Ventilatory function and personal breathing zone dust concentrations in Lancashire textile weavers

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Abstract

Background—To report findings on ventilatory function and estimations of concentrations of personal breathing zone dust in Lancashire textile weavers. Weaving room dust is considered to be less harmful than that encountered in the cardroom or spinning room and weavers are generally thought to have less respiratory disability than carders or spinners. However, this occupational group has not been extensively studied.

Methods—Each person was given a respiratory symptom questionnaire (modified Medical Research Council, UK, questionnaire on respiratory diseases). Ventilatory function tests, forced expiratory volume in 1 second (FEV₁) and forced vital capacity (FVC) were performed on each person. A representative sample of workers from each occupational group underwent dust sampling in their personal breathing zone. Dust concentrations and ventilatory tests were analysed statistically with the Student's *t* test, Pearson's correlation coefficient, and forward step regression for relations with symptoms and environmental factors. Significance was $p \geq 0.05$.

Results—The FEV₁ and FVC were reduced in workers with respiratory symptoms (non-specific chest tightness, shortness of breath, persistent cough, and wheezing) as well as in preparation room workers, current and former smokers, Asians, those working with predominantly cotton fibre (>50% cotton) and starch size. Mean total dust concentration (pd1) in the personal breathing zone was 1.98 mg/m³. The corresponding value for total dust with large fibres lifted off the filter paper (pd2) was 1.55 mg/m³. There was a strong correlation ($r=0.94$, $p<0.0001$) between pd1 and pd2. Non-specific chest tightness was predicted by low dust concentrations and persistent cough by high dust concentrations. On regression analysis, impairment of ventilatory function (FEV₁, FVC) was predicted by smoking, male sex, age, not working in the weaving shed, not being white, and personal dust concentrations.

Conclusions—The FEV₁ and FVC were impaired in smokers and those exposed to high dust concentrations in the personal breathing zone. Symptoms were inconsistently related to dust concentrations in the personal breathing zone.

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Keywords: weavers; dust concentrations; personal sampling; spirometry; textiles

It has been recognised for a long time that dust in the textile environment is related to respiratory illness.¹⁻³ Investigators at the turn of the century^{4,5} and in the 1930s⁶ documented the high prevalence of disease and disability among cotton operatives. Since then, important advances have been made in the epidemiology of disease associated with work in the cotton mills. Several investigators have shown respiratory disability in cotton workers, based on clinical and ventilatory function evaluation.⁷⁻¹⁹

There is some debate regarding the optimum ventilatory test for assessment of respiratory disability in textile workers.^{17,20,21} In the United Kingdom, the ventilatory test used most often is forced expiratory volume in 1 second (FEV₁).

Until recently, area or workzone sampling was carried out and used for setting standards of occupational exposure. Several studies showed a good correlation between respiratory symptoms and dust concentrations.^{10,11,22,23}

Cinkotai *et al*^{12,13} used both workzone and personal breathing zone dust sampling. They found that personal breathing zone dust sampling correlated better with byssinotic symptoms. Recent work has also shown that in operatives exposed to cotton, up to 10-fold variation in exposure to dust can occur when comparing these two methods.²⁴ However, most of the work already referred to has been carried out on cotton spinners, and not on weavers. It has been suggested that dust in the weaving shed is different, as a large part of it consists of "size" (a coating of starch, or other material, applied to yarn before it is submitted for weaving), which is liberated during the weaving process. Application of a coating of size may also prevent cotton dust from being liberated during the weaving process. The thought that weaving room dust is less injurious for health is reflected in the dust standards recommended by Corn, for the United States²⁵—that is, a level of 0.75 mg/m³ for weaving and sizing and 0.20 mg/m³ for yarn manufacture and cotton washing. The generally held view is that byssinosis and other symptoms are not major problems for textile weaving. However, a few investigators have reported high prevalence of byssinosis and respiratory disability in cotton weavers.²⁶⁻²⁹

We used a respiratory symptom questionnaire, spirometry, and measurement of total inhalable dust in the personal breathing zone to study textile weavers around Manchester. Respiratory symptoms and factors associated with them are the subject of a separate paper. Ventilatory function and dust concentrations in the

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Table 1 Number of people sampled and total number of samples in each mill

Mill	Total seen	People sampled (n)	People sampled twice (n)	Total samples (n)
1	261	39	35	74
2	144	23	NIL	23
3	32	12	12	24
4	99	21	19	40
5	64	21	18	39
6	29	13	NIL	13
7	71	15	NIL	15
8	34	11	11	22
9	30	16	10	26
10	93	20	NIL	20
11	50	12	12	24
12	79	19	NIL	19
13	19	11	NIL	11
14	19	8	NIL	8
15	39	20	20	40
16	232	41	32	73
Total	1295	302	169	471

