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Respiratory health and dust levels in cottonseed mills

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Jones, R. N., Carr, J., Glindmeyer, H., Diem, J., and Weill, H. (1977). *Thorax*, **32**, 281–286. **Respiratory health and dust levels in cottonseed mills.** Four cottonseed mills in the southern United States contained high levels of total and respirable dust. A survey of 172 workers showed low prevalences of byssinosis (2·3%) and chronic bronchitis (4%). Mean baseline (out of dust) lung function values were normal. Mean functional declines over the working shift were present on Monday and absent on Friday, indicating an acute bronchoconstrictor response. Despite limitations in translating measured dust levels into estimates of individual exposures, the overall dose–response relationship seems to differ from that found in the cotton textile industry.

Byssinosis may result from inhaling any of several vegetable fibres under a variety of occupational exposures. The cotton textile industry has been the locus of most of the systematic studies of the disease. Non-textile exposures to cotton dust have received little attention, probably because these operations are predominantly rural, dispersed, and seasonal, and have a high turnover of unskilled labour.

As a result of the morbidity and disability from byssinosis in textile workers, governments have undertaken to regulate the permissible exposure to cotton dust. The major task is to define a safe and feasible limit of exposure. It is reasonable also to consider whether to apply the same standard to all sources of airborne cotton dust. The answer to this question should depend upon whether byssinosis is found in non-textile workers, and whether the dust-dose biologic-response relationship is similar to that in the textile industry.

Cottonseed is an important product of cotton cultivation. Seed mills separate the raw cottonseed into 'linters' (attached short cotton fibres), hulls, and meats, the last being the source of oil and cake or meal. The early steps in processing involve removal of coarse trash by mechanical shakers, stripping the linters from hulls by revolving saws, and collecting the baling linters. These operations raise substantial amounts of dust. The cottonseed is not treated in any way before it reaches the mill.

Study population and methods

In the summer of 1975, we studied workers in four cottonseed mills in the southern United States. We attempted to recruit all workers in dusty jobs and a number of other cottonseed mill workers (thought to be only minimally exposed to dust) to serve as a comparison group. In three mills, we recruited as many workers as were willing to participate. In the fourth and largest mill, all workers in dusty jobs were recruited, and as many with minimal exposures as study time permitted. One hundred and seventy-two workers completed the interview; 153 completed function studies for inclusion in the Monday analysis (reasons for exclusion included having less than 40 hours off work before testing, or unexpected absence from work). Of these 153 workers, 145 were available for study on Friday of the same week.

Frequency distributions of the ages and length of employment in this population are shown in Figure 1. The age distribution is bimodal with a mean age of 40·5 years. The distribution of length of employment is skewed, 32% working for two or fewer years in these mills. Of the 153 men completing tests on Monday, 30% were non-smokers and 70% were smokers or ex-smokers. Based on job categories, 69 men were thought to have high, continuous dust exposure, 53 were assigned to an intermediate exposure group, and 31 were con-

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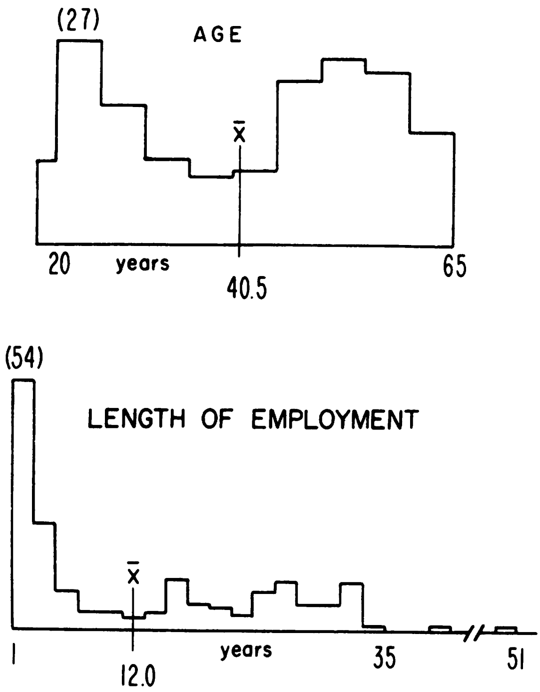

