Byssinosis in Guangzhou, China

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Abstract
***Objectives*—To study the prevalence of byssinosis and other respiratory abnormalities in workers exposed to cotton dust in Guangzhou in two factories that processed purely cotton.**
***Methods*—All the 1320 workers exposed were included. The controls were 1306 workers with no history of occupational dust exposure. Total dust and inhalable dust were measured by Chinese total dust sampler and American vertical elutriator respectively. A World Health Organisation questionnaire was used. Forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were measured by a Vitalograph spirometer.**
***Results*—The median inhalable dust concentrations ranged from 0·41 to 1·51 mg/m^3 and median total dust concentrations from 3·04 to 12·32 mg/m.^{3} The prevalence of respiratory abnormalities in the cotton workers were (*a*) typical Monday symptoms 9·0%; (*b*) FEV_1 fall by ⩾ 5% after a shift 16·8%; (*c*) FEV_1 fall by ⩾ 10% after a shift 4·2%; (*d*) FEV_1 < 80% predicted 6·1%; (*e*) FEV_1/FVC < 75% 4·0%; (*f*) cough or phlegm 18·2%; (*g*) chronic bronchitis 10·9%; and (*h*) byssinosis, defined by (a) plus (b) 1·7%. With the exception of (*d*), most of the prevalences increased with increasing age, duration of exposure, and cumulative inhalable dust exposure. No increasing trends of respiratory abnormalities were found for current total dust, inhalable dust, and cumulative total dust concentrations. Compared with controls, after adjustment for sex and smoking, with the exception of (*d*), all the pooled relative risks of respiratory abnormalities were raised for cotton exposure.**
***Conclusions*—It is concluded that cumulative inhalable cotton is likely to be the cause of byssinotic symptoms, acute lung function decrements, cough, or phlegm, and chronic bronchitis.**

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Although the prevalence of byssinotic symptoms has been declining in developed countries, a review by Parikh shows that the prevalence in developing countries is still high.[1] Varying effects can occur after exposure to cotton dust.[2] There are no universally accepted diagnostic criteria for byssinosis. The methods of cotton dust sampling and the allowable dust concentrations also vary in different countries.

China is one of the biggest countries for cotton production and consumption. In 1986, byssinosis was declared in law as an occupational disease. The exposure limit for cotton dust is based on total dust and is 3 mg/m.[3] In Guangzhou the cotton textile industry is important. In a 1969 study in a hemp or flax bag factory only total dust was measured and the concentrations ranged from 4 mg/m^3 to 43 mg/m^3; no case of byssinosis was reported (report not published). In 1985, a study of a cotton factory showed that the inhalable dust ranged from 0·2 mg/m^3 to 9·6 mg/m^3 and the prevalence of byssinosis was 9·9%.[3] Because of the problems in study design, methods, and small sample size, the results of the two studies were very different and could not represent the situation in Guangzhou.

The objectives of this study were to measure the dust concentrations in cotton spinning factories, to measure the prevalence of byssinosis and other respiratory abnormalities (including lung function), and to study the relation between respiratory abnormalities and exposures to cotton dust.

Materials and methods

FACTORIES AND SUBJECTS

In 1989, there were two factories in Guangzhou that processed purely cotton fibres. About 60% of the raw cotton was from China and the cotton bolls were hand picked. The rest was imported mainly from the United States, Pakistan, and India. The grades of cotton used were therefore variable. The products were mainly cotton yarn and jean. All the 1320 workers who were exposed only to cotton dust in these two factories were included. This was achieved by special effort in tracing the few absentees. Other factories and workers in Guangzhou who were exposed to flax, hemp, or synthetic fibres were excluded.

The controls were 1306 workers who assembled machinery, storage workers from other industries, and teachers (mostly women, 120 of them were included) from a middle school. They were selected because they had similar work and socioeconomic conditions and they had no occupational history of exposure to dusts or other toxic substances. The teachers were included to increase the proportion of women in the controls.