Table 2 Mean (SD) dust concentrations in the mills (mg/m³)

Mill	Workers sampled (n)	Total dust (mg/m ³)	Total dust less fly (manually removed) (mg/m ³)
1	39	2.38 (1.44)	1.42 (0.94)
2	23	2.60 (1.96)	2.27 (2.0)
3	12	2.49 (1.72)	1.82 (0.93)
4	21	2.24 (1.13)	1.98 (0.93)
5	21	1.52 (1.09)	1.29 (0.79)
6	13	1.10 (0.52)	1.04 (0.50)
7	15	1.26 (1.04)	1.08 (0.90)
8	11	1.03 (0.29)	0.73 (0.20)
9	16	2.59 (1.17)	2.11 (0.77)
10	20	0.62 (0.57)	0.58 (0.55)
11	12	2.77 (0.99)	2.04 (0.46)
12	19	2.28 (1.23)	1.94 (1.10)
13	11	2.08 (1.18)	1.82 (0.96)
14	8	6.67 (3.32)	5.48 (2.95)
15	20	2.69 (1.60)	2.41 (1.56)
16	41	1.24 (0.62)	1.00 (0.62)

personal breathing zone and their relation to symptoms are presented in this paper.

Methods

The study was cross sectional in design and conducted in the Lancashire area. Sixteen mills were surveyed. We did not have previous knowledge of working conditions in these mills. Every worker participating in the study was given a modified Medical Research Council (MRC), UK, respiratory symptom questionnaire. It is based on the original MRC respiratory questionnaire³⁰ with additional questions to identify byssinosis and other work related respiratory symptoms, and was validated for the study. If a symptom improved when away from work, it was said to be work related. Personal factors recorded were age, height, sex, and ethnic origin. Smoking data included questions to allow for a calculation of pack-years for ex-smokers or current smokers and years since stopped smoking for current non-smokers. Grade of cotton being processed (coarse, medium, or fine), type of preparation processes, and size (starch or polyvinylalcohol) were recorded. The type of loom (shuttle, air jet, projectile, rapier, or water jet) and its speed (in picks per minute) were also documented. Occupational histories included duration of all current and past textile experience. Four work-room and six occupational groups were identified from over 50 different occupations. These identified groups large enough to be included in statistical analysis, and which had similar type and extent of exposure in each mill.

LUNG FUNCTION TESTS

Measurement of timed vital capacity has been extensively used in the assessment of textile workers. The FEV₁ has good reproducibility,³¹ and is easily applied in a field setting. Changes in the maximal midexpiratory flow have been shown in cotton operatives by many workers.^{16 19 32} It has been suggested that indices based on the maximum expiratory flow volume curve are better than FEV₁, when studying ventilatory function of cotton workers, as the cotton dust reaction starts in peripheral airways. The reproducibility of forced expiratory flows, however, is only moderate.³³ Hence we measured FEV₁ and forced vital

capacity (FVC) in our study population. Because of the size of the workforce studied, it was not possible to perform spirometry across the shift, or measure ventilatory function at the same time of the day or on the same day of the working week. Every attempt was made to measure ventilatory function in the early part of the shift. The same Vitalograph-S model spirometer was used throughout the study. Before a visit to a mill the spirometer was calibrated with a precision 1 l syringe. Upon arrival in the mill, the instrument was left unused for 2 hours. A record of room temperature was kept. The forced expiratory manoeuvre was explained to the worker. Usually the subject required two or three practice measurements while any errors were corrected. The operative was encouraged to exhale for as long as he or she could. A nose clip was used only if the technique was unsatisfactory. Care was taken to avoid the Valsalva manoeuvre, obstruction by tongue, cough, or early termination. The acceptability of the manoeuvre was determined by satisfactory start and end of test criteria and a minimum exhalation time of 6 seconds. Three forced expiratory manoeuvres within 5% of each other were obtained in the standing position. The greatest values for FEV₁ and FVC were read off the scale at atmospheric temperature and pressure at saturation (ATPS), regardless of whether or not they occurred on the same curve. These values were later corrected for temperature.

For white workers, predicted spirometric values were derived from the summary equation of reference values.³⁴ To calculate predicted lung function variables for Asians, correction factors were used as suggested by Cotes³⁵—that is, for Asian men 0.7 l and 0.45 l were subtracted from the predicted FVC and FEV₁ of age and height matched white men; for Asian women the corresponding figures were 0.6 l and 0.4 l. The variables (FEV₁, FVC) were then stored as the percentage of predicted values.

