Lung function in Lancashire cotton and man made fibre spinning mill operatives

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Abstract

Objectives—This survey was conducted to investigate current lung function levels in operatives working with cotton and man made fibres. Dust concentrations, smoking history, and occupational details were recorded so that factors influencing lung function could be identified.

Methods—A cross sectional study of respiratory symptoms and lung function was made in 1057 textile spinning operatives of white caucasian extraction. This represented 96.9% of the total available working population to be studied. Most (713) worked currently with cotton. The remainder worked with man made fibre. Lung function was assessed by measuring forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC). Exposure to cotton dust was measured in the work area and personal breathing zones, and retrospective exposure to cotton dust over a working life was estimated with accurate work history and best available hygiene data.

Results—3.5% of all operatives had byssinosis, 55 (5.3%) chronic bronchitis, 36 (3.5%) work related persistent cough, 55 (5.3%) non-byssinotic work related chest tightness, and 56 (5.3%) work related wheeze. A total of 212 static work area dust samples (range 0.04–3.23 mg/m³) and 213 personal breathing zone samples (range 0.14–24.95 mg/m³) were collected. Percentage of predicted FEV₁ was reduced in current smokers (mean 89.5, 95% confidence interval (95% CI) 88–91) in comparison with non-smokers (93.1, 90.5–94.1) and FVC was reduced in operatives currently working with man made fibre (95.3, 93.8–96.9) in comparison with cotton (97.8, 96.6–99.0). Regression analysis identified smoking (P<0.01), increasing age (P<0.01), increasing time worked in the waste room (P<0.01), and male sex (P<0.05) as being associated with a lower FEV₁ and FVC. Current and retrospective cotton dust exposures did not appear as predictor variables in the regression analysis although in a univariate analysis, FEV₁ was reduced in those operatives exposed to high dust concentrations assessed by personal and work area sampling.

Discussion—This study has documented loss of lung function in association with exposure to cotton dust. Those operatives with work related symptoms had signifi-

cantly lower FEV₁ and FVC than asymptomatic workers. Although lung function seemed to be affected by high dust exposures when operatives were stratified into high and low exposure groups, regression analysis did not identify current dust concentrations as an independent factor influencing loss. Smoking habit was found to explain most of the measured change in FEV₁ and FVC. It is likely that smoking and dust exposure interact to cause loss of lung function in cotton textile workers.

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Byssinosis is a respiratory disease primarily associated with workplace exposure to cotton dust characterised by chest tightness that is worse on the first day of exposure to cotton dust after a break from work. Despite early references to the disease known commonly today as byssinosis,^{1,2} it was to be almost 100 years before serious epidemiological work was undertaken both in the Lancashire cotton mills and in mills throughout the other cotton producing countries of the world.^{3,4} The most recent study of this population has estimated the current prevalence of byssinosis to be 3.6%.⁵ This seems to be falling in comparison with earlier papers.³

This cross sectional study was performed to document the prevalences of work related respiratory symptoms in current textile workers and to associate them with dust exposures and measured lung function.

Methods

A cross sectional analysis of respiratory symptoms and lung function was made at 11 spinning mills in Lancashire. Two of these processed man made fibre, one a mix of cotton and man made fibre and the remaining eight processed cotton alone. These comprised a total consenting population of 360 man made fibre operatives and 730 cotton operatives. Of the possible population 97% took part from varying work areas in a standard spinning mill. Table 1 summarises the work areas. Table 2 shows details of mean age, smoking habits, and sex distribution for each mill. The respiratory questionnaire was modified from an MRC version designed to identify byssinosis, chronic bronchitis, work related wheeze, and cough.⁶ Non-byssinotic chest tightness is

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Table 1 Occupational codings

1	Blow room, opening room operatives
2	Card attendant
3	Draw, speed frame tenters and combers
4	Card room supervisors and instructors
5	Other card room operatives
6	Spinners
7	Doffers
8	Spinning supervisors and instructors
9	Other spinning room operatives
10	Winders
11	Winding room supervisors and instructors
12	Other winding room operatives
13	Managerial staff
14	Warehouse staff
15	All areas
16	Waste room operatives
17	Open end mill main work area

shown as a separate category to byssinosis as some operatives complained of chest tightness that improved on rest days but did not conform to the classic definition of byssinosis—that is, worse on the first working day. “Work related” was defined as any symptom improving on rest days or volunteered as being worse at work.

