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Smoking and Cotton Dust Effects in Cotton Textile Workers: An Analysis of the Shape of the Maximum Expiratory Flow Volume Curve

by E. Neil Schachter,*† Mary C. Kapp,* Lucinda R. Maunder,* Gerald Beck,* and Theodore J. Witek*

Cotton textile workers have an increased prevalence of both obstructive and restrictive lung function patterns when compared to control subjects. Similar abnormal lung function patterns may occur with other respiratory diseases, notably those associated with cigarette smoking. The shape of the maximum expiratory flow volume (MEFV) curve has been used to characterize patterns of lung function abnormality. We defined a new functional parameter (angle β) related to the shape of the MEFV curve in order better to characterize the respiratory effects of cotton dust exposure. In this study, 477 cotton textile workers, both current smokers and never smokers 45 years and older, were compared to 932 similarly aged control subjects from three communities: Lebanon and Ansonia, CT, and Winnsboro, SC. Smokers, regardless of their occupational exposure or sex, have smaller values of β than do nonsmokers. Cotton textile workers who have more abnormal lung function than do controls, cannot be distinguished from controls by β. We suggest that such functional differences between cotton and smoking effects may reflect injury to different portions of the bronchial tree.

Introduction

Epidemiologic studies of cotton textile workers have demonstrated evidence of chronic lung disease resulting from occupational exposure to cotton dust (*1*). In the earliest stages of byssinosis, workers have chest tightness and shortness of breath on the first day of the work week. These symptoms subside as the week continues (*2,3*). As the disease progresses, symptoms worsen and may persist through the work week as well as in the absence of work exposure. In this later stage, workers commonly display objective findings of pulmonary impairment (*4–6*). We have recently characterized the patterns of lung function abnormalities in older cotton textile workers and have documented that these may be both obstructive and restrictive (*7*). Furthermore, in an analysis of these older workers, we have shown separate smoking and cotton effects (*8*). In addition to these effects being independent (i.e., additive), we have shown that individual lung function parameters used to assess lung dysfunction are not equally affected by smoking and cotton dust exposure. For example, abnormalities in the maximum expiratory flows at 50% and 25% of vital capacity ($\dot{V}_{max50\%}$ and $\dot{V}_{max25\%}$) are more related to smoking than to cotton effects, whereas for the forced vital capacity (FVC) and the forced expiratory volume in 1 sec (FEV_1) cotton effects are either more important than or equally important as smoking effects.

Some authors such as Mead (*9,10*) have demonstrated that the shape of the maximum expiratory flow volume (MEFV) curve may be important in characterizing respiratory dysfunction. In order better to distinguish smoking and cotton effects in cotton textile workers, we describe a new functional parameter called angle β which has been defined in terms of the shape of the MEFV curve.

Methods and Subjects

In 1973 we examined a group of older white cotton textile workers who had worked in one of four mills in Columbia, SC. Cardroom and weaveroom workers who had worked in the mills for at least 3 years by 1946 formed an initial study group. Workers who had worked 3 years by 1955 formed a second group that included workers in areas other than the cardroom or weaveroom. Most of these workers had more than 20 years

*Departments of Internal Medicine and Epidemiology and Public Health, Yale University School of Medicine, 333 Cedar St., New Haven, CT.
†Present address: Mount Sinai Medical Center, 1 Gustave L. Levy Place, A24-30, New York, NY 10029.

of exposure in the cotton textile industry with an average length of exposure of 35 years. Details of the selection process have been described elsewhere (*5,6*). In brief, eligible workers were identified from company personnel records and membership lists obtained from the local union. Of those workers in the initial group (employed three years before 1946) who could be traced, over 95% participated, suggesting that the population studied is representative of the surviving population of cotton textile workers. Workers in the second group were obtained in a less systematic way but the two groups have been shown not to differ in terms of their respiratory symptoms or lung function and were, therefore, pooled for our analysis (*5*). The 477 white cotton textile workers studied were 45 years or older and were either nonsmokers or current smokers.

A control population of residents from Lebanon and Ansonia, CT, as well as Winnsboro, SC, was studied from 1972 to 1974 (*4,5*). All persons in the control population who had worked in a cotton textile mill for over one year were excluded for this analysis. Previous analyses of our data have documented that the residents of Connecticut were similar in their prevalence of respiratory symptoms and in lung function to those of Winnsboro, SC, a community near Columbia (*4*). This finding suggests that, the Connecticut controls were not inappropriate for comparison with our cohort of cotton textile workers. The 932 white community residents aged 45 years and older who were either never smokers or current (cigarette) smokers comprised the group of controls used for this analysis. Surveys were conducted in a standardized manner using trailers equipped with computer facilities for recording answers to a questionnaire on respiratory health and for collecting the results of pulmonary function tests (*10*). Standard pulmonary function parameters were recorded from maximal expiratory flow volume curves, including the forced vital capacity (FVC), the forced expiratory volume in 1 sec (FEV_1), the ratio FEV_1/FVC, the peak expiratory flow rate (PEFR), and maximal flow rate at 50% of vital capacity ($\dot{V}_{max50\%}$).

