CHAPTER 16

HEALTH STUDIES OF MINERS AND MILLERS EXPOSED TO TALC

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INTRODUCTION

This cross-sectional morbidity study involves miners and millers working with talc from four major talc-producing regions. The composition of the talc is different in each region. New York talc is 14–60% pure talc, while Montana talc is a cosmetic grade with greater than 90% purity. Texas talc is 70–95% pure, while North Carolina talc is 80–92% pure [1–3]. The purpose of this chapter is to examine the association of several risk factors (e.g., age, smoking, region and exposure) and respiratory symptoms, radiographic changes and pulmonary function changes.

At least two types of lung disease have been associated with occupational exposure to talc: (a) silicosis, or a mixed dust fibrosis (from silica content); and (b) interstitial fibrosis (from asbestos content) [4]. Prolonged exposure to cosmetic-grade talc is not associated with pneumoconiosis [4], although talcosis from pure talc has been described [5]. Silica content of the talcs in this study is low. Mineralogical content of the talcs is variable. Of particular interest is the association of pure talc with pleura changes that resemble those seen in workers exposed to asbestos minerals [6]. Pleural thickening has been called a "signpost of asbestos dust inhalation" [7]. The finding of increased prevalence of pleural thickening in talc workers with no known asbestos exposure is of interest in relation to nonasbestos causes of pleural thickening.

Pure talc is a hydrated magnesium silicate. Cosmetic-grade talc is a white, odorless, naturally occurring rock ore containing more than 90% pure talc after flotation. Industrial-grade talc contains variable amounts of the mineral talc and, in some cases, the bulk of the product may be associated minerals such as chlorite [1,8,9]. The United States is the world's largest talc-producing and -exporting nation [10].

The major domestic uses of talc in 1979 were in ceramics (28%), paint (21%), paper (9%), roofing materials (3%), insecticides (4%), cosmetics (6%), plastics (10%), refractories (5%), rubber (3%) and others (10%) (percentages include pyrophyllite) [11].

For the last several decades, industries producing ceramics have been the largest users of talc as virtually all U.S.-produced ceramic wall tile contains up to 65% talc. Talc that contains prismatic tremolite prevents delayed glaze crazing, lowers firing temperatures and reduces shrinkage [10]. Talc is useful in paint in that it improves exterior durability, controls viscosity, brushing and gloss properties, and reduces the cost. The third largest user of talc is the plastics industry, in which it is used as a filler and/or as reinforcement in either thermosetting or thermoplastic resins [11]. In the manufacture of paper, talc performs three functions: paper filling, pitch control and coating [10].

For several years now the U.S. has been nearly self-sufficient in the production of talc for cosmetics and pharmaceuticals. Domestic consumption of talc for all uses has increased from more than 600 short tons in 1960 to more than 900 short tons in 1976 [12]. The estimated demand in the year 2000 is expected to be between 1.5 million and 3 million tons [11]. The increased consumption is primarily the result of the increased use of talc in ceramics, paint, paper and toilet preparations [12].

METHODS

The study population consists of workers who mined and milled talc from four regions of the United States: New York, Montana, Texas and North Carolina. While the New York survey was done several years prior to the Montana, Texas and North Carolina surveys, the medical protocol and equipment were similar, and many of the medical research personnel were the same. Some results from these surveys have been reported elsewhere and include details of the protocol [3,6,13–16]. The industrial hygiene methods and findings in the New York study also have been reported separately [17].

Personal air samples were collected from the breathing zone of miners and millers to determine time-weighted average (TWA) exposures to respirable dust, free silica and mineral particulate. TWA exposures for each job classification in each facility were used in the estimate of dust exposure and particulate exposure for each job. Particulate exposure is reported as particles with an aspect ratio greater than 3:1 and greater than 5 μm in length [3,17]. Work experience at each talc facility was obtained from interviews or personnel records. Cumulative exposure was calculated by multiplying present dust exposure by time spent in a particular job, and then summing all the exposure multiplied by the time scores. The measure of talc exposure for each individual is a cumulative dust exposure score (mg/m^3 × years) and a cumulative particulate exposure score (fibers/mℓ × years). An alternative exposure variable is tenure (years worked in talc). Region, because of the variable nature of the talc, also provides a measure of exposure.

All workers were administered either a Spanish- or English-language version of the British Medical Research Council (BMRC) questionnaire by trained interviewers. Standard PA chest radiographs were read by three "B" readers using the ILO-UC 1971 classification system. A median of the three readings was used for analysis. Flow volume curves from a minimum of five forced expiratory maneuvers were recorded on magnetic tape. Values from the maximum envelope were used for the analysis.

Acute pulmonary function changes defined in terms of before and after shift pulmonary function difference were obtained in Montana, Texas and North Carolina. Association of acute changes with personal dust measurements were analyzed by multiple regression techniques.

A linear logistic model was used to assess the statistical relationship of the independent variables of sex, age, smoking, region and exposure to talc to the dependent variables of respiratory symptoms and pleural changes. Exposure and age were analyzed as continuous variables but were categorized for presentation of results. This analysis was done separately within each region and also with all regions combined.

The significance of each of the independent variables (sex, age, height, weight, smoking, region, exposure) on pulmonary function was assessed by multiple regression techniques.

The entire study population was classified according to smoking habits, and presence or absence of cough, phlegm, dyspnea and pleural thickening. Multiple regression techniques were used to adjust for the effects of age, height, sex, smoking and region. Residual pulmonary function is reported for each category.

RESULTS

Environmental Difference

Separation of the study population by region in part reflects the regional differences in talc composition and worker exposure to respirable dust, free silica and particulate. The mines in each region had less airborne dust than did the mill, although the mean difference was not large in New York. The Texas mills had the highest dust concentrations; North Carolina had the lowest. Free silica exposure was less than the 0.1 mg/m^3 federal standard in all regions. Six bulk samples from New York had a range of <0.25 to 2.6% free silica and a median value of 0.75% [3,16]. The range of TWA respirable free silica exposure was not detectable to 0.02 mg/m^3 [17]. Analyses from Texas and North Carolina showed 2.2% and 1.5% free silica, respectively, and free silica was below the limit of detection (<0.8%) for Montana (Table I).

A major difference in the talc was in the particulate content. No particulates were observed by light microscopy in talc from Montana, Texas and North Carolina. Airborne particulate greater than 5 μm in length was identified in the New York talc. When analyzed by the analytical electron microscope, selected area electron diffraction and microchemical analysis, it was found to contain 7% tremolite and 65% anthophyllite [3,17]. Airborne median fiber lengths determined by the electron microscope were 1.5 μm and 1.6 μm for tremolite and 1.4–1.5 μm for anthophyllite in the mill and mine. Median diameters were 0.13 μm for anthophyllite and 0.19 μm for tremolite. Median aspect ratio for anthophyllite was 9.5 (52% with <10:1 ratio). For tremolite, the median aspect ratio was 7.5 (70% with <10:1 ratio).

