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The Prevalence of Coal Workers' Pneumoconiosis in US Coal Miners

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The National Institute of Occupational Safety and Health of the US Public Health Service recently completed the first round of a large field study to determine the prevalence of coal workers' pneumoconiosis in working US coal miners. Between October 1969 and July 1971, a total of 9,076 miners from 29 bituminous and 2 anthracite mines were examined. An overall prevalence of nearly 30% was found. However, progressive massive fibrosis occurred in only 2.5% of the sample. When the data were broken down according to the geographic region in which the mine is situated, marked regional differences in prevalence were apparent. Thus, while 45% of the Eastern Pennsylvania anthracite miners had simple pneumoconiosis and a further 14% had progressive massive fibrosis, the comparable figures for bituminous miners in Colorado were 4.6% and 0%. No obvious cause for these disparities in prevalence was apparent.

Although there have been several studies of the prevalence of coal workers' pneumoconiosis (CWP) in the United States in the past 20 years, all were limited to a particular geographic location and the data from them are no longer current.[1-5] Thus, until a year or so ago, no information was available to indicate the current prevalence of CWP in working US coal miners. The US Public Health Service (USPHS) and the US Bureau of Mines of the Department of the Interior have recently completed the first round of a nationwide survey of the respiratory health of a large sample of working coal miners. This article includes the latest data on the prevalence of CWP and should serve as a basis for the objective assessment of the effect of recently introduced preventive measures, and in particular, dust control.

Material and Methods

In 1969, the USPHS and the Bureau of Mines began a nationwide study of the prevalence of CWP. This study is henceforth referred to as the Interagency Study of Coal Workers' Pneumoconiosis but has also been referred to elsewhere as the National Study. Thirty-one mines in ten states were selected for inclusion in the study. Twenty-nine were bituminous while two were anthracite mines. Eight mines were located in Pennsylvania (two anthracite, six bituminous); nine in West Virginia; three in Kentucky, two each in Virginia, Alabama, Illinois, and Utah; and one each in Ohio, Indiana, and Colorado. The mines were chosen not on a random basis but so as to represent different seams of coal and different mining methods. Other criteria for selection were a working force of at least 100 miners, an expected economic working life of at least ten years, and preferably some retrospective dust measurements.

Each miner employed at the 31 mines was asked to participate in the study. He was asked voluntarily to undergo, at no charge to him, a medical examination that consisted of standard posteroanterior and left lateral roentgenographic views of the chest, and some simple tests of ventilatory capacity. The latter consisted of three forced expiratory volume maneuvers recorded as flow volume loops.[6,7] Two practice attempts were performed first but were not recorded. Complete details of the equipment and methodology of the spirometric equipment have been published elsewhere. In addition, a slightly modified version of the British Medical Research Council's questionnaire on chronic bronchitis (1966) was administered and a detailed occupational history was taken.[8]

All roentgenograms were independently interpreted according to the UICC Classification[9] by a panel consisting of George Jacobson, MD, Professor and Head, Department of Radiology, University of Southern California; Eugene P. Pendergrass, MD, Emeritus Professor of Radiology, University of Pennsylvania; and the senior author (W.K.C.M.). If there was a consensus in regard to a major category (0, 1, 2, 3, and A, B, C), viz, either all three or two out of three were in agreement, the majority opinion was accepted. If all three disagreed, as occurred about 10% of the time, the opinion of a fourth reader was solicited. In the exceedingly rare instance in which a consensus was still not achieved (< 0.2%), a fifth reader was employed.