Fig. 1 *Study population (N=172).*

sidered to have minimal exposures. These assignments were based on observations of time spent in dusty areas, and were made because worker mobility prevented translation of area dust measurements into personal exposure levels. Dust measurements were made at the time of interviewing and lung function testing in each mill. Area samples were obtained using vertical elutriators that collected dust particles of less than 15 μm diameter. Total dust levels, obtained using personal monitors, were used to estimate exposures of persons who divided their time between several areas, or who worked in areas that could not be monitored with the vertical elutriator.

A trained interviewer administered a questionnaire containing standardised items about respiratory health and byssinosis. Byssinosis was defined as chest tightness, or cough, phlegm, or difficult breathing, occurring (or worsening) on the first day back at work after an absence of 40 or more hours. 'Chronic byssinosis' was defined by a past history of the symptoms defining byssinosis and a current history of lower respiratory symptoms. 'Chronic bronchitis' was defined by cough and phlegm on most days for three or more consecutive months, in two or more consecutive years. 'Dyspnoea' was considered present if the subject was breathless when hurrying on the level or walking up a slight hill, or on less exertion. 'Lengthy exposure' was defined as working more than five years in these mills.

Ventilatory function measurements were obtained using an electronic dry rolling-seal spirometer. Testing was done before work and after at least five hours' work on Monday and Friday of the same week. The measurements obtained were based on five maximum forced expirations displayed on volume-time and flow-volume plots. Predicted values for each subject took into account age, height, and race. Changes in flow rates over the working shift were calculated using an isovolume technique.

Analysis of results was directed toward determining the effects of three potential influencing variables: level of dust exposure (high, intermediate, or minimal); length of dust exposure ('lengthy', as defined above, or 'short'); and smoking.

Results

ENVIRONMENTAL MEASUREMENTS

A summary of results of dust sampling is provided in Table 1. The number of samples making up the mean and median values is highly variable, ranging from three to about 20. A number of area and personal dust levels are quite high, especially in mill III. In general, the elutriated samples show levels considerably higher than the 0·2 mg/m^3 standard proposed by the National Institute for Occupational Safety and Health (NIOSH) for textile mills, and in fact higher than the levels already attained by many textile mills.

SYMPTOMS

Three individuals fulfilled the criteria for 'byssinosis', giving histories of a Monday pattern of respiratory symptoms. One of these was a young man who answered yes to almost every question. He had been employed only one year in a job with minimal dust exposure, and was a nonsmoker. Although he was counted as having byssinosis, his answers were considered to be of doubtful veracity. He also failed to show a decline in forced expiratory volume in one second (FEV_1) over the working shift, although his isovolume forced expiratory flow over 25–75% of forced vital capacity (FEF_{25-75}) declined by 0·35 l/sec. The other two participants fitting this definition were both smokers and were in the intermediate exposure category. One had short and the other had lengthy employment, the former showed a decline