DUST SAMPLING

Personal breathing zone dust was measured with the sampler developed by the Institute of Occupational Medicine, Edinburgh (IOM).³⁶ Its performance is close to inspirability over a

Table 3 Mean (SD) dust concentrations by present workroom and occupation

	Total dust (mg/m ³)	Total dust less fly (manually removed) (mg/m ³)
Occupation:		
Weaving I	1.82 (1.00)	1.46 (0.78)
Weaving II	1.91 (1.63)	1.79 (1.54)
Cloth inspection	1.74 (1.95)	1.37 (1.43)
Weaving III	1.96 (1.59)	1.64 (1.26)
Preparation	1.69 (1.60)	1.23 (1.33)
Sewing room	2.58 (1.75)	1.79 (1.59)
Workroom:		
Weaving	1.86 (1.33)	1.57 (1.12)
Preparation	1.75 (1.60)	1.27 (1.35)
Sewing	2.52 (1.67)	1.78 (1.59)
Cloth inspection	1.90 (2.12)	1.38 (1.42)

Weaving I=those working directly on looms; weaving II=those in the proximal vicinity of looms; weaving III=those exposed to high dust levels while employed in the weaving shed.

wide range of particle size and wind speed. Whatman GF/A microglass fibre filters were mounted in the cassettes inside the sampling head. The cassettes were weighed before the sampling exercise on a single pan microbalance (Sartorius) having a verified precision better than ± 0.01 mg.³⁷ The sampling heads were then transported to the mill. In the mill, the sampling heads were pinned onto the lapels of operatives, secured safely, and connected to Casella pumps (worn on the waist) for the duration of the shift. Flow rate (2 l/min) was checked periodically with a flow meter. Pumps were switched off during breaks. Time of active sampler use was carefully recorded. On return from the mill, the cassettes inside the sampling heads were reweighed to obtain the weight change. A few sampling heads (blanks) were not opened in the mill, but treated like the active sampling heads for weighing before and after the visit. Mean change in the weight of blanks was called the correction factor. If positive, it was subtracted from (if the correction factor was negative, it was added to) the weight change of cassettes used for sampling to obtain the corrected weight change. The level thus measured was termed total inhalable dust in the personal breathing zone of the operative (pd1). In a study by Cinkotai *et al*¹³ good correlation was reported between symptoms and dust concentrations in the personal breathing zone (measured by a sampling head with a 2 mm wire gauze mesh mounted on it to exclude larger particles or fly). The IOM sampler does not have wire mesh mounted on it. Hence, another dust fraction called "total dust less fly" (pd2) was measured. After weighing after the visit, to calculate pd1 the "fluff" or "fly" was

Table 5 Work related symptoms associated with high dust concentrations (univariate analysis)

Factor	t Value	p Value
Total dust (pd1):		
Persistent cough	2.36	0.019
Total dust less fly (pd2):		
Ocular symptoms	-1.99	0.05
Persistent cough	2.24	0.025

Table 6 Mean (SD) values of ventilatory function for each mill

Mill	FEV ₁ (% predicted)	FVC (% predicted)
1	86.43 (25.67)	86.28 (24.48)
2	91.56 (22.70)	96.49 (22.70)
3	97.01 (13.74)	101.17 (10.16)
4	91.89 (23.73)	98.28 (25.39)
5	99.25 (17.15)	104.84 (15.40)
6	97.39 (17.44)	100.77 (17.00)
7	94.79 (20.62)	99.78 (21.56)
8	94.29 (27.80)	102.07 (26.47)
9	91.48 (21.60)	98.16 (16.79)
10	98.75 (19.14)	101.94 (19.10)
11	97.07 (14.54)	101.78 (13.31)
12	93.42 (25.48)	98.75 (25.50)
13	90.89 (19.46)	101.39 (17.89)
14	91.25 (15.94)	95.24 (15.63)
15	89.45 (26.83)	96.53 (27.28)
16	93.47 (23.32)	99.46 (22.57)

picked off with a pair of forceps and the cassette reweighed. The pd2 was calculated from this reading of the weight after the visit. This method, although rather crude, was performed to determine whether pd2 correlated better with symptoms.

The aim of the dust sampling exercise was to sample 20%–25% of the workers across the occupational groups encountered. Within a group, the required number of workers were chosen randomly. If a worker refused, another one from the same occupational category was asked to participate in dust sampling. The aim was to sample each worker on two separate occasions. On the second visit, if the same worker was not available, another one performing the same task was requested to wear the sampling equipment. The mean dust concentrations (pd1 and pd2) for each occupational group in a mill were obtained. This average value for each occupational group was ascribed to all members of the same occupation not undergoing sampling in the same mill. All occupations did not have the same number of workers, all occupations were not encountered in every mill, and all mills did not agree to two dust sampling visits. Hence, there was variation in the proportion of operatives sampled in each occupational group.