MEASUREMENT OF DUST

Inhalable dusts were sampled by American vertical elutriator (model GMW-4000) and American filters. Total dusts were sampled by Chinese total dust sampler (model FC-2) and Chinese filters. Calibration was carried out before measurements. The samplers were placed 155–160 cm above the floor to be at a suitable level for the average height of the subjects. A specific work site was sampled between two and seven times according to standard procedures. Because a worker could have worked at different locations with different dust concentrations, cumulative dust exposure is calculated by:

$$\sum_{i=1}^{k} Yi \times Ci \quad \text{where}$$

Yi = number of years of exposure at location i, Ci = median dust concentration at location i, and i = location 1,2, . . . *k*.

Because of lack of data of past dust concentrations, the median dust concentration of the current location was used to represent past concentration.

Analysis of free silica content was carried out for the dusts sampled.

QUESTIONNAIRE AND MEDICAL EXAMINATION

The World Health Organisation (WHO) questionnaire for byssinosis translated into Cantonese (and with slight modification on the section on occupational history) was used for respiratory symptoms.[4] The accuracy of the translation was checked by an epidemiologist fluent in English and Cantonese. All subjects, on the first working day after a break of 24 to 48 hours had lung function tests (before and after the shifts) with a Vitalograph spirometer and standard procedures of calibration and measurements were used (according to the American Thoracic Society). The forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were recorded at body temperature and pressure saturated with water vapour. The best values of three acceptable measurements of FEV_1 and FVC were used in the analysis.

The predicted FEV_1 was calculated by the formulas derived from Guangzhou normal values[5] as follows:

For women: FEV_1 predicted (l) $= -0{\cdot}753 - 0{\cdot}022$ age (y) $+ 0{\cdot}026$ height (cm)
For men: FEV_1 predicted (l) $= -1{\cdot}087 - 0{\cdot}029$ age (y) $+ 0{\cdot}033$ height (cm).

Table 1 General information and FEV_1 values of cotton workers and controls

	Cotton workers	*Controls*
Number examined	1320	1306
M (%)	25·7	31·0
F (%)	74·3	69·0**
Age (y)†	30·0 (8·0)	33·4 (8·8)***
Duration of work (y)†	10·2 (6·8)	13·5 (8·0)***
Height (cm)†	160·0 (6·4)	160·5 (6·8)
Smoking in men(%)	67·6	61·9
FEV_1, before shift (l)†	2·87 (0·56) } **	2·75 (0·57)
FEV_1 after shift (l)†	2·83 (0·57) }	2·75 (0·58)
Difference between FEV_1 before and after shift (l)†	−0·031 (0·16)	−0·005 (0·16)**

*P <0·05; **P <0·01; ***P <0·001; † values are mean (SD).

All subjects had their height measured without shoes and had a physical examination by physicians who paid special attention to respiratory and circulatory systems. A random sample of 602 cotton workers had chest *x* ray examinations.

All the members of the research team (including technicians for dust sampling and measurements, interviewers, physicians for lung function tests and physical examination) received training and a pilot test was carried out in another factory to standardise the methods before the main field work.

DATA ANALYSIS

All the data were coded, checked, and entered into the computer and then further checked before data analysis. The computer software used were SPSS-PC and Epi-info 5. The statistical procedures used included *t* test, χ^2, χ^2 test for trend, and relative risks (defined as the ratio of two prevalences) and 95% confidence intervals (95% CIs), and attributable risks (defined as the difference between two prevalences), were calculated by comparing cotton workers with controls. Pooled relative risk for stratified analysis was calculated by Mantel-Haenszel's method.[6]

SMOKING

A smoker was defined as one who smoked at least one cigarette a day for at least one year. There was only one woman in the control group who smoked and she was excluded. All women included were non-smokers. Because there were only a few ex-smokers, they were analysed as non-smokers.

