mn Whitney U test; [*]P<0.05; [**]P<0.01.

shortness of breath, chronic bronchitis, and reduced values of LFIs reflecting large-airway function. Results of the current study correspond to the results of other recent studies, where, the prevalence of cough and phlegm production was significantly higher among cotton dust exposed textile workers compared with unexposed workers in Egypt (35 and 22% respectively) (16), Ethiopia (28.1 and 9.6% respectively) (13), Benin (22 and 13% respectively) (10), and Nigeria (43 and 41% respectively) (15). Similar findings were reported in Khan *et al* study (2015) (11), which was conducted on 800 workers at 47 cotton factories in Pakistan (11). On the contrary, no significant association was found between cotton dust exposure and prevalence of respiratory symptoms in Hinson *et al* study (2016) (31), which could be attributed to the fact that cotton dust exposure was a public health problem at Southern of Benin, thus, unexposed workers selected in the study were probably exposed to cotton dust in the environment (31).

The prevalence of shortness of breath grade I, II, and II among cotton dust exposed workers in the current study was 6, 7.1 and 1.1% respectively. Similarly, high prevalence was reported in Greek cotton workers (9.8, 1.2% and 0.8 respectively) (32). Furthermore, in Wami *et al* study (2018) (13), 27.1% of cotton dust exposed workers had dyspnea (13). Moreover,

Table II. Respiratory symptoms and diseases among cotton dust exposed workers (n=184) and unexposed workers (n=180).

Symptoms and diseases	Cotton dust exposed workers (n=184) No.	%	Unexposed workers (n=180) No.	%	P-value
Respiratory symptoms					
Cough					
Cough in early morning	47	25.5	19	10.6	<0.01[a**]
Diurnal and/or nocturnal cough	49	26.6	19	10.6	<0.01[a**]
Chronic cough	31	16.8	11	6.1	<0.01[a**]
Phlegm production					
Phlegm production in early morning	30	16.3	9	5.0	<0.01[a**]
Diurnal and/or nocturnal phlegm	28	15.2	9	5.0	<0.01[a**]
Chronic phlegm production	25	13.6	7	3.9	<0.01[a**]
Shortness of breath[#]					
Grade I	11	6.0	7	3.9	0.02[a*]
Grade II	13	7.1	4	2.2	
Grade III	2	1.1	1	0.6	
Wheeze	10	5.4	4	2.2	0.11
Respiratory diseases					
Chronic bronchitis	22	12	7	3.9	<0.01[a**]
Bronchial asthma[^]	3	1.6	1	0.6	0.62[e]

[#]shortness of breath was categorized according to MRC scale into: grade I: breathless with strenuous exercise; grade II: short of breath when hurrying on the level or walking up a slight hill; and grade III: walk slower than people of the same age on the level or stops for breath while walking at own pace on the level.
[^]physician diagnosed bronchial asthma. [a]Chi square test; [e]Fisher's Exact test
[*]P<0.05; [**]P<0.01.

Table III. Mean percent predicted values of lung volumes and LFIs among cotton dust exposed workers (n=184) and unexposed workers (n=180).

Lung volumes and LFIs	Cotton dust exposed workers (n=184) mean ± SD (Min-Max)	Unexposed workers (n=180) mean ± SD (Min-Max)	P-value
Mean percent predicted values			
Large-airway			
VC (%)	84.3±11.61 (46-116)	89.4±11.04 (41-127)	<0.01[c**]
FVC (%)	81.23±7.34 (47-98)	88.81±8.95 (45-100)	<0.01[c**]
FEV_1 (%)	79.15±9.90 (33-92)	88.70±9.03 (52-109)	<0.01[c**]
FEV_1/FVC% (%)	79.13±6.64 (45.8-93.7)	82.58± 5.61 (66.6-100)	<0.01[c**]
PEFR (%)	93.23±25.09 (21-149)	102.74±24.31 (29-160)	<0.01[c**]
FEF_{75} (%)	87.43±24.35 (18-148)	91.94±18.14 (25-124)	0.04[c*]
Medium and small-airway			
FEF_{50} (%)	86.46±24.40 (29-187)	89±15.79 (32-146)	0.13[c]
FEF_{25} (%)	77.50±24.56 (17-178)	82±23.51 (30-176)	0.08[c]

LFIs, lung function indices; VC, vital capacity; FVC, forced vital capacity; FEV_1, forced expiratory volume in one second; FEV1%, forced expiratory volume in one second percent of FVC; PEFR, peak expiratory flow rate; FEF_{75}, forced expiratory flows at 75% of FVC; MVV, maximum voluntary ventilation; FEF_{50}, forced expiratory flows at 50% of FVC; FEF_{25}, forced expiratory flows at 25% of FVC; SD, standard deviation; [c]Student t-test. [*]P<0.05; [**]P<0.01.