STATISTICAL ANALYSIS

Data about lung function tests and dust concentrations were first stored in a database (dbase III plus), along with information about personal factors, environmental factors, and symptoms. Further analysis was carried out with the SPSS and BMDP programmes. Factors most likely to be associated with each symptom, lung function, and dust concentrations were identified. Forward step multiple regression analysis was carried out to identify factors associated with impairment in FEV₁ and FVC. When submitting variables for

Table 4 Factors associated with high dust concentrations (univariate analysis)

Factor	t Value	p Value
Total dust:		
Cotton rather than man made fibre	-7.5	0.001
Work in sewing room	ANOVA	0.05
Work with medium cotton grade	ANOVA	0.05
Work with starch size	ANOVA	0.05
Work with looms other than waterjet looms	ANOVA	0.05
Total dust with fly manually removed:		
Cotton rather than man made fibre	-4.3	0.001
Work in sewing room	ANOVA	0.05
Work with medium cotton grade	ANOVA	0.05
Work with starch size	ANOVA	0.05
Work with looms other than waterjet looms	ANOVA	0.05

Table 7 Factors associated with reduced lung function (univariate analysis)

Factor	t Value	p Value
FEV ₁ (% predicted):		
Present smoker	-2.33	0.02
Cotton rather than man made fibre	-2.2	0.03
Work in preparation room	ANOVA	0.05
Work with starch size	ANOVA	0.05
Asian ethnicity	2.31	0.02
Male sex	-1.24	NS
FVC (% predicted):		
Cotton rather than man made fibre	-2.4	0.016
Work in preparation room	ANOVA	0.05
Work with starch size	ANOVA	0.05
Medium grade cotton	ANOVA	0.05
Asian ethnicity	2.2	0.03
Male sex	-1.59	NS

Table 8 Work related symptoms associated with reduced lung function (univariate analysis)

Factor	t Value	p Value
FEV ₁ (% predicted):		
Chronic phlegm production	-3.34	0.001
Non-specific chest tightness	-2.66	0.01
Nasal symptoms	2.8	0.005
Shortness of breath	-4.26	<0.0001
Persistent cough	-2.43	0.019
Wheezing	-4.05	<0.0001
FVC (% predicted):		
Non-specific chest tightness	-2.09	0.04
Nasal symptoms	2.14	0.033
Shortness of breath	-2.96	0.006
Persistent cough	-2.38	0.021
Wheezing	-3.35	0.001

univariate and multivariate analyses, log normally distributed data were log transformed.

Results

Of the 1295 workers interviewed with a questionnaire, 302 participated in dust sampling. Seven mills (454 workers) did not agree to a second dust sampling exercise. Hence, only 169 of the 302 workers could be sampled twice. This gave a total of 471 dust samples (weaving shed 179, preparation 51, sewing room 35, cloth inspection 37). The number of workers sampled in each mill are given in table 1. The percentage of workers sampled in each workroom were: weaving 25.3%, preparation 26.7%, sewing 13.4%, and cloth inspection 30.3%. Table 2 lists the mean dust concentrations in each mill. Dust concentrations in the workrooms and occupations are shown in table 3. The highest dust concentrations were encountered in operatives of the sewing room. Dust concentrations in workers employed in the rest of the workrooms were very similar to each other. Factors associated with total inhalable dust (univariate analysis) are listed in table

Table 9 Independent predictors of reduced lung function (multivariate analysis)

Factor	B value	SEM	p Value
FEV ₁ :			
Cumulative smoking	-8.3E-4	1.30E-4	<0.0001
Asian ethnicity	-8.3	1.90	<0.0001
Age	-0.2	0.04	<0.0001
Male	4.9	1.09	<0.0001
Not working in the weaving shed	-3.3	1.07	0.0023
Total dust (pd1)	-1.4	0.70	0.0412
FVC:			
Asian ethnicity	-8.1	1.81	<0.0001
Age	-0.2	0.05	<0.0001
Male	5.96	1.05	<0.0001
Not working in the weaving shed	-5.3	1.05	<0.0001
Total dust (pd1)	-1.6	0.68	0.0195

4. These factors are similar for pd1 and pd2. Significantly higher dust concentrations were generated when cotton rather than man made fibre was being used, medium grade cotton was being woven, and when starch size was used. The lowest concentrations of dust were generated by water jet looms (mean pd1 0.27 mg/m³, pd2 0.23 mg/m³). Next dusty were air jet looms (mean pd1 1.49 mg/m³, pd2 1.13 mg/m³). They were significantly less dusty than the other loom types. The two dust fractions correlated well with each other ($r=0.94$, $p<0.0001$). No respiratory symptoms except work related persistent cough were associated with high concentrations of dust (pd1, pd1). Work related ocular symptoms were associated with lower concentrations of dust (table 5).