The miners were divided into five groups according to declining order of dust exposure: face, transportation, and maintenance workers, those employed in miscellaneous underground work, and finally surface workers. Previous measurements made by the Bureau of Mines have shown that among bituminous miners, face workers are exposed to the greatest, and surface workers to the least, concentrations of respirable dust and that there is a gradient of dust exposure that is related to the miner's job.[10] This information comes from a study of dust levels conducted by the Bureau of Mines in 29 selected under ground coal mines beginning in April 1968. Twenty-one of these 29 mines were included in the National Coal Study. By

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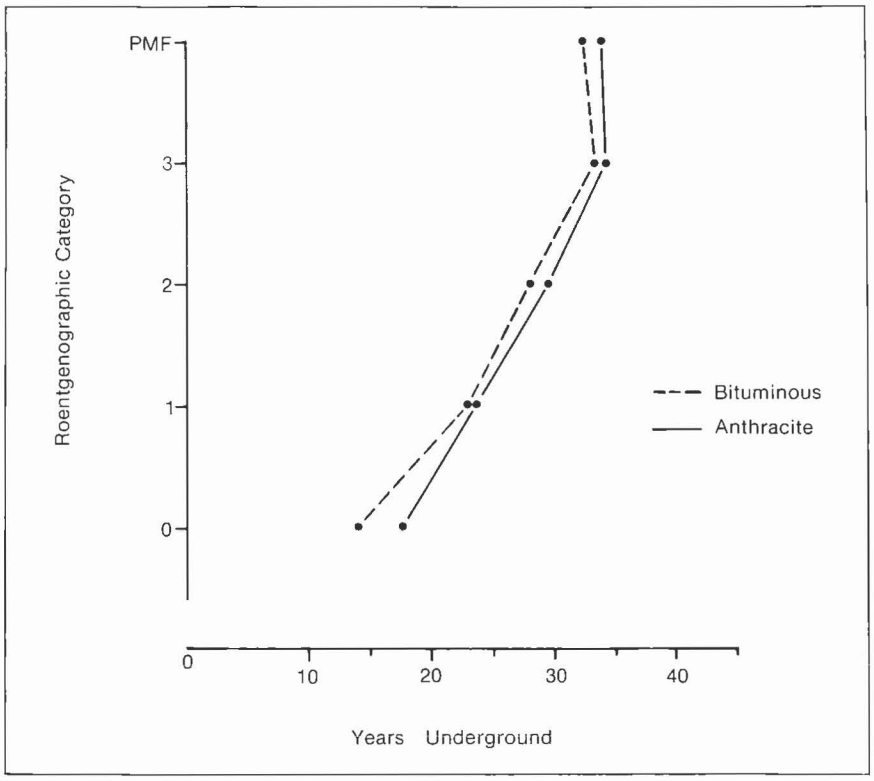
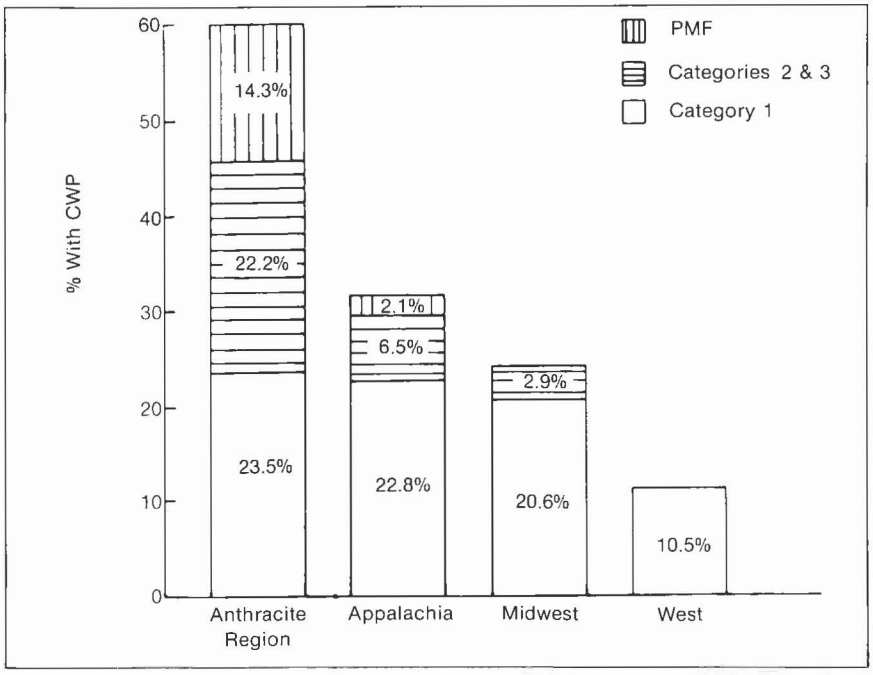


Fig I. – Relationship of CWP to years underground.