DIAGNOSTIC CRITERIA FOR BYSSINOSIS, CHRONIC BRONCHITIS, AND CHRONIC OBSTRUCTIVE AIRWAY DISEASE

When a subject had chest tightness or shortness of breath mostly on the first day back at work, or on the first and other days of the working week, and after exclusion of causes due to circulatory or other respiratory diseases, he or she was considered to have typical Monday symptoms. This definition is based on the WHO definition of clinical manifestation of byssinotic symptoms of chest tightness or shortness of breath.[4] Byssinosis was diagnosed for cotton workers if they had typical Monday symptoms plus an FEV_1 fall of >5% after the shift. This definition was adopted because in China, as well as the presence of typical Monday symptoms, a fall in FEV_1 was required to diagnose byssinosis. Chronic bronchitis was defined as cough or phlegm for three months a year for at least two successive years. Chronic obstructive airways disease (COAD) was defined by an FEV_1/FVC ratio <75%.

Results

Table 1 shows that in the cotton workers there were more women than in the controls. The cotton workers were younger and had a shorter duration of work but were of the same height. The prevalence of smoking in the men

Table 2 Dust concentrations in cotton mills and control worksites

	Opening and blowing	*Carding*	*Drawing*	*Coarse spinning*	*Fine spinning and winding*	*Controls*
Inhalable dust (mg/m^3):						
Sites (n)	12	9	5	8	10	19
Range	0·35–1·09	0·57–2·75	0·41–1·21	0·29–1·26	0·15–0·86	0·14–0·51
Median	0·61	1·51	0·67	1·00	0·41	0·30
Mean	0·63	1·56	0·75	0·85	0·50	0·30
(SD)	(0·25)	(0·65)	(0·31)	(0·40)	(0·24)	(0·11)
Total dust (mg/m^3):						
Sites (n)	12	9	9	6	13	18
Range	0·45–4·88	2·91–12·35	1·31–13·80	8·69–15·28	2·52–13·81	0·20–0·76
Median	3·04	6·96	6·09	12·32	5·79	0·56
Mean	2·94	6·88	6·29	11·83	3·30	0·52
(SD)	(1·20)	(2·83)	(4·16)	(2·45)	(3·82)	(0·19)

Table 3 Percentage of prevalence of respiratory abnormalities in cotton workers by work processes

	Opening and blowing	*Carding*	*Drawing*	*Coarse spinning*	*Fine spinning and winding*	*Subsidiary workers*	*Management*
Workers (n)	92	107	130	35	530	323	100
Typical Monday symptoms (a)	9·8	14·0	8·5	8·6	10·4	6·5	5·0
FEV_1 fall >5% after shift (b)	22·8	21·5	16·9	11·4	15·5	18·6	10·0
FEV_1 fall >10% after shift	4·3	4·7	3·8	8·6	4·2	4·6	2·0
FEV_1 <80% predicted	10·9	5·6	3·8	8·6	5·8	6·5	5·0
FEV_1/FVE <75%, (COAD)	3·3	5·6	3·1	0	2·1	6·8	7·0
Cough or phlegm	28·3	26·2	21·5	8·6	13·8	19·5	18·0
Chronic bronchitis	20·7	10·3	13·2	2·9	9·2	10·9	11·0
Byssinosis (a + b)	3·3	3·7	2·3	2·9	0·9	2·2	0

was higher but the difference was not significant. The mean FEV_1 before a shift was not significantly different in the two groups. The drop in FEV_1 after a shift was significant only in the cotton workers.

Table 2 shows the dust concentrations of the work sites of the cotton factories and the controls. The median concentrations of inhalable dust of the cotton factories ranged from 0·41 mg/m^3 to 1·51 mg/m^3. The highest concentrations were found in the carding sites. The exposure limit of 0·2 mg/m^3 recommended by WHO was exceeded in all the work sites.[4] The median concentrations of total dust ranged from 3·04 mg/m^3 to 12·32 mg/m^3 and they were higher than the newly established maximum allowable concentration of 3 mg/m^3 for cotton (total) dust in China. The highest concentrations were found in coarse spinning sites. The free silica content in the cotton dust ranged from 0·15% to 4·8%. All the measurements were much lower at the worksites of the controls.