A full work history including current and previous rooms of work, fibre type used, and use of respiratory protection was recorded to place operatives into occupational groups. Operatives were defined by their current position and most tended to keep to a particular occupation for many years.

A full smoking history was also recorded. For the purpose of analysis, operatives have been divided into current smokers and a combined category for ex and never smokers. A cumulative estimate of lifetime cigarette, cigar, and tobacco consumption has also been used (pack-years).

LUNG FUNCTION ASSESSMENT

Each operative was asked to perform a reproducible forced expiratory volume in one second (FEV₁) and a forced vital capacity (FVC) (greatest value of three values within 5%). A single dry wedge spirometer (Vitalograph, Bucks, UK) was used for the entire study and measurements were made by one of two investigators (DF and AMF). The FEV₁ and FVC were then converted to percentages of predicted values for further analysis with prediction equations,⁷ based on a non-smoking healthy European working population. Percentages of predicted values have been used as these were thought to be the most easily manipulated, understood, and most clinically relevant to investigating textile workers. Only those operatives of white caucasian extraction have been used in subsequent analysis.

COTTON DUST SAMPLING

This was performed in the work area by static L60 samplers (Rothero and Mitchell, Negretti Automation, Aylesbury, Bucks, UK) according to guidelines set down in the EH25 directive from the United Kingdom Health and Safety Executive⁸ and as described in a previous publication from this centre.⁵

Personal breathing zone cotton dust concentrations were assessed in nine of the 11 cotton mills with the Institute of Occupational Medicine dust sampling head already described recently by our group.⁹

Operatives were each ascribed a static work area dust concentration to serve as an estimate of their current cotton dust exposure and were placed into occupational sets to group operatives with similar occupations or cotton dust exposures. All man made fibre operatives were given a zero value. All values of current exposure were expressed in mg/m³ of total dust less fly.

Each operative was also assigned a personal cotton dust concentration in mg/m³ (except mill 2 as this closed before the dust sampling exercise).

A measure was also made of cumulative lifetime exposure to cotton dust. The method, previously described,⁵ used current dust exposures in the work area, work history, and known and estimated previous dust concentrations at each mill in the study. Cumulative exposure of dust was calculated by adding together individual exposures in each position at each mill while being blinded to the current work area and number of symptoms.

STATISTICAL METHODS

Lung function indices are presented as percentage predicted value for each operative (percentage of predicted FEV₁ (PPFEV₁), percentage of predicted FVC (PPFVC)). Means of these and the 95% confidence intervals (95% CIs) are used to compare lung function between symptom and dust exposure groups. Statistical significance was set at the conventional 5% level.

REGRESSION ANALYSIS

Forward stepwise analyses were performed to identify those factors independently influencing the level of current lung function and to estimate the relative magnitudes of their effects. Percentages of predicted FEV₁ and FVC were in turn tested against a variety of potential predictor variables including age, sex, current and previous workrooms, the three variables of exposure to cotton dust (present and past exposure, and personal dust) and smoking data. For each lung function variable, the order in which significant factors entered the equation is indicated along with the corresponding P and cumulative R² values.

Results

THE STUDY POPULATION

A total of 1057 operatives out of a possible 1090 (97%) took part in the study. Those who refused to take part in this study were of similar

Table 2 Personal characteristics and smoking habits by mill of work

Mill	n	Mean age (y)	Men (%)	Current smokers (%)
1	58	42	83	47
2	132	44	79	42
3	85	42	77	53
4	51	42	86	56
5	61	37	73	59
6	138	33	61	42
7*	151	37	62	58
8*	193	31	65	51
9	56	38	92	49
10	32	39	92	49
11**	86	37	61	51

*Man made fibre mill; **man made fibre and cotton blend mill.

