

CUMULATIVE ASBESTOS EXPOSURE AND FORCED VITAL CAPACITY

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ABSTRACT

This analysis uses a portion of the data from a retrospective study of asbestos textile workers to relate loss in forced vital capacity (FVC) to cumulative asbestos exposure. Individual cumulative asbestos fiber exposure for asbestos textile workers was estimated from occupational histories and results of air samples. Only workers with more than 10 years exposure were included in the analysis. Observed FVC/Predicted FVC was related to the logarithm of exposure by linear regression. Office workers in the same asbestos textile mills were also tested. The FVC of weavers and yarn production workers was less than predicted and less than that of the office workers. For asbestos yarn production workers, each doubling of cumulative asbestos fiber exposure above 100 fiber-years/cm³ resulted in a loss of 5 to 10 percent in FVC.

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INTRODUCTION

In 1964 the Division of Occupational Health of the U.S. Public Health Service, now the National Institute for Occupational Safety and Health (NIOSH), began a study of the asbestos manufacturing industry in the United States. The study was voluntary on the part of the manufacturing concerns, and was conducted in cooperation with the State Health Department industrial hygiene units in the States of North Carolina, Pennsylvania, New Hampshire and New Jersey. Plants were also surveyed in Indiana, Texas, Louisiana, California and Ohio. The study initially included collection of employment records for subsequent mortality analysis and environmental assessment of asbestos textile manufacture, friction product manufacture, asbestos cement pipe manufacture, and

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asbestos insulation manufacture.^{1,2} When funds became available, the study was expanded to include medical examinations in the asbestos textile portion of the industry. The medical examination included an occupational and medical history, a PA chest roentgenogram, a forced expiratory spirogram and other respiratory function tests.

Organization to fulfill the mission of the new National Institute necessitated reassignment of a number of the senior personnel involved in the study, and field work was discontinued. Collection of mortality data from the study continued and was, in fact, expanded in certain respects. A report has been presented on these data³, and they are now being updated.

An analysis to determine the association of environmental data with development of asbestosis and other physiological and medical changes in workers has not, however, been made. An exception was a preliminary report on cumulative dust exposure versus average percent of predicted forced vital capacity for workers with more than 10 years experience in one of five asbestos textile mills.⁴ That preliminary report included only groups of three or more workers for whom exposure could be estimated. This report uses the same dust count and forced vital capacity data, but includes all the workers

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for whom exposure estimates could be made, with an individual estimate for each worker.

METHODS

The environmental data collected by the NIOSH teams consisted of both impinger counts (the Threshold Limit Value for asbestos was 5 million particles per cubic foot (mppcf) at the initiation of the study) and counts of "total" fibers, fibers longer than 5 μm , and fibers longer than 10 μm .^{5,6} Samples counted were also analyzed for magnesium, which constitutes approximately 25 percent of chrysotile asbestos. Samples were also collected for other chemical and physical analyses.

Environmental data collected prior to the NIOSH study were all in the form of impinger counts. All particles were counted, as fibers represent only a small fraction of the particles seen in an impinger count. Data were available from company records, which were made freely available to the NIOSH team, and from State Health Department records, especially in North Carolina. These counts, although typically few in number at any one operation, went back in some cases to the 1930's. All these impinger counts were converted to equivalent counts of fibers longer than 5 μm in length, using the equivalent of 1 mppcf = 6 fibers/cm³.

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Cumulative exposure of workers was estimated by assigning an exposure to each operation at each plant for each year of exposure. For the NIOSH surveys, the fiber counts were averaged for the operation for each survey. For the previous years, the counts at an operation were averaged if there was more than one in the year. For those years where no counts existed, a linear interpolation was used between counts from previous and future years. The annual exposure was then summed for each worker to give an estimated cumulative exposure in terms of fibers-years/cm³.

Forced vital capacity (FVC) was measured by members of the Physiology Section, using Jones Pulmonors.* The best effort of three trials was ordinarily used. The predicted forced vital capacity was based on the worker's age, height and sex, using tables from the Committee on Rating of Physical and Mental Impairment, after the data of Kory et al.^{7,8}

Only workers with 10 or more years of work in the office, or at production operations for which there were environmental data, were included in the analysis.

*Mention of specific equipment does not imply endorsement by the Public Health Service.

RESULTS

Regression of FVC observed/FVC predicted versus arithmetic years, and arithmetic fiber-years/cm³, showed no relationship of FVC to exposure; therefore, the logarithms of these exposure parameters were used. The equations for fraction of predicted FVC versus log years are shown in Table 1 for smoking and non-smoking office workers, for smoking, non-smoking and ex-smoking yarn production workers, and for smoking and non-smoking weavers. The regression equations for fraction predicted FVC versus log cumulative exposure is presented in Table 2. For the yarn production workers, a further breakdown into male and female workers is included.