Tremolite and antigorite particulates 0.5–3 μm in diameter and 4–30 μm in length were identified by electron microscope in Texas talc, and North Carolina talc showed acicular particles with aspect ratios of 5–100:1 that may have resulted from mechanical destruction of talc plates [6,15,16].

Table I. Characteristics of Airborne Talc Samples by Region

	New York	Montana	Texas	North Carolina
Geometric mean TWA respirable breathing zone samples				
Mass, mg/m^3				
Mine	0.90	0.66	0.45	0.14
Mill	0.97	1.1	1.56	0.26
Free Silica, mg/m^3	0.06	<LOD[a]	0.09	<LOD[a]
Geometric mean airborne particulate concentration >5 μm/cc (optical microscopy)				
Mine	4.4	0	0	0
Mill	3.4	0	0	0

[a]Level of detection = 0.04 mg/m^3.

Demography

There were also regional differences in the study population of each region. There were no women working in the New York and Texas talc regions. The highest proportion of smokers was in North Carolina, but the heaviest smokers were in New York. Montana had the highest proportion of non-smokers; Texas smokers and ex-smokers smoked the least of all regions.

The average number of years worked was relatively short: 10 years in New York and North Carolina and about 5 years in Montana and Texas. Estimated cumulative dust exposure was highest in Texas and lowest in North Carolina, and is reflected in the very low average respirable dust exposure of 0.28 mg/m^3 in North Carolina and the high value of 2.64 mg/m^3 in Texas (Table II).

There were few large differences in age, height and weight among the regions. North Carolina males were, on average, about 10 years older than Montana males, and Texas males were on average 2–5 cm shorter and weighed 2 kg less than males in the other regions (Table III).

There was little evidence of pneumoconiosis as seen on the chest radiographs. There were four cases of Grade 1 irregular opacities and two cases of pleural calcification in New York and one case each in Texas and Montana of Grade 1 small rounded opacities. There was 9% pleural thickening in all regions. (Pleural thickening was the only radiographic change for which further analysis will be done.)

Symptoms and Pleural Thickening by Region

This section reports on whether, within each region, our measures of exposure are associated with (predictive of) changes in prevalence of respiratory symptoms and pleural thickening, after adjustments for age and smoking.

The predicted or expected prevalence of cough, phlegm, dyspnea and pleural thickening within each region was calculated using the logistic model: % prevalence = $\alpha + \beta_1(\text{age}) + \beta_2(\text{smoking})$.

The exposure variables, years worked and cumulative dust exposure were entered in the model separately; in New York, cumulative particulate exposure was included as a third exposure variable. The association of exposure with prevalence can be evaluated by comparing actual prevalence with age and smoking-adjusted predicted prevalence of respiratory symptoms and pleural changes (Tables IV–VIII).

In New York, Montana and North Carolina, cough and phlegm showed no demonstrated association with any of the exposure variables. In Texas, estimated dust exposure showed a statistically significant association with

Table II. Demographic Characteristics of Talc Study Population

	New York	Montana	Texas[a]	North Carolina	Total
n	121	177	71	51	420
Sex, %					
Male	100	81	100	78	89
Female	---	19	---	22	11
Smoking, %					
Nonsmokers	21	33	20	22	26.1
Ex-smokers	31	21	27	18	24.4
Cigarettes/day (SD)	27.8 (18.5)	22.6 (14.9)	12.2 (14.2)	21.4 (15.7)	22.4 (17.0)
Pack-years (SD)	25.2 (26.3)	15.7 (17.9)	13.3 (20.7)	18.2 (16.5)	18.9 (22.0)
Smokers	48	46	54	61	49.5
Cigarettes/day (SD)	27.0 (10.8)	20.4 (11.0)	14.5 (11.1)	20.4 (10.0)	21.1 (11.5)
Pack-years (SD)	26.1 (17.1)	17.9 (16.9)	14.3 (19.7)	23.7 (21.8)	20.1 (18.3)
Years Worked (SD)	10.6 (9.0)	6.6 (6.3)	5.5 (5.7)	10.1 (8.6)	7.9 (7.6)
Average Dust Exposure (mg/m^3)	0.70 (.45)	1.21 (.94)	2.13 (5.71)	0.28 (.33)	
Cumulative Dust Exposure (mg/m^3 × years)	7.0 (7.3)	5.9 (7.6)	11.3 (45.1)	3.0 (4.8)	5.9 (8.0)
Average Particulate Exposure (fiber/mℓ)	3.6 (2.2)	---	---	---	---
Cumulative Particulate Exposure (fiber/mℓ × years)	38.8 (43.0)	---	---	---	---

[a]Worker with cumulative exposure >300 was deleted.

Table III. Demographic Characteristics of Talc Study Population

	New York	Montana	Texas	North Carolina	Total
n	121	177	71	51	420
Mean Age (SD)	38.6 (11.7)	34.9 (11.5)	38.0 (13.7)	43.1 (12.6)	37.4 (12.3)
Males	38.5 (11.7)	33.3 (10.9)	38.0 (13.7)	43.7 (13.2)	37.0 (12.4)
Females	---	41.6 (12.1)	---	41.0 (10.4)	41.4 (11.6)
Height, cm (SD)	176.1 (6.0)	175.5 (8.8)	173.0 (6.9)	172.5 (8.3)	174.9 (7.8)
Males	176.0 (6.0)	178.6 (6.3)	173.0 (6.9)	175.1 (6.7)	176.4 (6.7)
Females	---	162.5 (5.5)	---	162.9 (6.2)	162.6 (5.6)
Weight, kg (SD)	80.8 (13.1)	77.8 (13.5)	78.3 (15.1)	78.2 (16.3)	78.7 (13.9)
Males	80.8 (13.1)	80.5 (12.4)	78.3 (15.1)	80.4 (16.9)	80.1 (13.5)
Females	---	66.6 (12.1)	---	70.0 (11.2)	67.4 (11.8)
Frequency of Radiograph Findings, n, %					
n	121	161	69	49	400
Round opacities (Grade 1)	1 (0.8)	1 (0.6)	1 (1.4)	1 (2.0)	4 (1.0)
Irregular opacities (Grade 1)	4 (3.3)	0	0	0	4 (1.0)
Pleural thickening					
Unilateral	4 (3.3)	1 (0.6)	5 (7.3)	3 (6.0)	13 (3.0)
Bilateral					
Extent 1	4 (3.3)	5 (3.1)	2 (2.9)	6 (12.0)	17 (4.0)
Extent 2	6 (5.0)	0	2 (2.9)	0	8 (2.0)
Pleural calcification	2 (1.7)	0	0	0	2 (1.0)

phlegm. However, it did not show a dose-response relation because prevalence in the high and low exposure categories was less than expected and elevated only in the medium exposure category (Tables IV and V).