Altogether, 1295 operatives completed the questionnaire, and 33 were unable to comply with American Thoracic Society guidelines.³⁸ Hence ventilatory function test results of 1262 workers are presented. Mean values by mill are listed in table 6. Univariate analysis of factors associated with reduced lung function are given in table 7. Both FEV₁ and FVC were significantly reduced in smokers, those handling predominantly cotton rather than man made fibre, starch size, and employees in the preparation room. Percentage predicted FEV₁ and FVC were lower in Asians than their white counterparts. The presence of work related chest symptoms was associated with reduced FEV₁ and FVC (table 8). For work related nasal symptoms, this was not the case. On multiple regression analysis (table 9), cumulative smoking emerged as the strongest predictor of a reduced FEV₁. Other factors predicting a reduction of this variable were greater age, male sex, and Asian ethnicity. Higher concentrations of total dust in the personal breathing zone predicted reduced FEV₁. A low FEV₁ was also associated with employment in workrooms other than weaving. Smoking habit was not an independent predictor of reduced FVC. Other predictors for this variable were similar to those for FEV₁.

Discussion

LUNG FUNCTION

A large body of data suggests that cotton operatives are susceptible to acute^{8 39} and chronic respiratory disability.^{7 14 40} An accelerated decline in lung function is also found in asymptomatic cotton workers^{11 17} and in ex-cotton workers.⁴¹ However, there is a paucity of lung function data for weavers. Because of the study design, changes in ventilatory function across the shift could not be assessed in our study. However, measurements were predominantly made at the beginning of the shift to minimise variation across the shift in the results.

White workers had higher values of FEV₁ and FVC compared with Asians. Ethnicity emerged as an independent factor on carrying out regression for FEV₁ and FVC. In their study of Lancashire spinners, however, Cinkotai *et al*¹³ and Fishwick *et al*¹⁸ described lower values of ventilatory function in the white workforce compared with Asians. They attrib-

uted this to a shorter duration of exposure to the cotton industry in the case of Asians. However, these studies used a different correction factor for Asian people. The use of a correction factor to calculate predicted ventilatory function values in Asians was essential but may not be accurate. It has been suggested that predicted values for normal ventilatory function should ideally be computed from healthy members (unexposed) of the same community. This was not possible in this study as the number of Asians was small and all were exposed—that is, there were no controls. Local geographic and social factors influencing the Asian population may affect the suitability of a given correction factor. Thus, these findings cannot be accepted as indicating an increased susceptibility of Asians.

Male sex and increasing age emerged as significant independent predictors of reduced FEV_1 , despite standard correction attempted for both of them when calculating predicted values. The effect of age may also highlight the inadequacy of the predicted values currently in use, or may be an effect of cumulative occupational exposure.

The pattern of sex distribution across various occupations and workrooms is quite distinctive. Men usually carry out most of the work with high exposure to dust—such as loom maintenance, loom sweeping, etc. Also, with the exception of beaming and creeling, the preparation department is almost exclusively manned by men. Employees of this workroom had the lowest values for lung function. Interestingly, on regression analysis, not working in the weaving shed was associated with lower values of FEV_1 and FVC. The preparation department is the next most dusty workroom after the spinning room.

Those exposed to starch size had significantly reduced FEV_1 compared with polyvinyl alcohol size. The starch size consists of organic matter and may be more bioactive. However, size did not emerge as an independent factor on regression. Contrasting with the findings of Roach²² and Mekky⁹ we did not find exposure to a particular grade of cotton to be associated with reduced ventilatory function. Overall, those exposed to predominantly cotton fibre had significantly lower FEV_1 ($p=0.027$) and FVC ($p=0.016$) compared with those exposed to fibres other than cotton. Accelerated loss of lung function has been shown in cotton operatives (compared with man made fibre operatives) by other research workers.^{10–14} In the present study (which documented predictors of FEV_1 , rather than a decline in FEV_1), work with cotton (rather than man made fibre) did not emerge as an independent predictor for FEV_1 .