Fig 2. – Prevalence of CWP in major geographic regions.



means of a 10-mm nylon cyclone (gravimetric) sampler, full-shift, breathing zone measurements were made of dust in various job categories for periods of up to ten days. The measurements were converted to dust levels that would have been found if the instrument described in the Federal Coal Mine Health and Safety Act of 1969 had been used.[10]

Participation in the first round was 90.5% and a total of 9,076 miners were fully examined. The Federal Coal Mine Health and Safety Act of 1969 requires that the medical examinations be repeated within three years from the time of the first round and then later at intervals of no greater than five years. Thus, as a result of the repeated examinations it will be possible, first, to assess progression of pneumoconiosis by serial roentgenograms and, second, to measure the rate of decrease of ventilatory capacity. This will allow the efficacy of dust control measures to be assessed and will permit appropriate preventive measures to be taken with special attention to miners who are particularly at risk.

Results

A total of 9,076 coal miners were examined, of which 8,553 were bituminous and 523 were anthracite workers. For both groups of miners the relationship of years spent underground to roentgenographic category is shown in Fig 1. It is apparent that roentgenographic category of simple pneumoconiosis increases with the number of years worked underground. Miners with progressive massive fibrosis (PMF) showed no increase in the amount of time spent underground over category 3 CWP. This is not surprising when it is remembered that the development of PMF leads to premature disability and sometimes death. A positive relationship also exists when age is plotted against roentgenographic category, since age and work experience are so highly interrelated.

Figure 2 relates the prevalence of pneumoconiosis to the major geographic regions in which the miners worked. Definite, significant regional differences exist in regard to both simple CWP and PMF. It is evident that there is a decline in prevalence from East to West, the disease being most common in Eastern anthracite miners and least common in miners from Utah and Colorado. From East to West, there tends to be a slight decrease in the miners' ages and, similarly, in the years spent underground. This accounts for a small portion of the marked discrepancy in the amount of disease from one area to another. Clearly, such glaring differences in the prevalence of this disease cannot be explained by the slight differences in mean age and years spent underground.

Figure 3 relates the prevalence of

CWP in the four main geographic regions to years of underground exposure. The same trend of the highest prevalence in the anthracite miners, with a decline from East to West, is evident. A slight departure from this regional trend exists in miners with 40 or more years underground. Thus, the prevalence of CWP in this group of Midwestern miners was slightly higher than in their counterparts in Appalachia. This may be a result of differential migration, possibly related to differences in workmen's compensation laws, and early retirement. It is apparent from this figure that, without exception, the prevalence of CWP increases as coal dust exposure increases.

The data are shown in more detail in Tables 1 and 2, and again wide regional differences in the prevalence of CWP are apparent. For example, in Colorado less than 5% of the men examined had roentgenographic evidence of CWP, while the corresponding figure for the anthracite miners was 60%. Since there was some geographic bias in the sample, in that the West was somewhat overrepresented, postproportional allocation adjustments were made to the several politically defined strata. Thus, in those regions where oversampling occurred subjects were removed at random, and where undersampling occurred subjects were added at random by duplicating results from the population making up the subsample. The adjusted figures for the bituminous miners are shown at the bottom of Table 1.