There was no demonstrated association of dyspnea with exposure in Montana, Texas or North Carolina. In New York, dyspnea showed no obvious association with tenure or estimated particulate exposure, but the prevalence was significantly higher than expected in the medium and high dust exposure groups (Table VI).

There was no statistically significant association of pleural thickening (unilateral and bilateral combined) with exposure in Montana, Texas or North Carolina. In New York, tenure was statistically associated with combined pleural thickening and the higher than expected prevalence occurred in the group working 15 or more years. A similar relationship was observed

Table IV. Prevalence of Cough[a] Among Talc Workers by Region and Exposure Category[b]

	Cumulative Exposure Categories								
	Years Worked			Dust			Particulate		
Region	0–5	6–15	>15	<1	1–5.9	>6	<19	19–79	>79
New York	$p > 0.30$			$p > 0.20$			$p > 0.40$		
n	55	29	37	18	56	47	59	39	23
Observed	25.5	48.3	35.1	16.7	39.3	34.0	30.5	41.0	30.4
Expected	28.9	42.2	34.8	27.9	32.4	38.0	32.0	37.2	33.2
Montana	$p > 0.60$			$p > 0.60$					
n	95	64	18	54	64	59			
Observed	14.7	20.3	11.1	14.8	17.2	16.9			
Expected	14.5	18.0	20.8	17.0	15.0	17.4			
Texas	$p > 0.10$			$p > 0.60$					
n	41	23	7	27	26	18			
Observed	19.5	17.4	0	7.4	30.8	11.1			
Expected	17.5	15.5	17.8	15.4	17.1	18.9			
North Carolina	$p > 0.20$			$p > 0.70$					
n	19	18	14	32	10	9			
Observed	26.3	27.8	21.4	18.8	50.0	22.2			
Expected	23.9	26.9	25.9	24.5	32.8	21.0			

[a]Cough = answering yes to the question: "Do you cough on most days for as much as three months each year?"
[b]Expected values adjusted for age and smoking.

Table V. Prevalence of Phlegm[a] Among Talc Workers by Region and Exposure Category[b]

	Cumulative Exposure Categories								
	Years Worked			Dust			Particulate		
Region	0–5	6–15	>15	<1	1–5.9	>6	<19	19–79	>79
New York	$p > 0.60$			$p > 0.40$			$p > 0.40$		
n	55	29	37	18	56	47	59	39	23
Observed	25.5	62.1	24.3	11.1	41.1	34.0	27.1	51.3	21.7
Expected	30.9	43.1	31.0	28.4	35.6	33.9	33.5	38.0	27.8
Montana	$p > 0.30$			$p > 0.50$					
n	95	64	18	54	64	59			
Observed	16.8	20.3	5.6	16.7	17.2	16.9			
Expected	16.1	18.0	17.8	17.1	16.5	17.4			
Texas	$p > 0.30$			$p > 0.05$			$p < 0.05$ for dust exposure when both exposure variables are in the model.		
n	41	23	7	27	26	18			
Observed	19.5	17.4	0	7.4	26.9	16.7			
Expected	18.8	14.1	14.9	15.2	17.4	18.7			
North Carolina	$p > 0.50$			$p > 0.60$					
n	19	18	14	32	10	9			
Observed	15.8	27.8	28.6	12.5	50.0	33.3			
Expected	15.7	25.5	31.6	21.0	30.5	25.0			

[a]Phlegm = answering yes to the question: "Do you bring up phlegm on most days for as much as three months each year?"
[b]Expected values adjusted for age and smoking.

with cumulative dust and particulate exposure groups, but the elevated prevalences in the high exposure categories were not statistically significant (Table VII).

Bilateral pleural thickening showed some statistically significant association with one of the exposure variables in each region. In New York, the significant association was with tenure and was elevated only in the group working longer than 15 years. In Montana, the significant association was with cumulative dust exposure. The association was dose related as the higher than expected prevalence occurred in the high exposure group. In Texas, the association was also with dust exposure but was not dose related as the higher than expected prevalence occurred only in the medium exposure category. The strongest association was in North Carolina and was with tenure. Twice the expected prevalence occurred in the >15 years worked category, and half

Table VI. Prevalence of Dyspnea[a] Among Talc Workers by Region and Exposure Category

	Cumulative Exposure Categories								
	Years Worked			Dust			Particulate		
Region	0–5	6–15	>15	<1	1–5.9	>6	<19	19–79	>79
New York	$p > 0.80$			$p < 0.025$			$p > 0.70$		
n	55	37	29	18	56	47	59	39	23
Observed	12.7	21.6	17.2	0	16.1	23.4	15.3	12.8	26.1
Expected	12.5	21.6	17.6	14.2	13.9	20.6	14.4	17.1	21.2
Montana	$p > 0.50$			$p > 0.30$					
n	95	64	18	54	64	59			
Observed	2.1	4.7	5.6	5.6	1.6	3.4			
Expected	2.2	4.5	6.1	2.7	3.0	4.4			
Texas	$p > 0.40$			$p > 0.70$					
n	41	23	7	27	26	18			
Observed	9.8	8.7	0	7.4	7.7	11.1			
Expected	7.4	10.2	8.8	6.7	9.9	8.9			
North Carolina	$p > 0.30$			$p > 0.30$			Expected values adjusted for age only, as there was 0 prevalence among nonsmokers.[b]		
n	19	18	14	32	10	9			
Observed	5.3	11.1	0	3.1	0	22.2			
Expected	3.5	5.4	9.7	5.2	4.8	9.3			

[a]Dyspnea = answering yes to the question: "Do you get short of breath walking with other people of your own age on level ground?"
[b]Expected values adjusted for age and smoking in New York, Montana and Texas; for age only in North Carolina.

the expected prevalence occurred in the 5 years worked category after adjustment for age (Table VIII).

Thus, within each region there was no consistent association of respiratory symptoms with estimated talc exposure or tenure. Bilateral (but not unilateral) pleural thickening was associated with either tenure or estimated dust exposure in each region.

Symptoms and Pleural Thickening–Role of Age, Smoking and Region

In this part of the analysis all regions are combined. The association of the independent variables of age, smoking and region with respiratory symptoms and pleural thickening are analyzed.