Table 3 Lung function results for operatives with and without byssinosis, across all fibre types

Symptoms	PPFEV ₁ Mean (SD) 95% CI	PPFVC Mean (SD) 95% CI
Byssinosis (n = 36)	76.0 (16.5) 70.0–81.5	85.2 (13.7) 80.1–89.7
No byssinosis (n = 1008)	91.7 (17.0) 90.7–92.8	97.4 (15.8) 96.4–98.4
Chronic bronchitis (n = 55)	82.7 (21.7) 77.0–88.4	90.8 (17.3) 85.5–96.2
No bronchitis (n = 953)	92.3 (16.6) 91.2–93.3	97.8 (15.3) 96.8–98.4
Non-byssinotic chest tightness (n = 55)	90.9 (19.4) 85.6–96.1	97.5 (19.3) 92.5–102.0
No non-byssinotic chest tightness (n = 953)	91.8 (16.8) 90.7–92.9	97.4 (15.5) 96.6–98.4
Work related wheeze (n = 56)	85.7 (16.7) 81.3–90.1	93.4 (15.2) 89.5–97.4
No work related wheeze (n = 952)	92.1 (16.8) 91.1–93.2	97.6 (15.8) 96.6–98.6
Work related cough (n = 36)	86.5 (19.7) 80.0–92.9	96.2 (16.0) 90.9–101.0
No work related cough (n = 972)	91.9 (16.9) 90.9–93.0	97.5 (15.7) 96.5–98.4

Table 4 Lung function and fibre type.

	PPFEV ₁ Mean (95% CI)	PPFVC Mean (95% CI)
Cotton operatives	91.3 (90.2–92.8)	97.8 (96.6–99.0)
Man made fibre	90.6 (88.8–92.3)	95.3 (93.8–96.9)

Table 5 Current static cotton dust concentration and current personal dust exposure ranges (mg/m³)

Mill	Current static cotton dust concentration range (n)	Current personal dust exposure range (n)
1	0.15–3.23 (28)	0.25–16.71 (39)
3	0.30–2.36 (26)	0.35–8.94 (25)
4	0.12–0.71 (20)	0.17–8.32 (14)
5	0.21–2.94 (26)	0.61–22.79 (22)
6	0.23–1.89 (28)	0.48–6.03 (30)
8	0.06–0.35 (19)	0.24–2.02 (20)
84	0.04–0.37 (6)	0.73–17.32 (7)
9	0.34–1.80 (19)	0.56–24.95 (15)
10	0.10–2.39 (20)	0.88–16.28 (10)
11	0.04–0.28 (20)	0.14–2.23 (31)

age to those studied and from a range of work areas. Of all operatives 36 (3.5%) had symptoms of byssinosis, 55 (5.3%) chronic bronchitis, 36 (3.5%) work related persistent cough, 55 (5.3%) non-byssinotic chest tightness, and 56 (5.3%) work related wheeze.

LUNG FUNCTION ANALYSIS

Reproducible lung function data were available on 1043 (98.7%) of a total study population of 1057 operatives. There was no reason to suspect that the operatives who refused to be studied were significantly more impaired than those who agreed. There were small but significant differences in measured lung function between the sexes; mean (95% CI) PPFEV₁ in women 92.3 (90.5–94.1) and in men 90.6 (89.3–91.9), and similarly for PPFVC in women 98.2 (96.5–99.9) and in men 96.4 (95.2–97.5).

The PPFEV₁ was lower in current smokers (mean 89.5, 95% CI 88–91) than in ex and

non-smokers (mean 93.1, 95% CI 90.5–94.1). The PPFVC did not differ between smoking categories.

Table 3 contains lung function data about byssinosis, chronic bronchitis, non-byssinotic chest tightness, work related wheeze, and persistent work related cough. Operatives with byssinosis, chronic bronchitis, and work related wheeze had significant impairment of their lung function compared with operatives without these symptoms.

Mean PPFEV₁ did not differ between operatives currently working with either cotton or man made fibres and PPFVC was significantly less in workers with man made fibres than in cotton workers (table 4).

Table 5 shows the numbers of dust samples collected and their range at each mill studied and the differences between sampling techniques and between different mills.

Table 6 shows the univariate relation between current lung function in those operatives exposed to either low or high current dust concentrations as assessed by current static work area and personal zone exposures. In each case the FEV₁ and FVC were lower in the high exposure group.

Regression analysis identified a measure of smoking, increasing age, increasing total time worked in the waste room (a traditionally dusty area), and being male as being associated with a lower PPFEV₁ and PPFVC. Tables 7 and 8 show the corresponding regression results. Regression analysis did not identify past exposure as an independent variable associated with loss of lung function. Mean (95% CI) past exposure values (per year worked with cotton) were 0.74 (0.70–0.77) mg/m³ in those with a PPFEV₁ of 90% or less in comparison with 0.71 (0.68–0.74) for those with PPFEV₁ greater than 90%.