The relative contribution of smoking and employment in the textile industry in the cause of respiratory disability is a subject of much debate. It has been suggested that morbidity among textile workers is due to smoking. However, several investigators have established that the textile environment also causes disability and when smoking is present, the two are additive.^{17, 41–42} In the present study, smoking

has, as expected, emerged as an independent predictor of reduced FEV_1 , but not FVC. However, equally important is the finding that two variables of the work environment (total inhalable dust and work not in the weaving shed) are also able to predict a reduced FEV_1 , independent of smoking. Equally interesting is the finding of a relation between total inhalable dust concentrations in the personal breathing zone and reduced FVC. The relation was stronger for FVC than FEV_1 . Such a relation has also been described for man made fibre.⁴³ Most weaving units process a mixture of cotton and man made fibre. Whether the reduced values of FVC are due to cotton dust or reflect use of man made fibre, size, or some other factor in the environment of the weaving room cannot be concluded from available data.

DUST CONCENTRATIONS

Workers participating in the study tolerated the sampling exercise very well. Every attempt was made to carry out dust sampling on a representative sample of people from each occupation and workroom in the mills, so that results of dust sampling in a mill could be extrapolated to the workers of the same occupation or workroom in that mill. However, the potential for bias remains due to refusal of some workers to wear the sampling equipment and due to some workers being sampled once rather than twice.

The samplers measuring total inhalable dust (pd1) in the personal breathing zone of operatives did not have a wire mesh excluding larger particles. Previous studies had measured dust concentrations by prefiltering air through 2 mm wire mesh. Hence, another variable was derived, by manually lifting the fluff off the filter paper (pd2). However, manual removal of these large textile fibres confounds the issue, as it also leads to loss of finer dust trapped therein. Also, this technique depends on the observer, and therefore is less accurate. Mean (SD) pd1 concentration was 1.98 (1.55) mg/m^3 . Mean (SD) pd2 concentration was 1.55 (1.30) mg/m^3 . The correlation between the two dust fractions was good ($r=0.94$, $p<0.0001$), but only pd1 was a predictor of reduced FEV_1 and FVC on regression analysis. Presumably, once pd1 had emerged as an independent predictor of loss of ventilatory function, pd2 was rendered less beneficial.

Correlation between FEV_1 and dust concentrations (time weighted, total dust less fly) was carried out by Fox *et al.*¹¹ The correlation coefficient for non-smokers was -0.08 and for smokers -0.13. Although we were dealing with a different population, and not measuring dust concentrations over time, we had very similar values of the correlation coefficient between dust concentrations and ventilatory function.

When cotton rather than man made fibre was being processed, pd1 and pd2 concentrations were higher. Generally, coarse cotton produces the highest dust concentrations.¹³ However, we found that pd1 and pd2 concentrations were higher for medium rather than coarse cotton. The pd1 and pd2 produced with starch size were higher than those for polyvinyl

alcohol or a combination of starch and polyvinyl alcohol size. This could, in part, explain the poor dose-response relation found for weaving sheds as most weaving room dust consists of size and not cotton dust. Also, the application of size reduces fragmentation and wear of the yarn, reducing the contribution of cotton fibres in weaving room dust. Studies showing a dose-response relation between dust concentrations and symptoms¹³ have had to exclude the weaving workforce, as inclusion of it led to annulment of the dose-response relation (Cinkotai FF, personal communication). Quite predictably, although we found a relation between dust concentrations and loss of ventilatory function, we were unable to show a relation between symptoms and dust concentrations. This is contrary to findings of other studies^{11 13 18} in which such a relation was documented. However, these studies have been conducted on spinners or cardroom workers. The only symptom of the lower respiratory tract for which a dose-response relation was shown was persistent cough. However, even for this symptom, the strongest predictors were smoking ($p=0.0003$), female sex ($p=0.0085$), fine grade cotton ($p=0.0268$), then pd_2 ($p=0.0246$). Persistent cough is probably a heterogeneous symptom. Some cases could be forerunners of chronic bronchitis, and hence related to smoking. Other cases could be due to an irritant effect. Other irritant symptoms (ocular or eye irritation) are also more common in women. Workers exposed to fine grade cotton also complained of more ocular or nasal irritation.

Perhaps exposure to dust in weaving is sufficiently irritant that continued exposure over a long period can cause reduced ventilatory function. However, compared with cotton spinning, it is not sufficiently harmful to induce acute symptoms.

In conclusion, therefore, this large study of weavers shows that the highest dust concentrations are in the sewing room. High concentrations are more likely to be associated with workroom factors. With the exception of work related persistent cough, total inhalable dust in the personal breathing zone is not related to lower respiratory symptoms. It is, however, an independent predictor of reduced FEV_1 . Other independent factors predicting a reduced FEV_1 are cumulative smoking, male sex, Asian ethnicity, and work in areas other than the weaving shed. Thus, reduced FEV_1 is predicted by smoking, and personal and environmental factors. A reduced FVC is predicted by the same factors (except cumulative smoking).