Table VII. Prevalence of Unilateral and Bilateral Pleural Thickening Among Talc Workers by Region and Exposure Categories[a]

	Cumulative Exposure Categories								
	Years Worked			Dust			Particulate		
Region	0–5	6–15	>15	<1	1–5.9	>6	<19	19–79	>79
New York	$p < 0.05$			$p > 0.80$			$p > 0.20$		
n	55	29	37	18	56	47	59	39	23
Observed	0	6.9	32.4	5.6	5.4	21.3	6.8	7.7	30.4
Expected	3.5	7.2	27.0	7.0	6.7	19.1	7.0	11.3	23.8
Montana	$p > 0.20$			$p < 0.10$					
n	82	62	17	51	55	55			
Observed	1.2	4.8	11.8	2.0	1.8	7.3			
Expected	2.2	4.8	7.3	3.2	3.2	4.7			
Texas	$p > 0.95$			$p > 0.10$					
n	40	23	6	27	26	16			
Observed	12.5	13.0	16.7	7.4	23.1	6.3			
Expected	11.6	14.9	15.8	9.7	14.3	16.6			
North Carolina	$p > 0.10$			$p > 0.95$					
n	19	17	13	31	10	8			
Observed	10.5	23.5	23.1	16.1	30.0	12.5			
Expected	15.7	18.3	22.4	17.6	18.8	20.8			

[a]Expected values adjusted for age and smoking in New York and Texas. Expected values adjusted for age only in Montana and North Carolina (zero prevalence among nonsmokers).

The age effects are adjusted for smoking, and smoking effects are adjusted for age differences. The association of prevalence with region is evaluated after adjustment for age, smoking and years worked.

Increased prevalence of cough was significantly predicted by increased age, current smoking habits and region. Ratios of observed to expected prevalence of cough were elevated 1.5 times in older compared to younger workers, almost 4 times in smokers compared to nonsmokers and 1.6–2.2 times higher in New York than in the other three regions (Table IX).

The results for phlegm are similar to those for cough, except that the association with age does not reach statistical significance (Table X).

The overall prevalence of dyspnea was about one-third that of cough and phlegm. Age was significantly related to the increased prevalence of dyspnea. There was no statistically significant association with smoking,

Table VIII. Prevalence of Bilateral Pleural Thickening Among Talc Workers by Region and Exposure Category[a]

	Cumulative Exposure Categories								
	Years Worked			Dust			Particulate		
Region	0–5	6–15	>15	<1	1–5.9	>6	<19	19–79	>79
New York	$p < 0.05$			$p > 0.80$			$p > 0.20$		
n	55	29	37	18	56	47	59	39	23
Observed	0	3.4	24.3	0	3.6	17.0	3.4	7.7	21.7
Expected	2.4	4.4	20.1	5.2	5.0	13.4	5.1	7.8	17.2
Montana	$p > 0.10$			$p < 0.05$					
n	82	62	17	51	55	55			
Observed	0	4.8	11.8	2.0	0	7.3			
Expected	1.5	4.2	7.0	2.5	2.6	4.2			
Texas	$p > 0.90$			$p < 0.05$					
n	40	23	6	27	26	16			
Observed	5.0	8.7	0	3.7	7.7	6.3			
Expected	5.1	6.9	6.2	4.0	7.0	6.9			
North Carolina	$p < 0.025$			$p > 0.30$					
n	19	17	13	31	10	8			
Observed	5.3	11.8	23.1	6.5	30.0	12.5			
Expected	12.0	12.3	12.6	12.2	12.3	12.4			

[a]Expected values adjusted for age and smoking in New York. Expected values adjusted for only age in Montana, Texas and North Carolina (zero prevalence among nonsmokers in Montana and North Carolina; zero prevalence among nonsmokers and ex-smokers in Texas).

although the ratio of observed to expected prevalence among ex-smokers was elevated compared to nonsmokers and current workers. Region was significant, as New York talc workers had a significantly higher prevalence of dyspnea than did workers in the other three regions (Table XI).

There was an overall prevalence of 3% unilateral pleural thickening and 6% bilateral pleural thickening (8 cases of Extent 2; 17 cases of Extent 1). All independent variables in the model (age, smoking, tenure, region) showed a statistically significant association with combined unilateral and bilateral pleural thickening. Age was strongly related to the occurrence of combined categories of pleural thickening as 85% of those with pleural thickening were over the age of 40. Smokers and ex-smokers had a slightly higher than

Table IX. Prevalence of Cough[a] by Age, Smoking and Region Among Talc Populations

	Prevalence, %				
	n	Observed	Expected	Ratio: Observed/ Expected × 100	Comment
Total	420	22.6			
Age					$p < 0.025$
≤40	248	19.0	22.8	83	Expected values adjusted
≥40	172	27.9	22.4	125	by smoking.
Smoking Status					$p < 0.0005$
Nonsmokers	111	8.1	21.1	38	Expected values adjusted
Ex-smokers	102	17.6	24.8	71	by age.
Smokers	207	32.9	22.4	147	
Region					$p < 0.005$
New York	121	33.9	22.8	149	Expected values adjusted
Montana	177	16.4	20.5	80	by age, smoking and years
Texas	71	16.9	24.4	69	worked. Years worked,
North Carolina	51	25.5	26.9	95	$p > 0.60$.

[a]Cough = answering yes to the question: "Do you cough on most days for as much as three months each year?"

expected prevalence, as did the longest tenured category of workers. Workers in Texas and North Carolina had a higher than expected prevalence, while Montana workers had less than expected prevalence. New York workers had an observed/expected ratio of about 1 (Table XII).

The independent variables of age, smoking and tenure were significant predictors of the prevalence of bilateral pleural thickening. Region, however, was not a significant predictor as there was no detectable difference among the four regions in the age, smoking and tenure-adjusted prevalence of bilateral pleural thickening (Table XIII).

In summary, the prevalence of respiratory symptoms was higher than expected in the older age group, among smokers and among the New York workers. Tenure was not a significant predictor for any of the respiratory symptoms. The major exception was for the symptom dyspnea, which showed no apparent association with the smoking variable.

The prevalence of pleural thickening was higher than expected in the older age group, higher than expected among smokers and elevated among workers with longer tenure. The age, smoking and tenure-adjusted prevalence of combined unilateral and bilateral pleural thickening was higher in

Table X. Prevalence of Phlegm[a] by Age, Smoking and Region Among Talc Populations

	Prevalence, %				
	n	Observed	Expected	Ratio: Observed/ Expected × 100	Comment
Total	420	22.6			
Age					$p > 0.10$
≤40	248	19.8	22.7	87	Expected values adjusted
≥40	172	26.7	22.5	119	by smoking.
Smoking Status					$p < 0.005$
Nonsmokers	111	12.6	21.6	58	Expected values adjusted
Ex-smokers	102	19.6	24.1	81	by age.
Smokers	207	29.5	22.5	131	
Region					$p < 0.005$
New York	121	33.9	22.4	151	Expected values adjusted
Montana	177	16.9	21.3	79	by age, smoking and years
Texas	71	16.9	24.3	70	worked. Years worked,
North Carolina	51	23.6	25.4	93	$p > 0.40$.