The percent predicted FVC from these equations is shown versus log exposure time in Figure 1. The office workers have a higher proportion of the predicted FVC than production workers at 10 years and in succeeding years. Weavers have better FVC than the yarn production workers as a group. For each of these groups, the non-smokers have better FVC's than the smokers.

Percent predicted FVC versus log cumulative exposure is shown in Figure 2. For the same apparent exposure above 100 fiber-years/cm³, the weavers have less loss in FVC. For both groups the same exposure causes more loss in the smokers, and the ex-smoker yarn workers are

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intermediate. For the smoking yarn production workers, each doubling of exposure above 100 fibers-years/cm³ appears to result in a decrease of about ten percent in predicted FVC. For the smoking weavers and non-smoking yarn production workers, the rate of decrease appears to be only about half as great for each doubling of exposure. The rate of decrease for non-smoking weavers is similar to that of non-smoking office workers, but the weavers have nine percent less of their predicted forced vital capacity. The yarn production workers are subdivided by sex in Figure 3. A statistically significant regression line was not obtained for non-smoking females.

DISCUSSION

The patterns of exposure of the production workers in this study reflect high exposures in the 1930's, dramatic reductions in the late 1930's to early 1940's, and some further reduction to about 1950, with little change from then until conclusion of the study. Thus, there is not a group reflecting a low exposure rate over a long time period; the lower exposures are shorter exposures.

The FVC of the weavers is better at 10 years and remains better than yarn production workers, reflecting less exposure to dust with an effect on pulmonary function. The apparent difference in the effect of an

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equivalent cumulative exposure (Figure 2) may, however, be an artifact. Except for the NIOSH study, samples at the production operations have emphasized those operations with the highest apparent dust concentrations. This makes little difference for the yarn-producing operations, where concentrations tend to be similar throughout each area. At weaving, however, certain looms which are run dry or otherwise are dustier would have been sampled in preference to other typical looms. (Such a sampling pattern would be required by regulation in proposed new health standards of the Occupational Safety and Health Administration.)⁹ There is, however, the possibility that at least part of this apparent difference is real, if the shape characteristics of fibers generated at weaving are such as to cause lower fiber deposition.¹⁰ Our data are not conclusive as to whether or not there is a real difference in the effect of a given dust concentration between weaving and yarn production.

The forced vital capacities average above 90 percent of predicted values for all groups at 100 fiber-years/cm³, and above 95 percent for all but male smokers. This would suggest that there is little effect upon pulmonary function at this cumulative exposure, were it

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not for the fact that office workers at 10 years were six to nine percent higher than production workers. Although differences in average FVC between racial and ethnic groups have been demonstrated, we believe it more likely that the difference between office and production workers represents the loss in FVC over the first 10 years in those production workers with higher exposures. The two mills with the lowest dust exposures both had regression lines for production workers giving FVC's well above 100 percent predicted at 10 years, while the other mills were below 100 percent predicted at 10 years.

The decrease in percent of predicted FVC among office workers with time probably reflects the fact that some of these workers may spend short periods of time in the plant. It should be noted that they still average more than 95 percent of predicted FVC after 40 years exposure, and the reduction in dust concentrations since this study should still further reduce this effect. We cannot estimate the effect, if any, of selection out of the group by disability of those most severely affected by the asbestos dust.

The variability of environmental measurements by count is widely recognized.¹¹ Further, there is additional variability added in the conversion of mppcf to fibers/cc.

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However, a factor of two in cumulative exposure results in only a five to ten percent decrease in percent predicted FVC. Thus, a factor of 4 in cumulative exposure is necessary to produce one standard deviation in the FVC, so that the variability of the data are probably related more to prediction variability than to variables in exposure estimation.

The difference in apparent effect of dust upon smokers and non-smokers is, at least in part, caused by the fact that the tables used for prediction of FVC did not distinguish between smokers and non-smokers.¹²

CONCLUSIONS

1. There is a progressive effect of asbestos dust upon forced vital capacity. For asbestos yarn production workers, the decrease in percent of predicted forced vital capacity averaged five to ten percent for each doubling of cumulative exposures above 100 fiber-years/cm³.
2. The regression equations for asbestos workers as of 1970 showed a predicted FVC of 100 percent or better at 10 years' exposure for smoking and non-smoking yarn production workers and weavers. However, office workers had higher percent predicted FVC's, and if individual mills were examined, some were under 100 percent predicted

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FVC, suggesting that decreases in FVC had already occurred. The respiratory function of workers with less than 10 years' exposure should be examined.