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- 1 Cited by Harris RT, *et al.* Byssinosis and respiratory diseases of cotton mill workers. *J Occup Med* 1974;14:199-206.
- 2 Mareska K, Heyman J. Enquete sur le travail et la condition et physique et morale des ouvriers employes dans les manufactures de coton, a Gand. *Ann Soc Med Gand* 1845;16:5. Translation cited by Bouhuys A. *Lung* 1976;154:3-16.
- 3 Kay JP. Observations and experiments concerning molecular irritation of lungs as one source of tubercular consumption; and on spinner's phthisis. *North England Medical Surgical Journal* 1831;1:348-63.
- 4 Arlidge JT. *The hygiene diseases and mortality of occupations*. London: Percival, 1892.
- 5 Collis EL. *Factories and workshops: annual report for 1908*. London: HMSO, 1908.
- 6 Prausnitz C. *Investigation on respiratory dust disease in operatives in the cotton industry*. Privy council, Medical Research Council. London: HMSO, 1936. (Special report series No 212.)
- 7 Schilling RSF, Hughes JPW, Dingwal-Fordyce I, *et al.* An epidemiological study of byssinosis among Lancashire cotton workers. *Br J Ind Med* 1955;12:217-26.
- 8 McKerrrow CB, McDermott M, Gilson JC, *et al.* Respiratory function during the day in cotton workers: a study in byssinosis. *Br J Ind Med* 1958;15:75-83.
- 9 Mekky S, Roach SA, Schilling RSF. Byssinosis among winders in the cotton industry. *Br J Ind Med* 1967;24:123-32.
- 10 Fox AJ, Tomblinson JBL, Watt A, *et al.* A survey of respiratory disease in cotton operatives. Part 1. Symptoms and ventilation test results. *Br J Ind Med* 1973;30:42-7.
- 11 Fox AJ, Tomblinson JBL, Watt A, *et al.* A survey of respiratory disease in cotton operatives. Part 2. Symptoms, dust estimation and the effect of smoking habit. *Br J Ind Med* 1973;30:48-53.
- 12 Cinkotai FF, Rigby A, Pickering CAC, *et al.* Recent trends in the prevalence of byssinotic symptoms in the Lancashire textile industry. *Br J Ind Med* 1988;45:782-9.
- 13 Cinkotai FF, Seaborn D, Pickering CAC, *et al.* Airborne dust in the personal breathing zone and the prevalence of byssinotic symptoms in the Lancashire textile industry. *Ann Occup Hyg* 1988;32:103-13.
- 14 Berry G, McKerrrow CB, Molyneux MKB, *et al.* A study of acute and chronic change in ventilatory capacity of workers in Lancashire cotton mills. *Br J Ind Med* 1973;30:25-36.
- 15 Imbus H, Suh MW. Byssinosis: a study of 10 133 textile workers. *Arch Environ Health* 1973;26:183-91.
- 16 Zuskin E, Valic F, Butkovic D, *et al.* Lung function in textile workers. *Br J Ind Med* 1979;32:283-8.
- 17 Beck GJ, Schacter EN, Maunder LR. The relationship of respiratory symptoms and lung function loss in cotton textile workers. *Am Rev Respir Dis* 1984;43:580-6.
- 18 Fishwick D, Fletcher AM, Pickering CAC, *et al.* Respiratory symptoms and dust exposure in Lancashire cotton and manmade mill operatives. *Am J Respir Crit Care Med* 1994;150:441-7.
- 19 Field GB, Owen P. Respiratory function in an Australian cotton mill. *Bulletin European de Physiopathologie Respiratoire* 1979;15:455-68.
- 20 Schacter EN, Kapp MC, Maunder LR, *et al.* Smoking and cotton dust effects in cotton textile workers: an analysis of the shape of the maximum expiratory flow volume curve. *Environ Health Perspect* 1986;66:145-8.
- 21 Schacter EN, Kapp MC, Beck, GJ, *et al.* Smoking and cotton dust effects in cotton textile workers. *Chest* 1989;95:997-1003.
- 22 Roach SA, Schilling RSF. A clinical and environmental study of byssinosis in the Lancashire cotton industry. *Br J Ind Med* 1960;17:1-9.
- 23 Merchant JA, Lumsden JC, Kilburn KH, *et al.* Dose response studies in cotton textile workers. *J Occup Med* 1973;15:222-30.
- 24 Niven R Mcl, Fishwick D, Pickering CAC, *et al.* A comparison of two dust sampling techniques. *Proceedings of the 15th Beltwide Cotton Dust Research Conference, 1991*. Memphis, TN: National Cotton Council, 1991.
- 25 Corn M. Methods to assess airborne concentration of cotton dust. *Am J Ind Med* 1987;12:677-86.
- 26 Bouhuys A. Byssinosis in a cotton weaving mill. *Arch Environ Health* 1963;6:465-8.
- 27 Shivapuri HN, Varma MS. Byssinosis. *J Indian Med Assoc* 1957;29:322-4.
- 28 Schrag PE, Gullett AD. Byssinosis in cotton textile mills. *Am Rev Respir Dis* 1970;101:497-503.
- 29 Gupta S, Gupta BK. A study of byssinosis and associated respiratory disorders in cotton mill workers. *Indian J Chest Dis Allied Sci* 1986;28:183-8.
- 30 Committee on Research into Chronic Bronchitis. *Questionnaire on respiratory symptoms*. London: Medical Research Council, 1966.
- 31 Quanjer PhH, Tammeling GJ, Cotes JE, *et al.* Lung volumes and forced expiratory flows. Report of the working party. Standardization of lung function tests. Official statement of the European Respiratory Society. *Eur Respir J* 1993;6(suppl 16):5-40.
- 32 Merchant JA, Halprin G, Hudson AR, *et al.* Responses to cotton dust. *Arch Environ Health* 1975;30:222-9.
- 33 McDonald JB, Cole TJ. The flow volume loop: reproducibility of air and helium-based tests in normal subjects. *Thorax* 1980;35:64-9.
- 34 Quanjer PhH, Dalhuijsen A, Van Zomeren BC. Summary equations of reference values. *Bulletin European de Physiopathologie Respiratoire* 1983;19(suppl 5):45-51.
- 35 Cotes JE. *Lung function, assessment and application in medicine*, 4th ed. Oxford: Blackwell, 1979:349.
- 36 Mark D, Vincent JH. A new personal sampler for airborne total dust in workplace. *Ann Occup Hyg* 1986;30:89-102.
- 37 Vaughan NP, Milligan BD, Ogden TL. Filter weighing reproducibility and the gravimetric detection limit. *Ann Occup Hyg* 1989;33:331-7.
- 38 American Thoracic Society, statement. Snowbird workshop on standardisation of spirometry. *Am Rev Respir Dis* 1979;119:831-8.
- 39 Walford J, Lammers B, Schilling RSF, *et al.* Diurnal variation in ventilatory capacity: an epidemiological study of cotton and other factory workers employed on shift work. *Br J Ind Med* 1966;23:142-8.