[a]Phlegm = answering yes to the question: "Do you bring up phlegm on most days for as much as three months each year?"

Texas and North Carolina than in New York and Montana; there were no significant regional differences in the prevalence of bilateral pleural thickening.

Pulmonary Function (Acute Effects)

The changes in pulmonary function (ΔPFT) over the shift were analyzed in Montana, Texas and North Carolina by multiple linear regression using this model:

$$\Delta PFT = \alpha + \beta_1(\text{sex}) + \beta_2(\text{region}) + \beta_3(\text{smoking status}) + \beta_4(\text{dust})$$

The only model that achieved statistical significance was that showing changes in FVC. Mean change was −21 mℓ (SD = 219). Smoking and region were statistically significant independent variables, and there was no apparent association with exposure.

Table XI. Prevalence of Dyspnea[a] by Age, Smoking and Region Among Talc Populations

	Prevalence, %				
	n	Observed	Expected	Ratio: Observed/ Expected × 100	Comment
Total	420	8.3			
Age					$p < 0.005$
≤40	248	5.2	7.6	68	Expected values adjusted
≥40	172	12.8	9.3	138	by smoking status.
Smoking Status					$p > 0.40$
Nonsmokers	111	6.3	7.0	90	Expected values adjusted
Ex-smokers	102	13.7	10.5	130	by age.
Smokers	207	6.8	8.0	85	
Region					$p < 0.005$
New York	121	16.5	9.0	183	Expected values adjusted
Montana	177	3.4	7.2	47	by age, smoking and years
Texas	71	8.5	8.8	97	worked. Years worked,
North Carolina	51	5.9	10.0	59	$p > 0.90$.

[a]Dyspnea = answering yes to the question: "Do you get short of breath walking with other people of your own age on level ground?"

Pulmonary Function (Chronic Effects)

The association of baseline pulmonary function with the exposure variables was estimated in a linear regression model that also included sex, age, height and smoking status. Within each region exposure was *not* a significant predictor of reduced pulmonary function. The three exceptions were the following: reductions in forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were associated with increasing particulate exposure among New York workers, and reduced FVC was associated with increasing dust exposure in Montana workers. Age was consistently a significant predictor for all pulmonary function parameters. The calculated age reductions in FEV_1 and FVC were larger in New York than in the other regions; the age coefficient for flowrates, however, showed no consistent regional pattern (Table XIV). If amount smoked (pack-years, cigarettes smoked per day), instead of smoking category, was the smoking variable in the model, there was little variance by region in the age coefficients for FEV_1. With that exception, it made little difference which smoking variable

Table XII. Prevalence of Unilateral and Bilateral Pleural Thickening by Age, Smoking, Years Worked and Region Among Talc Populations

		Prevalence, %			
	n	Observed	Expected	Ratio: Observed/ Expected × 100	Comment
Total	400	9.5			
Age					$p < 0.0005$
≤40	233	2.1	8.6	24	Expected values adjusted
≥40	167	19.8	10.7	185	by smoking status.
Smoking					$p < 0.025$
Nonsmokers	102	2.9	7.6	38	Expected values adjusted
Ex-smokers	98	15.3	13.2	116	by age.
Smokers	200	10.0	8.7	115	
Years Worked					$p < 0.01$
≤5	196	4.1	5.7	72	Expected values adjusted
6–14	131	9.2	10.4	88	by age and smoking.
≥15	73	24.7	18.1	136	
Region					$p < 0.01$
New York	121	11.6	12.1	96	Expected values adjusted
Montana	161	3.7	6.9	54	by age, smoking and years
Texas	69	13.0	8.3	157	worked.
North Carolina	49	18.4	13.4	137	

was entered in the model. Within each region, the most consistent predictors of pulmonary function were sex, age and height. There was no consistent association with smoking and exposure.

The effect of the independent variables (sex, age, height, smoking, region and tenure) can be seen more easily in the model, where all regions are combined (Table XV).

The smoking effect was analyzed using smoking categories (nonsmoker, ex-smoker, smoker) or the continuous measures of pack-years and cigarettes smoked per day. Discussion will be limited to the model using smoking categories, unless stated otherwise.

Weight was not a significant predictor for any of the pulmonary function parameters. Tenure was only a significant predictor for FVC and FEV_1. Smoking was significantly associated with reductions in FEV_1, FEF_{50} and FEF_{75}. While smoking status was not a significant predictor of FVC, pack-years and cigarettes smoked per day were significant predictors. The age coefficient of FVC for all nonsmokers was about half that for smokers

Table XIII. Prevalence of Bilateral Pleural Thickening by Age, Smoking, Years Worked and Region Among Talc Populations

		Prevalence, %			
	n	Observed	Expected	Ratio: Observed/ Expected × 100	Comment
Total	400	6.3			
Age					$p < 0.0005$
⩽40	233	1.3	6.0	22	Expected values adjusted
⩾40	167	13.2	6.6	200	by smoking.
Smoking					$p < 0.025$
Nonsmokers	102	2.0	5.0	40	Expected values adjusted
Ex-smokers	98	7.1	8.7	82	by age.
Smokers	200	8.0	5.7	140	
Years Worked					$p < 0.0005$
⩽5	196	1.5	3.6	42	Expected values adjusted
6–14	131	6.1	7.2	85	by age and smoking.
⩾15	73	19.2	11.5	167	
Region					$p > 0.30$
New York	121	8.3	8.3	100	Expected values adjusted
Montana	161	3.1	4.1	76	by age, smoking and years
Texas	69	5.8	4.9	118	worked.
North Carolina	49	12.2	10.0	122	

and ex-smokers. Smoking was a significant factor associated with FEV_1 reduction and is reflected in the −42 mℓ/yr age coefficient of smokers, compared to −31 and −24 mℓ/yr for ex-smokers and nonsmokers, respectively.

The statistical significance of region as a predictor of pulmonary function was the same whatever smoking parameter was used as the independent variable, but the rank order of mean pulmonary function by region changed. For example, region was a significant predictor of FVC, FEV_1 and FEF_{50}. The largest adjusted values for FVC and FEV_1 were in North Carolina, followed by Montana. The lowest values for FVC and FEV_1 were in Texas and New York. The rank order changes for FEF_{50}, with the largest mean adjusted FEF_{50} in Texas, the lowest in Montana; the other two regions are intermediate (see Table XV).