A lung function parameter was defined as normal if the observed value was within 1.96 standard errors of the estimate of the predicted value. Expected values for lung function parameters were based on the prediction equations of Schoenberg and coworkers (*11*). A lung function was defined as less than normal if it was less than the predicted value minus 1.96 standard errors of the estimate. It was defined as greater than normal if the observed value was greater than the predicted value plus 1.96 standard errors of the estimate.

We defined a mild obstructive pattern as one in which the $\dot{V}_{max50\%}$ was less than normal and all other parameters were normal. We defined moderate or severe obstruction (obstructive) as a pattern in which the FEV_1/FVC ratio was less than normal. We defined restrictive as a pattern in which the FVC and FEV_1 were less than normal and the FEV_1/FVC ratio was either normal or greater than normal. The remaining lung function patterns were classified as other.

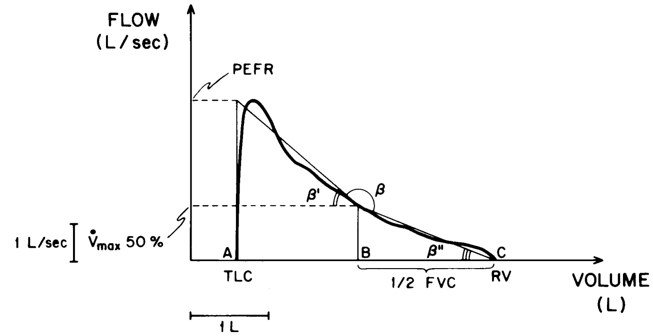

FIGURE 1. Maximum expiratory flow volume curve illustrating the construction of angle β: (*A*)total lung capacity point; (*B*) $\dot{V}_{max50\%}$ point; (*C*) residual volume point.

We defined smoking categories as follows. Never smokers were persons who had never smoked cigars, cigarettes, or pipes. Current smokers were persons who currently smoked cigarettes. Pack-years of smoking were calculated as the number of cigarettes smoked per day times the number of years smoking that amount, summed over all years of smoking then divided by 20.

We defined the angle β to characterize the shape of MEFV curve (see Fig. 1). The angle is defined by joining the residual volume point (RV) of the MEFV curve with the mid-flow point ($\dot{V}_{max50\%}$) and then the mid-flow point to a point at the level of total lung capacity (TLC) and at a height of the peak flow above the x-axis. The exact mathematical derivation of the angle β thus defined is

$$\beta = 180° - \tan^{-1}\frac{\text{PEFR} - \dot{V}_{max50\%}}{1/2\ \text{FVC}} + \tan^{-1}\frac{\dot{V}_{max50\%}}{1/2\ \text{FVC}}$$

Values for β in degrees were calculated by computer using the described formula.

In our analysis, comparisons of frequency distributions were made using the chi-square test; comparisons of mean values of β were made by the unpaired test. Statistical calculations were performed using standard SAS procedures (*12*).

Results

Table 1 describes the distribution of the populations by age, by sex, by smoking status, and by lung function pattern. No difference exists in the distribution of the study groups by sex although a significant difference exists for smoking prevalences (cotton textile worker = 35% vs. controls = 40%). However, for the smokers, the mean number of pack years smoked was not significantly different between cotton textile workers and controls even when examined by age categories (*8*).

A significant difference exists in the distribution of subjects by age group. However, differences in mean age between cotton textile workers and controls by age group were only 0.6, 0.2, and 1.6 years for age groups 45–54, 55–64 and 65+, respectively, with mean age

Table 1. Cotton textile workers (CTW) vs. controls: age 45+, never smokers and current smokers, whites only.

Study population	Number of subjects: CTW	Control	Total	χ^2	p
Total	477	932	1409		
Sex					
Male	153	298	451	0.001	NS
Female	324	634	958		
Smoking					
Current	167	379	546		
Never	310	553	863	4.02	0.045
Age					
45–54	140	390	530	21.01	< 0.001
55–64	207	335	542		
65+	130	207	337		
Pattern					
Mild obstructive	18	28	46	59.14	< 0.001
Obstructive	62	91	153		
Restrictive	33	18	51		
Normal	261	681	942		
Other	103	114	217		

being slightly greater for cotton workers in the two younger age groups and mean age being greater for controls in the 65+ group.