Discussion

Both acute, shift related effects¹⁰ and chronic, accelerated lung volume loss¹¹ associated with cotton dust exposure are described in the literature. The design of this study did not enable us to measure across shift changes and measurements were made as near the beginning of each shift as possible to attempt to reduce any "acute" effect of cotton dust exposure. Lung function data were available in most of the operatives in this study. Fourteen operatives either refused to have the investigation performed for varying reasons or were unable to produce a satisfactory reproducible spirometric curve.

In this study, female operatives were found

Table 6 Comparison of PPFEV₁ in low and high exposure groups

	Current static cotton dust		Current personal dust	
	High exposure (> 0.5 mg/m ³) Mean (SD) 95% CI	Low exposure (≤ 0.5 mg/m ³) Mean (SD) 95% CI	High exposure (> 0.5 mg/m ³) Mean (SD) 95% CI	Low exposure (≤ 0.5 mg/m ³) Mean (SD) 95% CI
n	432	611	263	497
PPFEV ₁	90.1 (17.7) 88.5–91.7	92.0 (16.9) 90.6–93.3	90.4 (16.9) 88.3–92.4	92.8 (17.0) 91.2–94.2

Table 7 Regression analysis results for PPFEV₁ as the dependent variable

Predictor variable	Estimate	SEM	R ² value	P value	f
Smoking (pack-years)	-0.0110	0.0021	6.34	<0.01	70.6
Age	-0.2399	0.04246	8.67	<0.01	26.5
Duration in waste room (y)	-1.012	0.3596	9.37	<0.01	8.1
Cotton grade:					
1	100.3	1.646	11.15	<0.01	5.2
3	108.2	2.282			
5	98.56	1.921			
6	102.4	1.837			
8	102.7	2.326	11.56	<0.05	4.75
Sex	2.398	1.101			

Table 8 Regression analysis results for PPFVC as the dependent variable

Predictor variable	Estimate	SEM	R ² value	P value	f
Smoking (pack-years)	-0.0048	0.0019	1.93	<0.01	20.5
Age	-0.1425	0.0396	5.37	<0.01	11.4
Duration in waste room (y)	-1.081	0.3354	6.36	<0.01	10.9
Cotton grade:					
1	100.4	1.535	4.33	<0.01	6.50
3	110.0	2.128			
5	101.1	1.792			
6	103.2	1.714			
8	104.7	2.169	6.79	<0.05	4.80
Sex	2.250	1.027			

to have significantly greater PPFEV₁ and PPFVC, both with univariate analysis and regression. Early epidemiological work tended not to comment on differences between men and women as most dusty occupations were carried out by men. Subsequent studies have, however, identified some sex differences.^{12,13} Elwood *et al*¹⁴ also documented less loss of lung function over time in women who smoked than in men who smoked. This paper also suggested other possible reasons for the observed reduction in lung function of cotton workers with particular reference to social circumstances, nutrition, and their reduced height. The differences in this study were small and probably of no clinical significance.

The effect of respiratory symptoms on lung function, other than those of byssinosis, were also considered in this study. Except for byssinosis, there is a paucity of epidemiological information in previous studies on symptoms and their associated physiological abnormalities.

Operatives without byssinosis who complained of work related wheeze had a lower PPFEV₁ and PPFVC than those without this symptom. Some of these people volunteered the fact that they had asthma and that the work environment made the wheeze worse. It is possible that a proportion of these people were workers with pre-existing asthma that tended to be exacerbated at work. A proportion, however, had become wheezy as a consequence of their work with cotton and the significance of this remains obscure as these people seemed not to have had byssinotic symptoms. A possibility is that some people become sensitised to a particular agent at work and have developed a form of occupational asthma discrete from the condition byssinosis.

One of the long term purposes of this study is to consider this issue.

Operatives with non-byssinotic work related chest tightness and work related cough did not seem to have notably impaired lung function compared with operatives without this additional symptom. This tends to imply that significant airflow obstruction was not the cause of these symptoms, although the lung function assessment was made only on one occasion and consequently did not reflect physiological changes when the symptom was being experienced nor did it enable conclusions to be drawn about falls in FEV₁ in these people during a shift.