The relationship of roentgenographic category to age and years spent underground for each region is shown in Table 2. From area to area, the relationship between mean years spent underground and roentgenographic category of simple pneumoconiosis is a monotonic increasing trend, which has striking similarities (Table 3). What is perhaps less apparent is the increased risk in certain areas of the disease's more frequent progression. For example, exposure in terms of years spent underground is roughly the same for the miners whether they worked in Western Pennsylvania or in Eastern Pennsylvania. However, a far larger proportion of the Eastern Pennsylvania miners showed evidence of CWP, especially categories 2, 3, and PMF. Thus, it is evident that anthracite miners are not only at an increased risk of contracting the disease, but once they have developed category 1, they may also be more likely to progress to the more advanced stages more often than are their bituminous counterparts. At this juncture the latter remains sup-

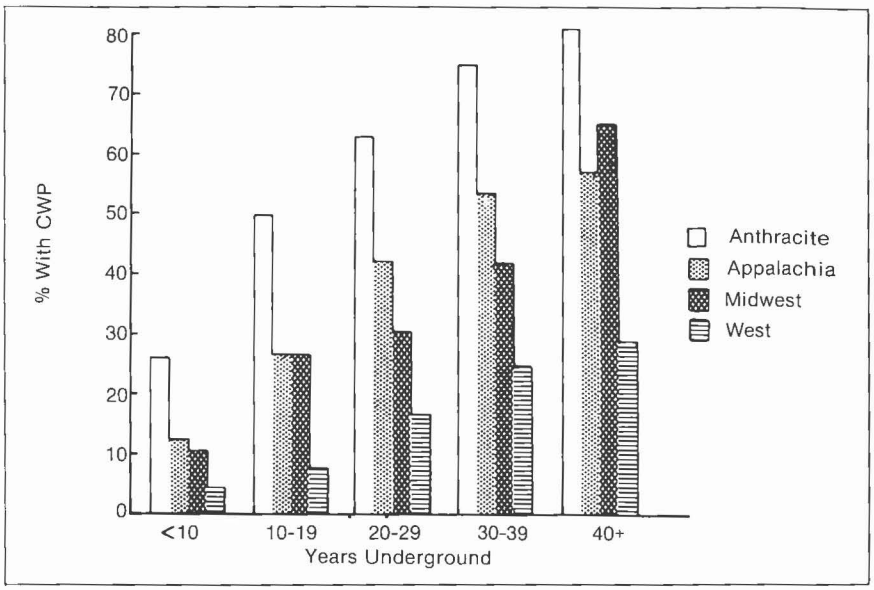


Fig 3.—Relationship of prevalence of CWP by region to years of underground exposure.

Fig 4.—Relationship of CWP to principal job according to geographic region.