In summary, within each region the only independent variables consistently associated with reduced pulmonary function were sex, age and height. When all regions were combined, the independent variables consistently

Table XIV. Pulmonary Function of Talc Workers by Region
MODEL: PFT = $\alpha + \beta_1$(sex) + β_2(age) + β_3(height) + β_4(smoking status) + β_5(years worked) + β_6(cumulative dust exposure) + β_7(cumulative particulate exposure)

	n	Age	Smoking Status	Years Worked	Cumulative Exposure Dust	Cumulative Exposure Particulate	r^2
FVC							
New York	120	−39 (8)[a]	b	+ 2 (12)[b]	+16 (18)[b]	−7 (3)[c]	0.58
Montana	177	−18 (5)[a]	b	+ 8 (9)[b]	−23 (6)[a]	---	0.74
Texas	70	−23 (6)[a]	b	−11 (15)[b]	−11 (7)[b]	---	0.45
North Carolina	46	−12 (20)[b]	b	+ 2 (19)[b]	−33 (31)[b]	---	0.63
FEV_1							
New York	120	−42 (7)[a]	c	− 1 (10)[b]	+16 (15)[b]	−5 (2)[c]	0.65
Montana	177	−33 (5)[a]	c	− 9 (9)[b]	− 7 (6)[b]	---	0.71
Texas	70	−32 (6)[a]	b	− 2 (14)[b]	− 9 (6)[b]	---	0.45
North Carolina	46	−31 (10)[d]	b	+ 6 (16)[b]	−20 (26)[b]	---	0.60
Peak Flow							
New York	120	−46 (22)[c]	c	−15 (35)[b]	− 8 (51)[b]	−4 (8)[b]	0.32
Montana	177	−46 (15)[a]	b	− 8 (26)[b]	0 (18)[b]	---	0.49
Texas	70	−53 (15)[d]	b	+69 (38)[b]	−26 (17)[b]	---	0.22
North Carolina	46	−76 (23)[d]	b	+24 (37)[b]	−75 (60)[b]	---	0.56
FEF_{50}							
New York	120	−47 (18)[c]	b	−26 (28)[b]	+09 (41)[b]	0 (7)[b]	0.30
Montana	177	−60 (12)[a]	c	−35 (22)[b]	+15 (15)[b]	---	0.39
Texas	70	−54 (14)[a]	b	+ 6 (35)[b]	−11 (16)[b]	---	0.24
North Carolina	46	−75 (16)[a]	b	+23 (26)[b]	+ 7 (42)[b]	---	0.43
FEF_{75}							
New York	120	−42 (7)[a]	b	0 (11)[b]	+ 9 (16)[b]	−1 (3)[b]	0.53
Montana	177	−42 (6)[a]	d	−16 (10)[b]	+ 7 (7)[b]		0.55
Texas	70	−35 (6)[a]	b	+ 1 (16)[b]	− 8 (7)[b]		0.36
North Carolina	46	−43 (7)[a]	b	− 2 (11)[b]	+24 (17)[b]		0.62

[a] $p < 0.0005$.
[b] NS $p > 0.05$.
[c] $p < 0.05$.
[d] $p < 0.005$.

associated with reduced pulmonary function were age, height and smoking. For FEV_1 and FVC, sex, region and tenure were also significant predictors of reduced function.

Symptoms and Pleural Thickening–Relation to Pulmonary Function

Workers with cough, phlegm, dyspnea and pleural thickening had a reduced FEV_1 and FVC compared to workers without these symptoms and X-ray changes (Table XVI).

Table XV. Pulmonary Function in the Entire Talc Population

MODEL: $PFT = \alpha + \beta_1(\text{sex}) + \beta_2(\text{age}) + \beta_3(\text{height}) + \beta_4(\text{cigarettes/day}) + \beta_5(\text{region}) + \beta_6(\text{years worked})$

	FVC	FEV_1	Peak Flow	FEF_{50}	FEF_{75}
Sex	a	a	a	b	b
Male	4.89 (0.04)	3.78 (0.03)	8.92 (0.09)	4.40 (0.08)	1.51 (0.03)
Female	4.16 (0.13)	3.32 (0.11)	7.61 (0.34)	4.28 (0.28)	1.42 (0.12)
Age	a	a	a	a	a
	−23 (3)	−34 (3)	−46 (9)	−55 (7)	−40 (3)
Height	a	a	a	c	d
	+63 (5)	+45 (4)	+89 (13)	+33 (10)	+12 (4)
Cigarettes/day	d	c	d	c	a
	−4 (2)	−7 (2)	−11 (6)	−13 (5)	−8 (2)
Region	a	d	b	d	b
New York	4.39 (0.09)	3.46 (0.08)	8.27 (0.22)	4.38 (0.18)	1.53 (0.08)
Montana	4.66 (0.06)	3.57 (0.06)	8.49 (0.16)	4.03 (0.13)	1.39 (0.06)
Texas	4.36 (0.11)	3.45 (0.09)	8.41 (0.28)	4.56 (0.23)	1.42 (0.10)
North Carolina	4.70 (0.11)	3.72 (0.10)	7.88 (0.28)	4.40 (0.23)	1.52 (0.10)
Years Worked	d	d	b	b	b
	−13 (5)	−11 (5)	−8 (14)	−12 (11)	−4 (5)
r^2	0.61	0.63	0.39	0.31	0.50

[a] $p < 0.0005$.
[b] NS $p > 0.05$.
[c] $p < 0.005$.
[d] $p < 0.05$.

Table XVI. Characteristics of Talc Workers With and Without Cough, Phlegm, Dyspnea and Pleural Changes

		Residual Pulmonary Function			
	n	FVC (mℓ)	FEV_1 (mℓ)	FEF_{50} (mℓ/sec)	FEF_{75} (mℓ/sec)
Cough					
None	258	55 (604)	55 (505)	84 (1,294)	25 (595)
Mild (morning or day)	61	– 21 (718)	– 49 (703)	–130 (1,329)	– 50 (543)
Chronic (<3 mo/yr)	93	–137 (632)	–121 (553)	–147 (1,357)	– 37 (496)
Phlegm					
None	252	44 (647)	31 (574)	7 (1,326)	– 1 (599)
Mild	65	– 50 (515)	– 36 (477)	24 (1,365)	75 (577)
Chronic	95	– 83 (656)	– 59 (543)	– 34 (1,291)	– 26 (461)
Dyspnea					
None	284	74 (616)	63 (541)	71 (1,302)	20 (596)
Grade 1	93	–187 (618)	–119 (519)	– 9 (1,303)	– 18 (478)
Grade 2	35	–102 (690)	–194 (647)	–551 (1,360)	–117 (539)
Pleural Thickening					
None	355	53 (577)	31 (502)	26 (1,321)	7 (573)
Unilateral	13	–378 (487)	–166 (402)	23 (1,116)	– 28 (394)
Bilateral	24	–506 (849)	–469 (746)	–651 (1,443)	–196 (434)

DISCUSSION

In this chapter we have tried to answer basically two questions. The first concerns the within-region relationship of exposure to respiratory symptoms, radiographic changes and pulmonary function changes. The independent variables, such as sex, age and smoking, have been treated as confounding variables; thus, the dose-response relationship is adjusted for differences in these variables. The measures of exposure we have used are tenure and calculated cumulative exposure to respirable dust. In New York, an additional exposure parameter was cumulative particulate exposure. Particulate is defined as particles seen under the light microscope and with dimensions greater than 5 μm in length and aspect ratios greater than 3:1.