Table 1 *Dust levels*

	Area samples Elutriated dust (mg/m³)				*Personal samples Total dust (mg/m³)*		
	Median	*Mean*	*Range*	*n*	*Median*	*Mean*	*n*
Mill I							
Seed feeder	—	—			7·4	12·6	8
Cleaning room	1·8	1·9	1·3–2·3	5	1·3	1·6	9
Huller room	1·7	1·4	0·4–3·7	21	1·3	1·6	9
Lint room	0·4	0·7	0·2–3·0	32	1·4	1·4	7
Baler	—	—			1·2	1·4	7
Shift foreman	—	—			0·9	0·9	6
Mill II							
Seed feeder	—	—			0·9	2·2	5
Cleaning room	0·6	0·7	0·5–1·1	5	3·8	3·4	8
Huller room	1·5	1·6	0·5–1·8	29	3·8	3·4	8
Lint room 1	0·8	1·1	0·4–3·5	18	2·2	3·6	10
Lint room 2	0·8	1·1	0·4–3·5	18	1·8	2·0	7
Saw filer	—	—			2·0	2·2	3
Shift foreman	—	—			0·8	0·9	8
Mill III							
Seed feeder	—	—			4·1	5·2	10
Cleaning room	1·5	1·8	1·2–3·4	12	6·1	5·7	9
Huller room	2·0	2·7	0·9–10·0	17	6·1	5·7	9
Lint room	0·8	0·8	0·3–1·4	30	1·6	1·6	5
Baler	11·3	7·6	0·8–15·9	10	4·9	5·6	19
Foreman	—	—			1·2	1·2	3
Saw filing area	0·3	0·4	0·2–0·8	5	—	—	
Lint beating room	4·3	4·3	4·1–4·6	5	—	—	
Mill IV							
Cleaning room	—	—			1·1	1·1	8
Huller room	0·6	0·7	0·2–2·1	20	1·0	2·0	8
Lint room operator	—	—			0·6	0·8	7
Lint room cleaner	0·4	0·4	0·1–1·2	19	3·5	5·5	6
Lint room	—	—			1·1	1·1	3
Baler	—	—			2·2	2·0	7
Hull sacker	—	—			5·8	5·9	3
Cleaning–baling	0·6	0·9	0·1–4·4	28	—	—	
Saw filing	0·3	0·3	0·1–0·4	5	—	—	
Huller room 2	0·4	0·4	0·2–0·5	15	—	—	

of 300 ml and the latter of 60 ml in FEV_1 over the working shift. A fourth individual fitted the definition for 'chronic byssinosis'. He was a 62-year-old man who had worked in a foundry for 15 years and had a 'heart condition'. He was a smoker with only three years of work in the mill, in a job with intermediate dust exposure. His FEV_1 was 99% of the predicted value, and his ventilatory function did not decline over the working shift. The prevalence of byssinosis in this group of workers is thus four of 172, or 2·3%.

Seven of 172 participants had chronic bronchitis. This prevalence of 4% is lower than has been found for most working populations. The explanation may include both the relative youth of this population and the effects of geography and climate. When the definition of chronic bronchitis was relaxed to require only one or more years with productive cough of three months or more, only 24 participants (14%) fit this definition. Forty-nine participants had 'dyspnoea', as defined above. This symptom, however, was not related to level of dust exposure, length of exposure, or smoking.

LUNG FUNCTION STUDIES

Baseline ventilatory function values, obtained from 158 subjects before work on Monday, are displayed as frequency distributions of percentages of predicted values in Figure 2. For each parameter, the probability of an individual having an observed value below 80% predicted was examined in the terms of the variables of level of exposure, length of exposure, and smoking. For the forced vital capacity (FVC), only three subjects had values less than 80% predicted; and only seven subjects had FEV_1 values less than 80% predicted. These proportions were too small for statistical analysis of relationship to the influencing variables. For the FEF_{25-75}, 66 individuals (42%) had values less than 80% predicted. On statistical analysis, the probability of having a subnormal FEF_{25-75} was found to depend upon smoking and lengthy dust exposure but not upon current level of exposure.