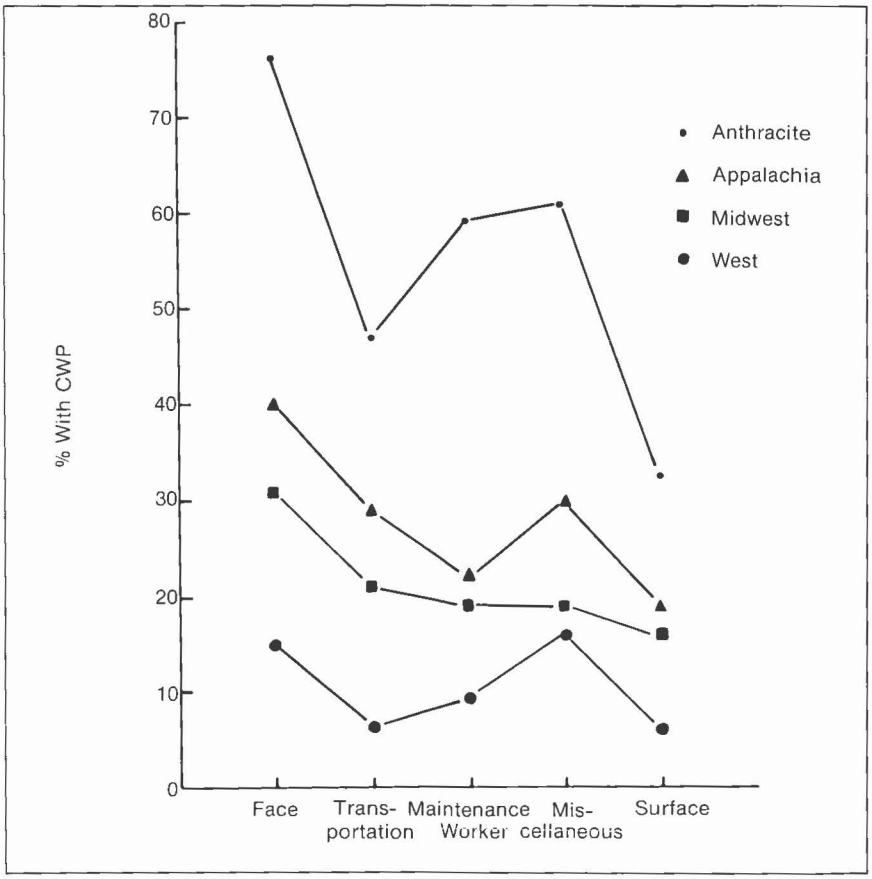


Table 1.—Regional Prevalence of CWP Roentgenographic Category

Region	Category 0 No.	0 Percentage	1 No.	1 Percentage	2 No.	2 Percentage	3 No.	3 Percentage	PMF No.	PMF Percentage	Total
Eastern Pennsylvania (anthracite)	209	40.0	123	23.5	93	17.8	23	4.4	75	14.3	**523**
Central Pennsylvania	268	58.9	98	21.6	61	13.4	6	1.3	22	4.8	**455**
Western Pennsylvania	507	50.4	367	36.5	110	10.9	9	0.9	13	1.3	**1,006**
Northern West Virginia	650	70.8	227	24.7	36	3.9	5	0.6	0	0.0	**918**
Southern West Virginia	1,197	72.7	284	17.2	96	5.8	7	0.4	63	3.8	**1,647**
Virginia	401	71.6	128	22.8	20	3.6	1	0.2	10	1.8	**560**
Ohio	307	68.2	112	24.9	26	5.8	2	0.4	3	0.7	**450**
Kentucky	681	71.0	226	23.6	30	3.1	2	0.2	20	2.1	**959**
Alabama	647	83.3	99	12.7	21	2.7	1	0.1	9	1.2	**777**
Indiana	178	65.0	82	29.9	11	4.0	0	0.0	3	1.1	**274**
Illinois	445	84.9	73	13.9	5	1.0	0	0.0	1	0.2	**524**
Utah	664	86.9	93	12.2	2	0.3	0	0.0	5	0.7	**764**
Colorado	209	95.4	10	4.6	0	0.0	0	0.0	0	0.0	**219**
Appalachia (bituminous)	4,343	68.6	1,442	22.8	380	6.0	33	0.5	136	2.1	**6,334**
Midwest	938	75.9	254	20.6	36	2.9	0	0.0	8	0.6	**1,236**
West	873	88.8	103	10.5	2	0.2	0	0.0	5	0.5	**983**
Total (bituminous-unadjusted)	6,154	72.0	1,799	21.0	418	4.9	33	0.4	149	1.7	**8,553**
Total (bituminous-adjusted*)	5,985	70.0	1,905	22.3	452	5.3	38	0.4	173	2.0	**8,553**
Grand total (anthracite & bituminous-unadjusted)	6,363	70.1	1,922	21.2	511	5.6	56	0.6	224	2.5	**9,076**

*Adjustments made due to oversampling in some areas. Method used was postproportional allocation. Percentages may not add to 100.0 due to rounding error.

position, since the only way to confirm this impression would be to study groups of new miners in several areas over many years and to assess the rate at which they develop the various categories of the disease.