Table IV. Personal and occupational characteristics of cotton dust exposed workers with byssinosis (n=42) and without byssinosis (n=142).

	Workers with byssinosis (n=42)		Workers without byssinosis (n=142)		
Characteristics	No.	%	No.	%	P-value
Personal characteristics					
Age (years)					0.26[b]
30-	11	26.2	34	23.9	
40-	17	40.5	76	53.5	
50-60	14	33.3	32	22.5	
Mean ± SD (Min-Max)	44.88±7.72 (30-59)		44.11±6.44 (30-59)		0.51[c]
Level of education					0.91[a]
Illiterate	6	14.3	25	17.6	
Read and write	23	54.8	68	47.9	
Basic	10	23.8	35	24.6	
Technical	3	7.1	12	8.5	
University	0	0.0	2	1.4	
Weight (Kg)					
Mean ± SD (Min-Max)	85.90±15.33 (59-112)		86.90±15.51 (50-130)		0.71[c]
Height (m)					
Mean ± SD (Min-Max)	1.72±0.07 (1.60-1.95)		1.73±0.07 (1.60-1.90)		0.6[c]
Smoking status					0.1[b]
Never smoker	28	66.7	112	78.9	
Current smoker	14	33.3	30	21.1	
Smoking index[^]					0.32[a]
Light	1	7.1	5	16.7	
Moderate	2	14.3	9	30.0	
Heavy	11	78.6	16	53.3	
Mean ± SD (Min-Max)	527.1±245.2 (120-1200)		369.6±158.6 (50-660)		0.03[d*]
Occupational characteristics					
Job duration					0.04[b*]
<10	11	26.2	26	18.3	
10-	16	38.1	85	59.9	
20-30	15	35.7	31	21.8	
Mean ± SD (Min-Max)	15.92±6.45 (7-30)		14.35±5.19 (5-29)	0.1[c]	
PPE usage					<0.6[a]
No	37	88.1	125	88.0	
Yes, occasionally	4	9.5	9	6.3	
Yes, all the time	1	2.4	8	5.6	

SD, standard deviation; PPE, personal protective equipment; [^]among smokers, smoking index (SI) was calculated by multiplying No. of cigarettes smoked/day by number of smoking years; light (<200), moderate (200-400), and heavy (>400); [a]Monte Carlo test; [b]Chi square test; [c]Student's t-test; [e]Fisher's Exact test; [d]Man Whitney U test; [*]P<0.05; [**]P<0.01.

the probability of occurrence of dyspnea among cotton dust exposed workers was 2.38 times fold higher than unexposed workers in Nagoda *et al* study (2012) (15).

The prevalence of chronic bronchitis among cotton dust exposed workers in the current study (12%) was slightly lower than that reported in an earlier study conducted at Assuit spinning factory, Egypt (13.4%) (33), and much higher than that reported in Central India (5.8%) (34), and Southern of Benin (3.4%) (31). The relatively low prevalence of bronchial asthma among textile workers in the current study compared with the general population may be explained by the healthy worker effect that could underestimate the actual burden of bronchial asthma among textile workers. It might also be due to the protective effect of endotoxin exposure at the textile industry on bronchial asthma (35).

Coinciding with the pulmonary function results of the present study, Tageldin *et al* study (2017) in Egypt (16),

Table V. Respiratory symptoms and diseases among cotton dust exposed workers with byssinosis (n=42) and without byssinosis (n=142).