The conclusion from the analysis of intraregion dose-response relations is that there is no consistent or strong association of exposure with respiratory symptoms and pulmonary function. The major exceptions were among New York talc workers, where there was a statistically significant dose-response relationship of dust with dyspnea and particulate with FVC and FEV_1. The associations are not particularly strong ones.

The difference between observed and expected dyspnea in the medium and high exposure categories is only 2%. The reduction of FEV_1 with increased particulate exposure would result in a calculated mean reduction of about 194 mℓ FEV_1 (−5 mℓ/average particulate/cc × years). The loss of FEV_1 attributed to age is larger in New York than the other regions, but the difference is not great and becomes smaller if the smoking adjustment is cigarettes per day or pack-years instead of just smoking status. In fact, when cigarettes per day is the smoking variable, the association of particulate exposure with reductions in FEV_1 is not significant. When pack-years is the smoking variable, the reduction of FEV_1 associated with age is −33 mℓ/yr, which is similar to the −27 mℓ/yr and −28 mℓ/yr in Montana and Texas. The association of reduced FVC with particulate exposure is of the same order of magnitude as for FEV_1, but the reduction of FVC with age is considerably greater in New York than in the other regions, thereby making the FVC-particulate association more biologically significant. In Montana there was a strong association of dust exposure with reduced FVC. The reduction of FVC with age, however, was small (−18 mℓ/yr).

The most consistent intraregion dose-response relationship was with bilateral pleural thickening. There was a statistically significant association of bilateral pleural thickening with exposure estimate in each of the regions, and it was dose related in all regions except Texas. We will discuss this association further later in the chapter.

The problems of estimating the true significance of these statistical relationships are many. They include such things as variability in dose and response measurements at the time of the study and selection. A problem in all occupational epidemiological studies relates to the estimate of past exposure. For this analysis we have assumed past exposure in each job to have remained the same, or at least proportionally the same. There is evidence that in at least some jobs over these past few years there has been a reduction in the exposure. If so, then some individuals have a higher actual cumulative exposure than was calculated in this study. If this were the only exposure misclassification occurring, then the calculated dose-response association would appear to be of greater magnitude that it is in truth, and the biological significance of these statistical associations would be reduced. As we cannot know the true relationship, we cannot just isolate one or two p values less than 0.05 and attach great significance to those one or two findings. Our interpretation must be made in light of all that we know from this, as well as other studies.

The second major concern of this study was to examine the relationship of our "health measures" with independent variables such as age, smoking, tenure and region. We looked not at each region separately, as in the first question, but at the total talc population. Exposure in this analysis was tenure (years worked). Estimated dust and particulate exposure cannot be used in this analysis because of the regional differences in talc mineralogy and composition. Thus, to some extent, region is also a measure of exposure. The appropriateness of region as an exposure variable is, in part, a function of the importance of nonoccupational regional differences such as climate, health, nutrition, preexisting medical conditions and selection. The differences in the amount of talc dust exposure also may be important but, like the nonoccupational regional differences, are not quantitatively evaluated in the combined analysis.

The conclusions from the analysis of the total talc populations are generally consistent with what has been observed in other occupational groups. The most predominant variables associated with increased respiratory symptoms were increased age and smoking. While age was not a statistically significant predictor of the prevalence of phlegm, the observed prevalence was in the expected direction and was quite similar in magnitude to that seen in cough. While smoking was not a statistically significant predictor for dyspnea, the highest prevalence was among ex-smokers, a finding that does not contradict the idea that smokers stop smoking because they are getting short of breath. Smoker's cough and phlegm may not be taken as seriously as dyspnea and, therefore, the same selection process may not be occurring.

Tenure, which is closely correlated with age ($r = 0.60$), was not a significant predictor of symptom prevalence. The lack of association of chronic cough and chronic phlegm with tenure in the total population and with all measures of exposure within each region does not support the idea that talc dust exposure plays a role in causing "occupational" or "industrial" bronchitis [18]. Both FEV_1 and flow at low lung volumes were reduced in workers with cough and phlegm, suggesting that both dust and cigarette smoke may be the etiologic agents [19].

Airway obstruction was related to increasing severity of cough and phlegm. However, the dose-response relation was better with FEV_1 than with expiratory flow at low lung volumes.

The finding of regional differences in the prevalence of respiratory symptoms is not unexpected, as the principal causes of "obstructive bronchitis" appear to be smoking and social factors [4], and significant regional differences in prevalence are not uncommon [4,18,20]. Part of the excess may be due to the greater amount of smoking among New York talc workers, but it is unlikely to be the complete answer. The differences also may be due to the small size of the populations.

Sex, age, height and smoking were, in general, significant predictors of pulmonary function. The exceptions are interesting in that sex and height were not as significant as predictors for expiratory flowrates as they were for FVC and FEV_1. Smoking was a significant predictor for all pulmonary function parameters, although there was no statistically significant difference in FVC by smoking category.

Tenure was only a significant predictor for FVC and FEV_1, and the predicted loss associated with tenure was one-third to one-half that associated with age. The most consistent regional differences were in FVC and FEV_1. North Carolina workers had the largest adjusted mean FVC and FEV_1, while New York and Texas workers had the lowest mean values. There were some significant regional differences in FEF_{50}, but the order was different than for volumes, as the lowest values were among Montana workers and the highest among Texas workers.

The explanation for a regional difference in pulmonary function and symptoms is a difficult one, especially in the absence of local comparison populations and a large biologically significant association with exposure. Symptoms and pulmonary function do not show a convincing association with exposure, and the regional differences could well be due to unmeasured and unknown factors.

Pleural thickening presents a somewhat different picture. There is a fairly consistent association with some measures of exposure (tenure, dust). The association with age and smoking is even stronger. Bilateral pleural thickening is commonly associated with asbestos exposure, although the causal agent remains unclear [4,7].