The relationship of CWP to the miner's principal job is shown in Fig 4. It must be stressed that the occupational data for the anthracite miners are somewhat less reliable, as the job distinctions in anthracite mines tend to be less rigid, many anthracite miners being employed in two or three different capacities. Nonetheless, there is clear-cut evidence that the prevalence of CWP is highest at the face and least on the surface. The apparent anomaly of a high prevalence of the disease among miscellaneous underground workers may be explained by the fact that many of these men have duties which, at times, involve face work, and also have duties at coal transfer points on conveyer systems where dust concentrations may be high.

Comment

The results of this study indicate that there is an overall prevalence of pneumoconiosis of nearly 30% in our sample of bituminous coal miners. Of the total, something over 20% have category 1 simple pneumoconiosis while categories 2 and 3 combined amount to just under 6%. Only 2% have PMF. Unfortunately the comparable figures for anthracite miners are much higher throughout and no less than 14% of our sample had PMF. The proportion of men with categories 2 and 3 was likewise much higher, viz, more than 20%.

Marked regional differences in the prevalence of the disease are to be found if bituminous miners are considered separately. The disease appears to be more common in Pennsylvania than in the rest of Appalachia. It occurs less frequently in the Midwest and much less so in the West. Progressive massive fibrosis occurs most often in the anthracite region but is found fairly frequently in central Pennsylvania and southern West Virginia. In contrast, in the Midwest and West it is distinctly uncommon. These differences in prevalence cannot be entirely accounted for by years spent working underground, and hence other factors have to be considered. Obviously the most important of these is the respirable dust levels that have prevailed over the past 25 years. Unfortunately, no program for systematic dust sampling in the US mines existed before 1970 and the role played by dust remains largely a mystery.

Other factors that may be partly responsible for regional differences in prevalence are the physical and chemical composition of the coal mined. Thus, certain coals may fragment more easily and tend to form a greater proportion of harmful particles of around 1μ in size, while other coals may tend to generate larger and less dangerous particles of around 4μ to 5μ. Data to confirm these hy-

Table 2.—Relationship of Roentgenographic Category to Age and Years Underground (UG) According to Geographic Region Roentgenographic Category*

Region	Category 0 Mean Age	0 Mean Years UG	1 Mean Age	1 Mean Years UG	2 Mean Age	2 Mean Years UG	3 Mean Age	3 Mean Years UG	PMF Mean Age	PMF Mean Years UG
Eastern Pennsylvania (anthracite)	48.98 (10.09)	17.55 (13.99)	50.85 (8.96)	23.49 (13.07)	54.00 (6.13)	29.34 (10.55)	55.39 (4.77)	34.39 (9.60)	55.52 (4.55)	33.95 (7.75)
Central Pennsylvania	42.21	14.13	47.38	23.83	50.84	26.84	54.33	37.33	53.46	30.96
Western Pennsylvania	48.79	21.90	51.61	25.21	53.04	29.48	51.89	31.44	57.00	35.38
Northern West Virginia	37.41	10.09	46.50	18.84	51.39	27.47	52.60	33.80	. . .	. . .
Southern West Virginia	39.03	12.41	47.48	22.51	50.11	27.13	54.14	32.14	53.62	29.65
Virginia	40.90	13.80	48.48	22.24	49.80	26.80	53.00	29.00	55.00	31.50
Ohio	37.95	12.23	47.77	23.64	52.04	28.54	56.00	37.00	58.33	36.67
Kentucky	39.40	12.72	48.08	23.12	51.63	25.43	61.50	33.00	58.15	35.40
Alabama	44.28	17.13	51.61	26.95	56.38	33.81	60.00	38.00	56.00	36.56
Indiana	45.61	14.65	50.32	21.72	54.45	27.09	. . .	. . .	61.67	38.00
Illinois	43.15	13.13	52.30	25.06	58.60	37.80	. . .	. . .	70.00	56.00
Utah	44.05	14.08	52.88	24.25	50.00	24.00	. . .	. . .	57.80	37.40
Colorado	41.12	12.00	51.80	21.40	. . .	. . .	. . .	. . .	. . .	. . .
Appalachia	41.16 (12.00)	14.25 (12.85)	48.89 (9.07)	23.31 (12.45)	51.60 (6.73)	28.14 (9.98)	54.03 (5.54)	33.58 (6.65)	54.88 (5.30)	31.84 (7.85)
Midwest	41.76 (12.61)	12.69 (12.32)	49.61 (10.08)	22.25 (13.36)	54.56 (6.05)	28.25 (12.62)	. . .	. . .	59.75 (6.65)	38.88 (10.37)
West	43.35 (13.13)	13.58 (12.95)	52.78 (8.11)	23.97 (12.96)	50.00 (9.90)	24.00 (1.41)	. . .	. . .	57.80 (2.28)	37.40 (8.20)
Total (bituminous)	41.56 (12.28)	13.92 (12.80)	49.21 (9.21)	23.19 (12.61)	51.84 (6.72)	28.13 (10.20)	54.03 (5.54)	33.57 (6.65)	55.24 (5.41)	32.40 (8.16)
Total	41.80 (12.29)	14.04 (12.85)	49.32 (9.20)	23.21 (12.63)	52.24 (6.66)	28.35 (10.26)	54.59 (5.22)	33.91 (7.92)	55.33 (5.14)	32.93 (8.05)