3.a. At an estimated average cumulative exposure of 100 fiber-years/cm³, the basis of the British Occupational Hygiene Society's Hygiene Standards for Chrysotile Asbestos, percent predicted FVC was below 100 percent for male yarn production workers, and below 95 percent predicted for those who smoked. When the variation among workers is considered, this limit may only prevent significant decreases in pulmonary function when combined with periodic spirometry and further reduction of exposure for affected workers.

3.b. Both the environmental and medical monitoring parts of the asbestos standard of the U.S. Occupational Safety and Health Administration appear necessary to prevent degradation of pulmonary function in susceptible asbestos-exposed workers.

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Table 1.-Regression Equations for Fraction of Predicted
 Forced Vital Capacity by Years Exposure in
 Asbestos Textile Work: 1970

<u>Group</u>	<u>n</u>	<u>Fraction Pred. FVC</u>
<u>OFFICE WORKERS</u>		
Smokers	53	1.215 - 0.156 y
Non-smokers	67	1.348 - 0.235 y
<u>WEAVING</u>		
Smokers	60	1.421 - 0.393 y
Non-smokers	67	1.271 - 0.246 y
All	143	1.296 - 0.280 y
<u>YARN</u>		
Smokers	92	1.588 - 0.580 y
Non-smokers	137	1.436 - 0.409 y
Ex-smokers	40	1.561 - 0.535 y

where $y = \log_{10}$ [years exposure]

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Table 2.-Regression Equations for Fraction of Predicted
Forced Vital Capacity Versus Log Cumulative
Asbestos Exposure

<u>Group</u>	<u>n</u>	<u>Fraction Pred. FVC</u>
<u>YARN PRODUCTION</u>		
All smokers	92	1.608 - 0.318 X
All non-smokers	137	1.333 - 0.172 X
All ex-smokers	40	1.44 - 0.236 X
Male smokers	47	1.46 - 0.265 X
Female smokers	45	1.886 - 0.429 X
Male non-smokers	99	1.388 - 0.199 X
Male ex-smokers	34	1.443 - 0.235 X
Female non-smokers	38	N.S.
<u>WEAVING</u>		
Smokers	60	1.281 - 0.153 X
Non-smokers	67	1.167 - 0.086 X
All	143	1.165 - 0.095 X

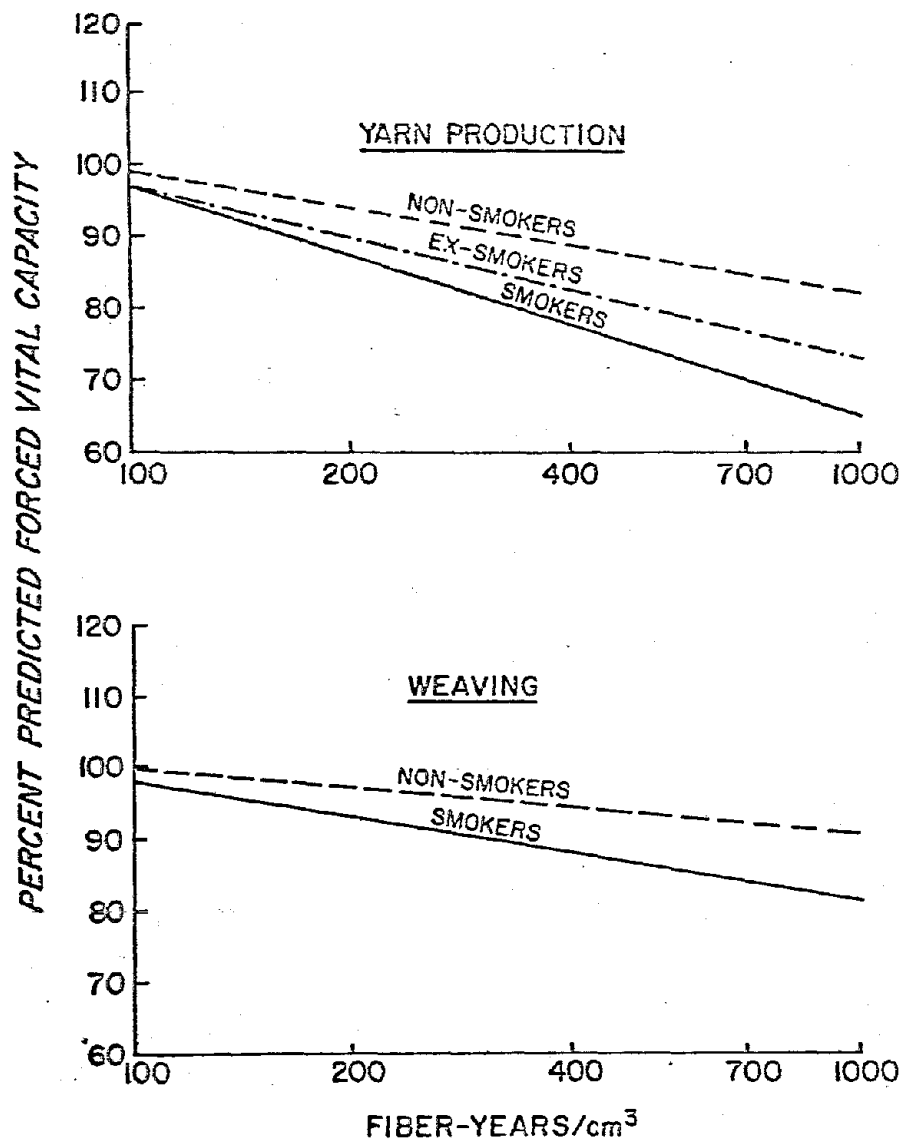
where X = \log_{10} [fiber-years/cc]