Finally, as previously described (*7*), there were significant differences between the patterns of lung function seen in the cotton worker and control groups with the prevalence of abnormal lung function being consistently greater for textile workers.

Table 2 illustrates the effects of smoking and cotton dust on the shape of the MEFV curve in terms of β. It can be seen that smokers, whether cotton textile workers or controls, have smaller β than nonsmokers, but that cotton textile workers, whether they are smokers or nonsmokers do not have β different from controls. Table 3 analyzes separately the effect of sex, smoking status, age, and pattern of lung function on β in cotton textile workers and controls. Consistently, each of these factors significantly influences β. Males, smokers, and older individuals have smaller values of β. Subjects with abnormal lung function both obstructive and restrictive have lower β than persons with normal patterns, and, moreover, subjects with obstructive patterns have lower β than those with restrictive patterns. No significant differences are seen in β between cotton textile workers and controls for these subgroups.

Discussion

By using a new derived lung function parameter β describing the shape of the flow volume curve, we have been able to show differences in effects due to occupational exposure and those effects related to cigarette smoking. Current cigarette smokers, regardless of their occupational exposure or sex, have lower β than individuals who have never smoked. In contrast, cotton textile workers cannot be distinguished from controls by virtue of their β angle. What these findings suggest is a difference in the way cotton dust exposure affects lung function when compared to the way smoking affects function.

The shape of the maximum expiratory flow volume curve has been associated with abnormal lung function (*10*). Subjectively, curves that are convex to the volume axis have been associated with obstructive patterns while those with shapes that are concave have been associated with younger healthy individuals (*13*). Our data support this relationship between lung function pattern and the shape of the MEFV curve.

Evidence from pathologic studies of cotton workers shows differences in the histologic appearance of lung specimens in terms of occupational exposure and cigarette related damage. An extensive literature indicates that cigarette smoking is associated with a number of pathologic respiratory events including chronic bronchitis, emphysema, and damage to smaller airways. By contrast, studies of cotton textile workers have shown inflammation and hyperplasia of the larger airways (*14,15*).

We suggest that the differences in lung function patterns described may relate to these differences in pulmonary pathology. Previously, in our analysis of cotton and smoking effects (*8*), we demonstrated that lung function abnormalities due to cotton dust are equal to or greater than those of smoking when FVC and FEV_1 are considered. By contrast, when $\dot{V}_{max50\%}$ and $\dot{V}_{max25\%}$ are considered, smoking effects are more important.

Table 2. Comparison of angle β by smoking and cotton dust exposure status.

	Current smoker	Never smoker	
CTW	183.29 ± 20.54	194.98 ± 21.32	p = 0.0001
(n)	(167)	(310)	
Controls	186.28 ± 20.97	194.68 ± 19.30	p = 0.0001
(n)	(379)	(553)	
	p = 0.1241	p = 0.8366	

Table 3. Comparison of angle β for cotton textile workers and controls by sex, smoking status, by age, and by lung function pattern.

	β, degrees (mean ± SD): Cotton textile workers	Controls
Sex		
Male	185.1 ± 21.12	184.3 ± 19.84
Female	193.6 ± 21.54	194.5 ± 19.85
	p < 0.001	p < 0.001
Smoking		
Current	183.3 ± 20.54	186.3 ± 20.97
Never	195.0 ± 21.32	194.7 ± 19.30
	p < 0.001	p < 0.001
Age		
45–54	194.4 ± 21.31	191.0 ± 19.21
55–64	189.8 ± 22.38	192.5 ± 20.41
65+	188.8 ± 20.91	189.6 ± 22.45
	p = 0.064	p = 0.176
Pattern		
Obstructive	167.9 ± 18.71	165.4 ± 16.25
Restrictive	185.0 ± 16.50	180.0 ± 14.80
Normal	193.9 ± 17.04	194.0 ± 16.74
Other	202.9 ± 22.74	203.6 ± 22.63
	p = 0.001	p = 0.001

Since the latter two variables are more directly related to MEFV shape than the former, our present analysis is consistent with our earlier observations.

We conclude that, as previously shown, cotton textile workers display an excess of lung function abnormalities when compared to a community control population. Whereas such abnormal patterns among smokers are associated with changes in the shape of the MEFV curve, among cotton textile workers these changes are not associated with differences in the contour of the MEFV curve as measured by β. We suggest that these findings may reflect injury to different portions of the bronchial tree and possibly more than one mechanism of injury.

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