*Standard deviations are shown in parentheses below the appropriate means for major geographic areas.

potheses are similarly not presently available. Alternatively, the chemical composition of the coal mined may account for the higher prevalence of the disease in certain regions. In this regard, although silica has often been incriminated as the responsible agent, most of the available evidence does not bear out this theory. The rank of the coal may also play a role, as may many other chemical constituents.[11] "Rank" is a term that refers to certain properties of coal as described by the American Society for Testing and Materials: the higher ranked coals are the oldest, contain the most fixed carbon, have the greatest calorific value, and contain the least volatile matter.

The data from this study suggest that anthracite miners contract CWP more frequently and may likewise be more prone to progress to the serious stages, 2, 3, and PMF, than their bituminous counterparts. Although categories 2 and 3 simple pneumoconiosis are associated with little in the way of respiratory impairment and

Table 3.—Relationship of CWP to Years Underground for Each Major Region

	Years Underground	Roentgenographic Category 0	1	2	3	PMF	Total
Anthracite	0	41	10	3	0	0	**54**
	1-9	34	12	1	0	0	**47**
	10-19	31	21	7	1	2	**62**
	20-29	54	38	34	5	16	**147**
	30-39	35	27	30	10	38	**140**
	40+	14	15	18	7	19	**73**
	Total	**209**	**123**	**93**	**23**	**75**	**523**
Appalachia	0	410	83	8	0	0	**501**
	1-9	1,655	182	10	0	1	**1,848**
	10-19	641	188	38	0	5	**872**
	20-29	997	510	152	9	46	**1,714**
	30-39	495	363	130	19	58	**1,065**
	40+	145	116	42	5	26	**334**
	Total	**4,343**	**1,442**	**380**	**33**	**136**	**6,334**
Midwest	0	84	11	2	0	0	**97**
	1-9	400	42	1	0	0	**443**
	10-19	145	49	4	0	0	**198**
	20-29	208	74	13	0	2	**297**
	30-39	78	49	6	0	2	**135**
	40+	23	29	10	0	4	**66**
	Total	**938**	**254**	**36**	**0**	**8**	**1,236**
West	0	83	9	0	0	0	**92**
	1-9	357	11	0	0	0	**368**
	10-19	111	9	0	0	0	**120**
	20-29	205	38	2	0	0	**245**
	30-39	90	27	0	0	3	**120**
	40+	27	9	0	0	2	**38**
	Total	**873**	**103**	**2**	**0**	**5**	**983**