	Workers with byssinosis (n=42)		Workers without byssinosis (n=142)		
Symptoms and diseases	No.	%	No.	%	P-value
Respiratory symptoms					
Cough					
Cough in early morning	16	38.5	31	21.8	0.03[a*]
Diurnal and/or nocturnal cough	18	42.9	31	21.8	<0.01[a**]
Chronic cough	12	28.6	19	13.4	0.02[a*]
Phlegm production					
Phlegm production in early morning	11	26.2	19	13.4	0.04[a*]
Diurnal and/or nocturnal phlegm	10	23.5	18	12.7	0.07[a]
Chronic phlegm production	10	23.5	15	10.6	0.02[a*]
Wheeze	3	7.1	7	4.9	0.69
Respiratory diseases					
Chronic bronchitis	10	23.8	12	8.5	<0.01[a**]
Bronchial asthma[^]	0	0.0	3	1.6	1[e]

[^]physician diagnosed bronchial asthma; [a]Chi square test; [e]Fisher's Exact test; *P<0.05; **P<0.01.

Table VI. Correlation between job duration and mean values and mean percent predicted values of FEV_1 and PEFR among cotton dust exposed workers (n=184).

		FEV_1 (L)	PEFR (L/S)	FEV_1 % predicted	PEFR % predicted
Job duration (years)	r	-0.058	-0.45	-0.25	-0.15
	p	0.01*	0.04*	0.01*	0.03*

FEV_1, forced expiratory volume in one second; PEFR, peak expiratory flow rate; r, correlation coefficient; *P<0.05.

revealed significant reduction in FVC%, FEV_1%, FEV_1/FVC and PEF% among cotton dust exposed workers (16). Similarly, Anyfantis *et al* study (2017) (32), found a significant reduction in FEV_1% predicted and FEV_1/FVC% among Greek cotton workers; the number of exposed workers with FEV_1>80% and FEV_1/FVC>70% was significantly higher than the comparison group (32). Moreover, studies in Iran, Benin, Nigeria, and India found significant reductions in FEV_1 (10,15,36), FEV^1/FVC (37), and PEFR (15,36) among cotton dust exposed textile workers. Findings suggest that textile workers in the less developed countries, are still at risk of developing pulmonary impairment of obstructive pattern.

Similar to the findings in earlier studies (38,39), FEV_1 and PEFR in the current study were negatively correlated with the duration of exposure. This would support the idea that the impact of cotton dust exposure on lung function depends on duration of exposure. However, Tageldin *et al* study (2017) in Egypt (16), found no correlation, which would indicate that other occupational factors such as dose of exposure, engineering measures, and compliance with PPE might have a role and should be considered.

In the current study, the prevalence of byssinosis among cotton dust exposed workers (22.8%) was considerably lower than that reported in studies in Benin (44%) (31), Ethiopia (38%) (12), and India (98) (40). However, it was higher than the prevalence reported in Nigeria (5%) (15). On the contrary, in Paudyal *et al* study (2015) (41) conducted on 938 cotton workers in Nepal, none of the exposed workers reported symptoms of byssinosis; however, most workers in that study were young with short service duration, moreover, the early stages of cotton processing were not involved in cotton industries included in that study, so the cotton handled was not biologically active (41). The variability in the prevalence of byssinosis in different studies can be explained in several ways. The study subjects came from different workplaces where exposure level varied widely. Besides, diagnostic criteria of byssinosis were not identical in different studies. Similar to findings reported earlier (20), the current study found that respiratory symptoms and chronic bronchitis were more prevalent among workers with byssinosis. In addition, the mean values of lung volumes and LFIs for large, medium, and small-sized airway function were significantly lower among workers with byssinosis compared with those without byssinosis.

Table VII. Mean percent predicted values of lung volumes and LFIs among cotton dust exposed workers with byssinosis (n=42) and without byssinosis (n=142).

	Workers with byssinosis (n=42)	Workers without byssinosis (n=142)	
Lung volumes and LFIs	mean ± SD (Min-Max)	mean ± SD (Min-Max)	P-value
Mean percent predicted values			
Large-airway			
VC (%)	81.59±12.46 (44-103)	85.20±11.26 (46-116)	0.09[c]
FVC (%)	78.07±10.73 (47-91)	82.17±5.71 (58-98)	<0.01[c**]
FEV_1 (%)	73.97±14.33 (33-88)	80.68±7.56 (36-92)	<0.01[c**]
FEV_1/FVC% (%)	76.47±7.83 (45.85-87.12)	79.92± 6.06 (51.48-39.70)	<0.01[c**]
PEFR (%)	80.57±29.08 (21-145)	97.66±22.17 (29-149)	<0.01[c**]
FEF_{75} (%)	77.23±28.03 (18-148)	90.45±22.39 (18-139)	<0.01[c**]
Medium and small-airway			
FEF_{50} (%)	76.59±21.43 (30-126)	89.30±24.59 (29-187)	<0.01[c**]
FEF_{25} (%)	74.26±25.16 (17-132)	78.58±24.38 (21-178)	0.54[d]