- 40 Kamat SF, Kamat GR, Salpekar VY, et al. Distinguishing byssinosis from chronic obstructive pulmonary disease; results of a prospective five year study of cotton mill workers in India. *Am Rev Respir Dis* 1991;124:31-40.
- 41 Elwood PC, Sweetnam PM, Bevan C, et al. Respiratory disability in ex-cotton workers. *Br J Ind Med* 1986;43:580-6.
- 42 Niven R Mcl, Fletcher AM, Pickering CAC, et al. Chronic bronchitis in textile workers. *Thorax* 1997;52:22-7.
- 43 Glindmeyer HW, Lefante RN, Jones RN, et al. Exposure-related declines in the lung function of cotton textile workers. *Am Rev Respir Dis* 1991;144:675-83.

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All manuscripts submitted to *Occup Environ Med* should conform to the uniform requirements for manuscripts submitted to biomedical journals (known as the Vancouver style.)

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References should be numbered consecutively in the order in which they are first mentioned in the text by Arabic numerals on the line in square brackets on each occasion the reference is cited (Manson[1] confirmed other reports[2][3][4][5]). In future references to papers submitted to *Occup Environ Med* should include: the names of all

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Examples of common forms of references are:

- 1 International Committee of Medical Journal Editors. Uniform requirements for manuscripts submitted to biomedical journals. *JAMA* 1993;269:2282-6.
- 2 Soter NA, Wasserman SI, Austen KF. Cold urticaria: release into the circulation of histamine and eosinophil chemotactic factor of anaphylaxis during cold challenge. *N Engl J Med* 1976;294:687-90.
- 3 Weinstein L, Swartz MN. Pathogenic properties of invading micro-organisms. In: Sodeman WA Jr, Sodeman WA, eds. *Pathologic physiology, mechanisms of disease*. Philadelphia: W B Saunders, 1974:457-72.