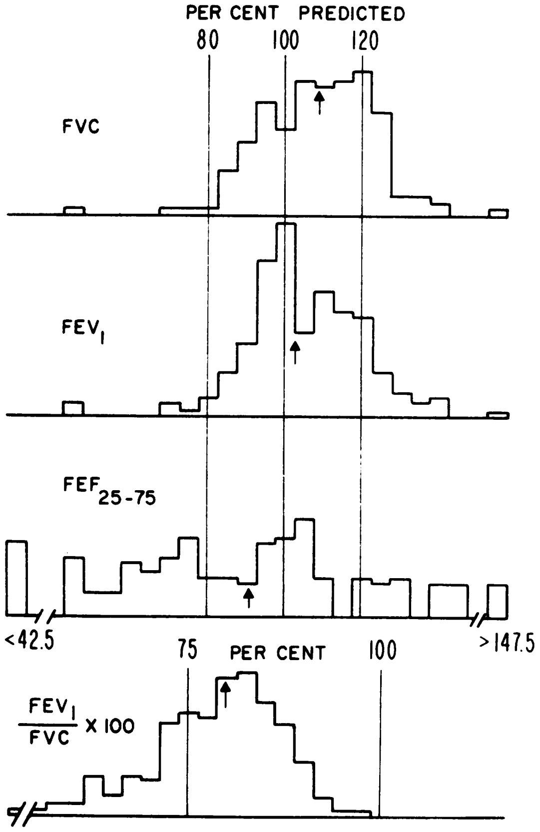

Fig. 2 *Baseline ventilatory function (158 subjects).*

The same was true of the ratio $FEV_1/FVC \times 100$ ($FEV_1\%$), where having a value of less than 75% depended on smoking and length of exposure but not on level of exposure. It must be acknowledged, however, that while we have treated length of exposure as a separate variable, it shows a strong correlation with age and, in smokers, with duration of smoking. It is thus possible that associations with lengthy dust exposure are actually observed because of ageing and prolonged use of tobacco.

Mean functional changes over the working shift were assessed in 153 workers who completed tests before and after work on Monday. These values are shown in Table 2, the negative signs indicating declines. Except for the negligible change in $FEV_1\%$, all of the mean changes were significantly different from zero or no change. Twenty-one per cent of the population showed a decline in FEV_1 of more than 150 ml, and 29% showed a decline in FEF_{25-75} of more than 0·4 l/sec. Similar proportions had significant declines of maximum

Table 2 *Mean lung function changes over the working shift (negative number indicates decline)*

Test	*Monday (n=153)*		*Friday (n=145)*
	Mean change (±SE)	*% with change larger than (level)*	*Mean change (±SE)*
FVC	−52 ml* (±13)		−27 ml (±13)
FEV_1	−48 ml** (±14)	21 (−150 ml)	6 ml (±11)
FEF_{25-75}	−0·173 l/sec** (±0.042)	29 (−0·4 l/sec)	−0·035 l/sec (±0.038)
$FEV_1\%$	−0·3% (±0·2)		0·6% (±0·1)
$V_{max}E_{50}$	0·102 l/sec* (±0·051)	23 (−0·6 l/sec)	0·019 l/sec (±0·051)
$V_{max}E_{25}$	−0·136 l/sec** (±0·033)	25 (−0·35 l/sec)	−0·035 l/sec (±0·029)

*Decline significantly ($P < 0·05$) greater than zero.
**Decline significantly ($P < 0·05$) greater than zero and greater than decline over the Friday working shift.

expiratory flow at 50% ($V_{max}E_{50}$) and 25% ($V_{max}E_{25}$) of FVC. For the FEV_1, FEF_{25-75}, and maximum expiratory flow rate at 25% of FVC, the observed mean decline was not only significantly greater than zero but was significantly greater than the observed mean change over the working shift on Friday. These findings document an acute bronchoconstrictor effect in this population despite the low prevalence of byssinosis as defined by questionnaire response.

The probability of showing an excessive decline in FEV_1 or FEF_{25-75} did not, however, depend on smoking, length of exposure, or level of exposure. This was also true of the maximum expiratory flow at 50% of FVC. For the maximum expiratory flow at 25% of FVC there were paradoxical relationships with smoking and length of exposure, ie, excessive declines occurred significantly more often in non-smokers and in workers with short dust exposures.