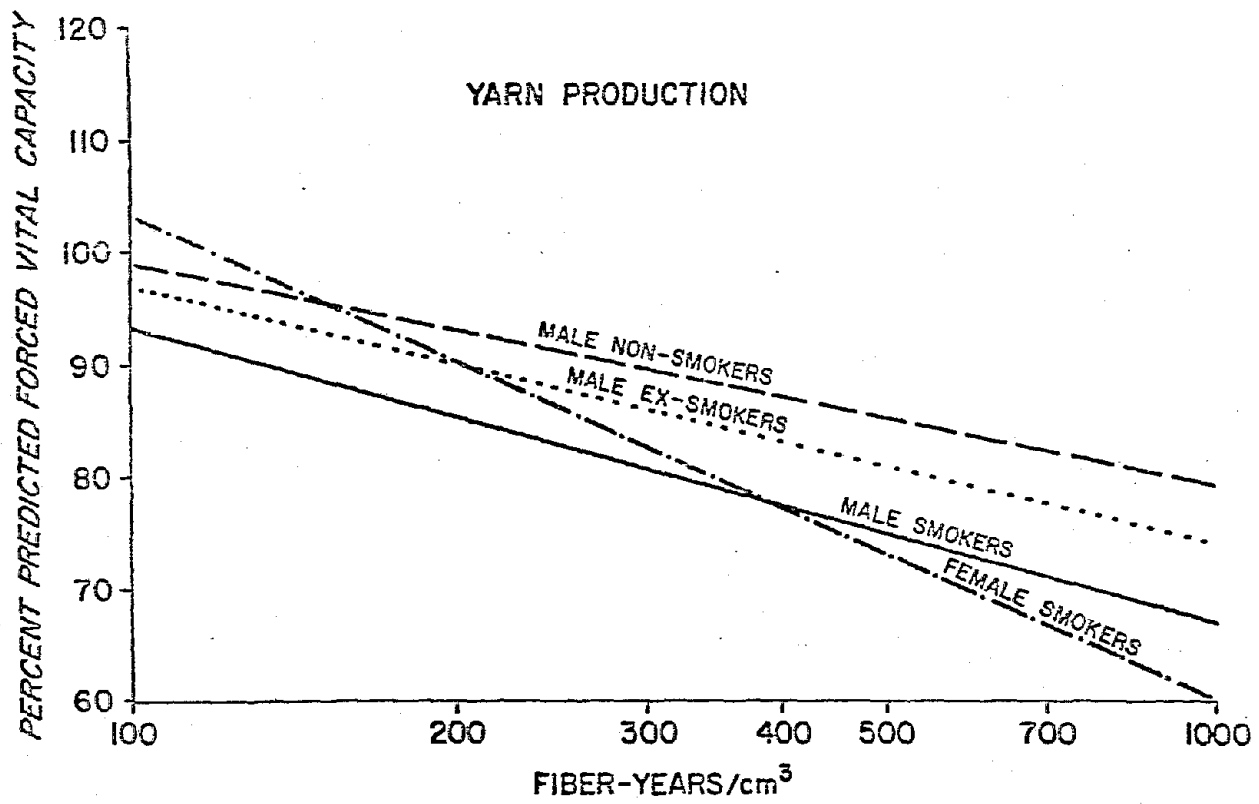
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Figure 1. Regression lines of percent of predicted forced vital capacity vs. years worked (logarithmic scale) for office and production workers with more than 10 years' experience in any of five asbestos textile mills.

Figure 2. Regression lines for percent of predicted forced vital capacity vs. cumulative asbestos exposure (logarithmic scale) for production workers with more than 10 years' exposure in any of five asbestos textile mills.

Figure 3. Regression lines for percent of predicted forced vital capacity vs. cumulative asbestos exposure (logarithmic scale) by sex and smoking for yarn production workers with more than 10 years' exposure in any of five asbestos textile mills.





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