Parkes [4] points out that pleural changes associated with asbestos exposure are bilateral and entirely distinct from diffuse fibrosis. About half the time that pleural plaques are present there is no evidence of asbestosis. The correlation of pneumoconiosis and pleural changes in this study was even less, as there was a total of only eight cases of Grade 1 pneumoconiosis (four round opacities, four irregular opacities). The prevalence of pleural thickening in these talc populations was elevated compared to other mining populations [6,14]. Several items suggest that asbestos may not be the (only) causal agent for pleural thickening:

1. This study and others [4,6] show a lack of a close association between pleural changes and pneumoconiosis.
2. This study and others [6,15,16,21-23] show the presence of pleural changes in populations with no known asbestos exposure.
3. There is an absence of pleural changes in populations with asbestos exposure [24,25].

The role of asbestos in the etiology of pleural thickening is of interest in this study because of the original finding of an excess prevalence of pleural thickening among New York talc workers. Because of the association of pleural thickening with tremolite and anthophyllite exposure in the New York talc population [6,13,14,17], and the association of pleural thickening with previous exposure to commercial types of asbestos (particularly anthophyllite) [7], we hypothesized that the etiology of the increased prevalence of pleural thickening was from the tremolite and anthophyllite contamination in the talc [3,13,14,16].

While the composition of the talc from these four regions varies considerably, all the talcs in this study appear to be biologically active in terms of the genesis of pleural thickening. Pleural thickening and fibrosis have been observed in workers with prolonged exposure to high concentrations of cosmetic-grade talc [26]. It will be of interest to compare the prevalence of pleural changes in the talc miners and millers exposed to Vermont talc. An increased prevalence of pleural thickening would support the hypothesis arising from this study, i.e., the mineral talc is an etiologic agent in the development of pleural thickening.

A final question pertains to the significance of pleural thickening. Parkes [4] says that plaques themselves have no effect on life expectancy and are not known to result in complications. This study cannot answer questions relating to mortality. Workers with pleural thickening tended to have lower pulmonary function than those without pleural thickening, but these reductions had no clinical significance.

In summary, the most striking finding in this study is the lack of any significant differences in the prevalence of pleural changes, despite the lack of any known asbestos exposure in at least some of the populations. The reasons for these changes are obscure. The known common factor among all four populations is some exposure to the mineral talc.

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REFERENCES

1. Grexa RW, Parmentier CJ: Cosmetic talc properties and specifications. Cosmetics and Toiletries 94:29–33, 1979.
2. McCrone WC, Associates: Analysis of talc by x-ray diffraction and polarized light microscopy. USDHEW/PHS/CDC/NIOSH Contract No. CDC-210-75-0063.
3. Dement JM, Zumwalde RD, Gamble JF, et al.: Occupational exposure to talc containing asbestos. Morbidity, mortality, and environmental studies of miners and millers. DHEW Publication No. (NIOSH)80–115, 1980.

4. Parkes WR: Occupational lung disorders, 2nd ed. London: Butterworths, 1982.
5. Leophante P, et al.: Les pneumoconioses par le talc. Rev Fran Mal Resp 3:363, 1975.
6. Gamble J, Greife A, Hancock J: An epidemiologic-industrial hygiene study of talc workers. Presented at the Inhaled Particles and Vapours Symposium, Cardiff, Wales, September 1980.
7. Sargent EN, Jacobson G, Gordonson JS: Pleural plaques: a signpost of asbestos dust inhalation. Sem Roentgenol 12:287–297, 1977.
8. Hamer DH, Rolle FR, Schelz JP: Characterization of talc and associated minerals. Am Ind Hyg Assoc J 37:296–304, 1976.
9. Cosmetic, Toiletry and Fragrance Association, Inc. Specification for cosmetic talc. October 7, 1976.
10. Clarke GM: Talc, industrial minerals. Metal Bulletin Limited, September 1979.
11. Clifton RA: Talc and pyrophyllite. In: Mineral facts and problems. BOM Bull 671, 1980.
12. Kirk-Othmer Encyclopedia of Chemical Technology, 2nd ed. New York: John Wiley & Sons, Inc., 1969.
13. Gamble JF, Fellner W, DiMeo MJ: Respiratory morbidity among miners and millers of asbestiform talc. In: Lemen R, Dement JM, eds. Dusts and disease. Park Forest South, Illinois: Pathotox Publishers, Inc., 1979.
14. Gamble JF, Fellner W, DiMeo MJ: An epidemiologic study of a group of talc workers. Am Rev Respir Dis 119:741–753, 1979.
15. Gamble JF, Greife A, Hancock J: Cross-sectional epidemiologic and industrial hygiene survey of talc workers mining ore from Montana, Texas, and North Carolina. Proceedings of the National Workshop on Substitutes for Asbestos. EPA Publication No. 560/3-80-001, 1980.
16. Gamble JF, Greife A, Hancock J: Preliminary findings of an epidemiologic study of talc workers. Proceedings of first NCI/EPA/NIOSH Collaborative Workshop, May 6-8, 1980.
17. Dement J, Zumwalde RD: Occupational exposures to talc containing asbestiform minerals. In: Lemen R, Dement JM, eds. Dusts and disease. Park Forest South, Illinois: Pathotox Publishers, Inc., 1979, p. 287.
18. Lapp NL: Industrial bronchitis. In: Morgan WKC, Seaton A, eds. Occupational lung diseases. Philadelphia: W. B. Saunders Co., 1975.
19. Morgan WKC: Industrial bronchitis. Br J Ind Med 35:285–291, 1978.
20. Enterline PE: The effects of occupation on chronic respiratory disease. Arch Environ Health 14:189–200, 1967.
21. Zolov C, Burilkov T, Babadjov L: Pleural asbestos in agricultural workers. Environ Res 1:287–292, 1967.
22. Navratil M, Morgukova K, Trippe F: Follow-up study of pleural hyalinosis in individuals not exposed to asbestos dust. Environ Res 15:108–118, 1978.
23. Rous V, Studeny J: Aetiology of pleural plaques. Thorax 25: 270–284, 1970.
24. Gibbs GW: Etiology of pleural calcification: a study of Quebec chrysotile asbestos miners and millers. Arch Environ Health 34:76–83, 1979.
25. Cortier P: Discussion on pleural plaques. Ann NY Acad Sci 132:387–388, 1965.
26. Vallyathan NV: Talc pneumoconiosis. Resp Ther Nov/Dec 1980.

DISCUSSION

Question: What was your reference population for estimating the expected number of respiratory symptoms?

Response: The total population of talc workers. This is a comparison within this population.

Question: Did you look at any interaction between age and smoking on FEV_1?

Response: No.

Question: Is there tremolite or anthophyllite in any of the talcs?

Response: Tremolite and anthophyllite have been said to be in the New York talc, some tremolite and actinolite can be seen under the electron microscope in Texas talc. Neither of these, as far as I know, is found in either North Carolina or Montana talc.

HEALTH ISSUES RELATED TO METAL AND NONMETALLIC MINING

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