Table 3 shows the prevalence of respiratory abnormalities by work processes. The highest prevalence of typical Monday symptoms and byssinosis was found in the carding sites (14·0%). The opening and blowing sites had the highest prevalence of FEV_1 fall of >5% after a shift, FEV_1 <80% predicted, cough or phlegm, and chronic bronchitis. Table 4 shows a comparison between all cotton workers and controls. All the relative risks were greater than unity except for FEV_1 <80% predicted. Typical Monday symptoms were found in 119 cotton workers and in four women controls and the attributable risk was 97%. The attributable risk was the lowest for COAD (18%), which showed that exposure to cotton dust could only account for a small excess in the prevalence of COAD.

No fibrosis or nodules were seen on any chest *x* ray films in either group. There was no case of abnormalities of grade 1/0 or above according to the International Labour Office (ILO) classification (1980).

Table 5 shows that the prevalence of respiratory abnormalities significantly increased with increasing age, duration of work, and cumulative inhalable dust exposure, with the most notable exception of FEV_1 <80% predicted. For typical Monday symptoms, the linear trend was significant only for cumulative inhalable dust. Similar analysis was carried out for current total dust, inhalable dust, and cumulative total dust concentrations, but no linear trends were found (results not shown).

Table 6 shows the prevalence of respiratory problems by sex and by smoking. The pooled relative risks for cotton exposure were

Table 4 Prevalence, relative risks, and attributable risks of respiratory abnormalities in cotton workers and controls

	Cotton workers (%, n = 1320)	*Controls (%, n = 1306)*	*Relative risk (95% CI) cotton workers/controls*	*Attributable risk (%) cotton workers —controls/cotton workers*
Typical Monday symptoms (a)	9·0	0·3	30·0** (10·9–79·5)	97
FEV_1 fall >5% after shift (b)	16·8	11·9	1·4** (1·2–1·7)	29
FEV_1 fall >10% after shift	4·2	2·5	1·7* (1·1–2·7)	40
FEV_1 <80% predicted	6·1	8·7	0·7* (0·5–0·9)	–43
FEV_1/FVC <75% (COAD)	4·0	3·3	1·2 (0·8–1·8)	18
Cough or phlegm	18·2	8·4	2·2** (1·8–2·7)	54
Chronic bronchitis	10·9	5·3	2·1** (1·6–2·8)	51
Byssinosis (a + b)	1·7	0	∞ —	100

*P <0·05; ** P <0·001; missing data = three cotton workers.

Table 5 Prevalence of respiratory abnormalities by age, duration of exposure, and cumulative exposure to inhalable dust in cotton workers