Chronic bronchitis was a commonly reported symptom in those with byssinosis and also an isolated symptom. As early as 1955, Schilling *et al* noted a smaller loss in lung volumes in cotton workers with chronic bronchitis than in byssinotic workers. In this study, there was a large overlap between byssinosis and chronic bronchitis, with 20% of all byssinotic workers complaining of work related phlegm production on a regular basis compared with a background rate in all other operatives of about 5%.¹⁵ This reaffirms the original concept suggested by Massoud *et al* of two distinct forms of byssinosis; pure byssinosis and byssinotic symptoms with chronic bronchitis.¹⁶

Schilling and Lond described early experiences in assessment of lung function in byssinotic workers.¹⁷ They documented diminished maximum voluntary ventilation in grade one and two byssinotic workers compared with control subjects from local Lancashire engineering firms. Belin *et al* compared FEV_{0.75}/body height ratio measurements from 15 byssinotic workers with a non-byssinotic control population of prisoners.¹⁸ The byssinotic values were notably lower. These data are difficult to interpret as smoking data were not recorded. Beck *et al* and Zuskin *et al* similarly documented that byssinotic workers had lower mean FEV₁s than non-byssinotic workers.^{13,19}

The PPFEV₁ and PPFVC were lower in smokers compared with non-smokers across all fibre groups, and the regression analysis ranked smoking pack-years as the strongest predictor variable for both PPFEV₁ and PPFVC. The exact relation between smoking and lung function abnormalities in the presence of exposure to cotton dust remains controversial. Early epidemiological studies tended not to include information on smoking habit. Merchant *et al* documented decrement in lung function in smokers compared with non-smokers, although men who smoked and had occupations exposed lightly to dust had significantly better lung function than those in heavily exposed occupations.¹² Their subsequent work indicated that smoking and dust exposure may act independently to influence loss in lung volume.²⁰ Imbus concluded that smoking was far more important than dust exposure in causing loss of FEV₁.²¹ When dust exposure was considered in this study, division of operatives into high and low exposures seemed to suggest an effect of current expo-

sure on measured lung function. The regression analysis, however, did not identify a relation between current or past dust measurements and lung function. This is contrary to the findings of Jones *et al* who studied lung function variables in cotton operatives and man made fibre control workers.²² Mill of work, current dust concentrations, and occupation had no bearing on impairment of FEV₁ and FVC although an association was found between increased duration of exposure to cotton dust and impaired FVC.

Beck *et al* suggested that the effects of dust and cigarette smoke may both have an independent role in influencing loss of lung function.²³ They compared 477 cotton textile workers with 932 non-exposed controls. Cotton workers were found to have significantly lower FEV₁ and FVC. The authors postulated that smoking and dust may have differential discrete actions on the smaller and larger airways, respectively; the combination of which led to the clinical syndrome of byssinosis.

The present study identified a function of cotton grade and a measure of duration of exposure to a known dirty environment as significant, although smoking pack-years was the most significant predictor of reduced lung function. Whether this finding indicates that there is a particular agent or quality of cotton dust within the waste area that causes accelerated loss of lung function is unknown and this study, due to its limitation as a cross sectional analysis, cannot add to this intriguing point.

In this study there did not seem to be an obvious effect of fibre type. In fact, mean PPFVC was significantly greater in cotton than in man made fibre mills. This paradoxical decrement in workers of man made fibre has previously been documented.¹² The cause for this finding is not fully understood, but may represent the converse of the healthy worker effect in that operatives who cannot tolerate the cotton exposure, possibly with pre-existing lung disease, may move into a similarly skilled occupation in a man made fibre process.

It was intriguing to find that the FEV₁ was significantly reduced from predicted values in asymptomatic operatives both in cotton and man made fibre mills. It is difficult to assume that this was due to a subclinical effect of cotton dust on the airways as it occurred equally in operatives exposed to man made fibre. It may, more likely, reflect the relatively high proportion of current smokers in both fibre groups.

In summary, this cross sectional study has documented reduced lung function associated with workplace exposure to cotton dust. Operatives with byssinosis, chronic bronchitis, and work related wheeze had significantly impaired lung function compared with operatives without these symptoms. Women operatives and those working with man made fibres or blends seemed to have less impairment of

measured lung function. Regression analysis identified smoking, however, as the most significant single determinant of a reduced FEV₁ and FVC although the duration of cotton exposure in the waste room did enter into the prediction for loss in FEV₁ and FVC. The likely situation is that smoking and dust exposure interact in a complicated manner to augment the loss in lung volume.

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