Discussion

Recent studies in cotton textile mills have demonstrated biological effects with low exposure levels (Fox *et al.*, 1973; Merchant *et al.*, 1973; Berry *et al.*, 1974). Non-textile sources of cotton dust exposure have received, as stated above, little systematic study. Gilson *et al.* (1962) measured dust levels in several cotton ginneries in Uganda, and compared these with ventilatory changes over the Monday working shift. A substantial mean decline was documented in one ginnery. The fine dust concentration was 20 times that in a Ugandan textile mill, suggesting that the biological 'effect is much less marked than in cotton mills'. Khogali

(1969) recorded histories of chest tightness (after annual holiday) in 20% of ginnery and 48% of farfara workers in the Sudan. Two years later, Khogali (1976) found that the same workers showed a mean FEV_1 increase; dust levels and prevalences of respiratory symptoms remained high. El Batawi (1962) found that symptoms of byssinosis were actually more prevalent in ginning (38%) and bale pressing (53%) than in carding (27%), although the last operation had a higher proportion with grade II byssinosis. Ginning seemed safer in Greece, there being no cases of byssinosis in 70 workers evaluated by Kondakis and Pournaras (1965). There were no byssinotics in a study by Palmer *et al.* (1974) in the south-western United States. Workers in the waste cotton industry were evaluated by Dingwall-Fordyce and O'Sullivan (1966): 5% had disabling byssinosis and 25% had byssinosis of milder grades. Cotton garnetting, the production of mattress stuffing from linters, cardroom waste, and waste cotton, was associated with total dust levels up to 21 mg/m^3 in a study by Simpson (1970). The 26 workers in that study had a mean FEV_1 post-shift decline of 120 ml, a subgroup with the dustier jobs having a mean decline of 280 ml. There was no significant decline in those exposed to total dust levels of 6 mg/m^3 or less, again suggesting less bioactivity than cardroom dust.

The health effects of exposure to dust in Australian cottonseed mills was examined by Barnes and Simpson (1968). The first mill studied used hydrochloric acid to remove linters and anhydrous ammonia to neutralise the acid. Total dust levels ranged from 7 to 32 mg/m^3. Six of 11 subjects had work-related respiratory symptoms, but there was no case of byssinosis. A mean post-shift FEV_1 decline of 300 ml was observed. Simpson and Barnes (1968) later published a similar study in a mill using mechanical saws for delinting. Total dust levels of 15–37 mg/m^3 were found. A 160 ml mean decline of FEV_1 occurred over the working shift in 16 exposed workers, compared to a 90 ml increase for a group of 11 non-exposed workers. There was no mention of symptoms in this article.

Noweir *et al.* (1969) administered a questionnaire to workers in Egyptian cottonseed mills. The raw seed had been subjected to steam sterilisation before being shipped to the mill. Thirty-five of 110 workers exposed to cotton dust had work-related respiratory symptoms, but these became worse on each succeeding day in the working week, reaching a maximum on the sixth day.

The present study documents relatively high levels of respirable and total dust, and a low prevalence of byssinosis, in four cottonseed mills. Despite the low prevalence of symptoms, the study population showed an acute bronchoconstrictor response on Monday that was not present on Friday of the same week. This response provides evidence of bioactivity of the dust and indicates a need for reduction of current dust levels. The inability to relate post-shift functional declines to current exposure levels is due probably to difficulty in arriving at good estimates of individual exposures. The gravimetric samples may provide poor estimates of individual exposures because of crowding and overlapping of different milling operations, considerable worker movement during the shift, and lack of a personal monitor capable of sampling only respirable dust. Further, the composition and bioactivity of dust samples from different milling operations, and from mill to mill, may be expected to vary. In spite of this lack of precise data on individual exposures, the generally high respirable dust levels and low prevalence of byssinosis suggest that the overall dose–response relationship differs from that found in the cotton textile industry.

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