disability, their presence is ominous in that they predispose to the onset of PMF. It is imperative, therefore, to prevent the development of the higher categories of simple CWP and for this reason an effective dust-control program is of paramount importance. In the case of anthracite miners, and in contrast to their bituminous counterparts, the onset of category 1 appears to be a poor prognostic sign. Various efforts have been made to relate the medical and engineering findings without success. This is probably not surprising in view of the uncertainty as to what prevailed in the mines during the preceding years, the wide ranges of exposure levels found in each work category, and the movement of men over the years from one work category to another. It is, however, interesting to note that the dust levels reported in 1970 for the two anthracite mines show them at that time to have respirable dust concentrations well below most of the bituminous mines. Thus, it is difficult not to conclude that there is something in the environment of the anthracite miners that puts them in special jeopardy. However, it is doubtful that the quantity of respirable dust alone is responsible.

It is inevitable that the present Interagency Study will be compared not only with the previous USPHS. Prevalence Study of 1963 through 1965, but also with data generated as a result of the Federal Coal Mine Health and Safety Act of 1969. The prevalence of pneumoconiosis in Appalachian working miners during the 1963-1965 time period was reported as around 10%, of which just under a third had PMF. A superficial assessment of the situation might suggest that the prevalence of the disease has increased and the situation deteriorated. There are several reasons for doubting that this is indeed so. At this juncture, it is of vital importance to catalog the profound differences in methodology between the studies. If these are kept in mind, the futility of comparing the studies will be realized. First, the panel of interpreters differed for the two studies. Second, in the 1963-1965 study, when there was a difference of opinion as to major category, a meeting was held and a decision forced. This practice is open to question in that the most forceful and dogmatic person prevails most often. In the present study, a consensus opinion was accepted without discussion. Third, the roentgenograms in the earlier study were interpreted according to the 1959 ILO Classification; in contrast, the present study utilized the UICC/Cincinnati Classification. Previous work has shown that the substitution of the UICC/Cincinnati Classification for the ILO Classification results in an appreciably greater number of films being placed in category 1.[12] This is related to the fact that many of the roentgenograms, which were formerly interpreted as either category Z (suspicious) or L (linear) under the ILO Classification of 1959, are likely to be read as category 1 with the UICC/Cincinnati Classification. Finally, sampling errors, and interobserver and intraobserver variation also probably played a significant role in producing the disparities between the studies. Nonetheless, if those categories not affected by the change in classification are considered, viz, categories 2 and 3 and PMF, the figures for the bituminous miners in Appalachia are roughly comparable and indeed the prevalence of PMF appears to have declined. Thus, for category 2 the figures for the 1963 and current studies were 4.8% and 6.0%; for category 3 they were 0.3% and 0.5%; and for PMF 3.0% and 2.1%, respectively.

The 1963-1965 study reported around 10% of the sample with CWP and another 5% as suspect.[4] Data from the mass x-ray program administered under the 1969 Federal Coal Mine Health and Safety Act show a prevalence rate of around 13%, while the comparable figure for the Interagency Study is 28%. Because of the poor participation in the mass program and because of lack of uniformity in roentgenographic interpretation, it is our opinion that the Interagency Study data reported in this article are probably more reliable than those generated by the mass x-ray program.

Underground mines in the United States vary greatly in their mining methods and in the number of miners employed. According to the Bureau of Mines, of the 110,000 to 120,000 active miners, around 60% are employed in mines with over 100 employees. Numerous small nonunionized mines employing between 3 and 20 men are to be found in southern West Virginia, western Virginia, and eastern Kentucky. Many of the miners employed at these mines work only part time and their labor force is constantly changing. Little information is available concerning either the medical or environmental conditions in these mines. Nonetheless, it is known that the larger mines included in this study are more mechanized than most of the smaller mines and this probably means that the dust levels are likely to have been lower in the latter. Thus, it could well be that the prevalence of CWP is higher in the larger, more mechanized mines and that our prevalence figures do not apply to the total US coal mining population.

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