(1) *Age (y) (n)* (2) *Exposed duration (y) (n)* (3) *Cumulative inhalable dust exposure, (mg.y/m³) (n)*		*<20 (52)* *<5 (350)* *<2 (286)*	*20–30 (688)* *5–10 (321)* *2–4 (431)*	*30–40 (420)* *10–15 (406)* *4–6 (261)*	*40–50 (137)* *15–20 (98)* *6– 8 (147)*	*≥ 50 (23)* *≥ 20 (144)* *≥ 8 (192)*	*Test for trend* χ^2	*P value*
Typical Monday symptoms (a) (%)	(1)	7·7	7·7	10·2	11·7	13·0	3·65	0·056
	(2)	8·0	7·5	11·8	8·2	7·6	0·31	0·578
	(3)	6·6	8·5	8·8	9·5	13·1	5·00	0·025
FEV_1 fall >5% after shift (b) (%)	(1)	11·5	14·2	19·0	23·4	26·1	11·23	0·001
	(2)	14·0	12·5	20·2	19·4	21·5	8·37	0·004
	(3)	13·6	15·1	16·1	20·4	23·6	9·90	0·002
FEV_1 fall >10% after shift (%)	(1)	3·8	3·1	5·0	7·3	8·7	6·41	0·011
	(2)	2·6	2·8	5·7	4·1	6·9	6·60	0·010
	(3)	1·4	4·9	3·4	7·5	5·2	5·13	0·024
FEV_1 <80% predicted (%)	(1)	9·6	5·4	6·2	6·6	17·4	1·12	0·291
	(2)	7·4	4·7	5·2	7·1	8·3	0·07	0·785
	(3)	7·3	5·3	6·1	5·4	6·8	0·03	0·875
FEV_1/FVC <75% (COAD) (%)	(1)	1·9	2·2	4·0	10·9	21·7	32·35	0·000
	(2)	2·3	2·8	2·2	4·1	16·0	31·65	0·000
	(3)	2·4	3·0	2·7	5·4	9·4	14·54	0·000
Cough or phlegm (%)	(1)	7·7	13·7	25·0	24·1	17·4	19·68	0·000
	(2)	8·6	16·5	21·2	33·7	26·4	39·98	0·000
	(3)	9·8	13·5	21·8	26·5	29·8	45·43	0·000
Chronic bronchitis (%)	(1)	1·9	6·6*	15·5	20·4	17·4	36·77	0·000
	(2)	3·7	7·5*	12·1†	25·4	22·2	57·39	0·000
	(3)	3·1	7·2*	15·7	14·4‡	21·5	49·57	0·000
Byssinosis (a + b) (%)	(1)	0	0·7	2·4	5·1	4·3	14·76	0·000
	(2)	0·9	0·3	3·0	3·1	2·8	6·34	0·012
	(3)	0·3	1·6	1·1	2·0	4·7	10·34	0·001

* Because of missing values, the denominators were 685, 319, 429 respectively; † the denominator was 405; ‡ the denominator was 146.

adjusted for sex and smoking. All the pooled relative risks were raised (greater than unity) for cotton exposures, with the exception of predicted FEV_1 <80%. Less cotton workers had FEV_1 below the predicted values than controls (mainly in men smokers and women).

In the cotton workers, women had a higher prevalence of typical Monday symptoms (10·4%) than men (smokers 5·2% and non-smokers 4·5%), but less COAD. In the control men, smokers had a higher prevalence of COAD (8·8%) than non-smokers (1·9%); the relative risk for smoking was 4·52 (95% CI 1·37–14·84). In the male cotton workers, more non-smokers (6·4%) had an FEV_1 fall of >10% after a shift than smokers (1·3%); the relative risk was 0·21 (95% CI 0·05–0·78), possibly due to a survivor effect of smokers in the cotton factories. The other differences between smokers and non-smokers were not significant. No significant differences were found in the age of smokers and non-smokers for all men (mean (SD) age 34·8 (8·9) years and 34·2 (9·7) years, respectively) and for male cotton workers (smokers 33·1 (8·7) years, non-smokers 33·6 (9·8) years).

Discussion

This is the first major study on byssinosis in Guangzhou. All the workers exposed to cotton dust (but not dusts from other natural or synthetic fibres) in the spinning mills were included and compared with workers not exposed to cotton dust. The dust concentrations in the factories were high: the total dust concentrations were often higher than the exposure limit of 3 mg/m³ in China and the inhalable dust concentrations often higher than the WHO recommended exposure limit of 0·2 mg/m³. The median inhalable dust concentrations of 0·41–1·51 mg/m³ in our study were very similar to the medians of

Table 6 Percentage of prevalence of respiratory abnormalities by sex and smoking and pooled relative risks for cotton exposure