LFIs, lung function indices; VC, vital capacity; FVC, forced vital capacity; FEV_1, forced expiratory volume in one second; FEV1%, forced expiratory volume in one second percent of FVC; PEFR, peak expiratory flow rate; FEF_{75}, forced expiratory flows at 75% of FVC; MVV, maximum voluntary ventilation; FEF_{50}, forced expiratory flows at 50% of FVC; FEF_{25}, forced expiratory flows at 25% of FVC; SD, standard deviation; [c]Student t-test; [d]Man Whitney test; [*]P<0.05; [**]P<0.01.

Table VIII. Cross shift changes in PEFR among cotton dust exposed workers with byssinosis (n=42) and without byssinosis (n=142).

	Workers with byssinosis (n=42)	Workers without byssinosis (n=142)	
PEFR	Mean ± SD (Min-Max)	Mean ± SD (Min-Max)	P-value
Pre-shift PEFR (L/M)	456.07±153.02 (160-770)	523.42±122.42 (150-795)	0.04[c]
Post-shift PEFR (L/M)	424.02±152.79 (125-752)	516.20±121.84 (145-790)	<0.01[c**]
Δ PEFR (L/M)	32.04±12.19 (11-58)	7.21±3.21 (1-19)	<0.01[c**]
Δ PEFR (%)	8.10±4.97 (2.34-21.88)	1.44±.68 (0.19-4.26)	<0.01[c**]

PEFR, peak expiratory flow rate; SD, standard deviation; [c]Student t-test; [*]P<0.05; [**]P<0.01.

Few studies explored the cross-shift change in PEFR in response to cotton dust exposure in textile workers (15,19,42). In the current study, the mean cross-shift change (reduction) in PEFR (%) was significantly higher in workers with byssinosis (8.10%) compared with workers without byssinosis (1.44%). Though a similar finding was reported in Ghasemkhani *et al* study (2006) (19), no significant cross-shift change in PEFR was found in Nagoda *et al* study (2012) (15), and Saha *et al* study (2014) (42) which was conducted on workers engaged in ginning processes; this might be due to interrupted exposure to cotton dust since ginning activity is conducted in a seasonal manner (3 to 4 months per year) (42).

Limitations of the study. Assessment of respiratory morbidity in relation to the level of exposure to cotton dust was not possible in the current study since environmental exposure measurements were not carried out in this study.

Conclusions

Occupational exposure to cotton dust in the textile industry is associated with cough, phlegm production, shortness of breath, chronic bronchitis, and reduced values of LFIs for large-airway function. The prevalence of byssinosis was 22.8% among cotton dust exposed workers. Job duration was negatively correlated to FEV_1 and PEFR. Respiratory symptoms and chronic bronchitis were more prevalent among workers with byssinosis; In addition, they had significantly lower values of LFIs for large, medium, and small-sized airway function; and a significantly higher cross-shift change in PEFR compared with workers without byssinosis. For early diagnosis of byssinosis, cross-shift change in PEFR is recommended to be recorded regularly among workers. Further research is required to correlate environmental cotton dust exposure measurements with respiratory morbidity.

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Availability of data and material

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Contributions

NE, analysis and interpretation of data, drafting the article and revising it critically for intellectual content; NF, conception and design of the study; SS, data collection and analysis; NF, SS, revising the manuscript for submission. All the authors approved the final version to be published.

Ethical approval and consent to participate

The study received ethical approval from the Research Ethics Committee at the Faculty of Medicine affiliated with Alexandria University in Egypt (serial number: 0105532; IRB NO: 00007555; FWA NO: 00018699). The confidentiality of the collected data was ensured throughout all stages of the study.

Conflict of interest

The authors declare no potential conflict of interest.

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