	Men				*Women*		
	Smokers		*Non-smokers*		*Non-smokers*		*Pooled relative risk for cotton exposure (95% CI)*
	Cotton workers	*Controls*	*Cotton workers*	*Controls*	*Cotton workers*	*Controls*	
Typical Monday symptoms (a)	5·2	0	4·5	0	10·4	0·4	27·82** (10·41–74·38)
FEV_1 fall >5% after shift (b)	12·2	9·2	16·4	7·8	17·9	13·3	1·39** (1·15–1·68)
FEV_1 fall >10% after shift	1·3	1·2	6·4	1·3	4·7	3·0	1·69* (1·11–2·59)
FEV_1 <80% predicted	6·1	7·6	10·0	9·1	5·7	8·9	0·72* (0·54–0·94)
FEV_1/FVC <75% (COAD)	8·3	8·8	6·4	1·9	2·8	2·0	1·27 (0·86–1·88)
Cough or phlegm	17·0	10·4	20·9	7·8	18·1	8·0	2·16** (1·75–2·68)
Chronic bronchitis	9·7	7·6	11·8	4·5	11·0	4·8	2·06** (1·56–2·72)
Byssinosis (a + b)	0·9	0	1·8	0	1·9	0	—

* P <0·05, ** P <0·001

0·45 mg/m^3 to 1·52 mg/m^3 in the factories in Shanghai. The prevalence of typical Monday symptoms of 9·0% was slightly higher than the prevalence of 7·6% in Shanghai.[7] Also similar to the finding of greater falls in FEV_1 within a shift in cotton workers compared with silk workers in the Shanghai study, our study found a significant reduction in FEV_1 in cotton workers compared with controls.[8] Both the present and the Shanghai studies found that duration of exposure was associated with acute decrements in FEV_1.

In China, the diagnosis of byssinosis based only on typical Monday symptoms is not widely accepted, especially when it involves compensation. A fall in FEV_1 of 10% after a shift has been proposed as an additional criterion. If this were accepted, however, there would be only six cases of byssinosis with a prevalence of 0·46% in our study. Hence, a small fall of 5% was adopted to define byssinosis in our study and the prevalence was low, only 1·7%.

It is also interesting to note that typical Monday symptoms were found in four women in the control group. Early studies on byssinosis did not include controls and it was assumed that all the typical Monday symptoms were attributed to cotton exposure. In the present study, only 97% could be attributed to cotton exposure. When a fall in FEV_1 after a shift was included, the attributable risk became 100% but the criteria were probably too strict resulting in a prevalence that was too low.

As for other respiratory abnormalities, a comparison with controls, after adjustment for sex and smoking, shows that exposure to cotton dust was significantly associated with a fall in FEV_1 after a shift, cough or phlegm, and chronic bronchitis. The exception of FEV_1 <80% predicted may be explained by a survivor effect (or healthy worker effect) because of the factory policy of removing workers who had low tolerance to cotton exposure. The relative risks, estimated in a cross sectional study like ours, would tend to underestimate the chronic effect of cotton exposure.

In the cotton workers, the results on exposure to cumulative inhalable dust also support the hypothesis that exposure to cotton dust was responsible for a fall in FEV_1 after the shift, cough or phlegm, chronic bronchitis, and COAD.

In China, it was considered that working in the cotton textile industry caused varying degrees of interstitial fibrotic changes seen on chest radiographs mainly as reticular opacities.[9] Lu *et al* found that cotton dust induced non-specific abnormalities in chest radiographs in some workers.[9] Liu also found more chest radiographic abnormalities in cotton workers than controls.[10] In our study, no chest *x* ray film abnormalities were found in the cotton workers and our results confirmed that chest radiographs are not necessary for the diagnosis of byssinosis.[11]

To conclude, our study showed that the dust concentrations and prevalence of respiratory problems were high in the cotton spinning industry in Guangzhou. In the diagnosis of byssinosis, a fall in FEV_1 after a shift should be taken into account although to include it as a necessary criterion would result in a very low prevalence. The results also suggest that exposure to cumulative inhalable cotton dust is likely to be a cause of byssinotic symptoms, acute lung function decrements, cough or phlegm, and chronic bronchitis. Further follow up studies are needed to clarify the long term effects of cotton exposure and the subjects in our study will form a cohort for such a study.

An international workshop on byssinosis was held in Guangzhou in December 1993 and researchers from China met to discuss the current situation of byssinosis in China and recommendations for prevention and future research.[12]

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